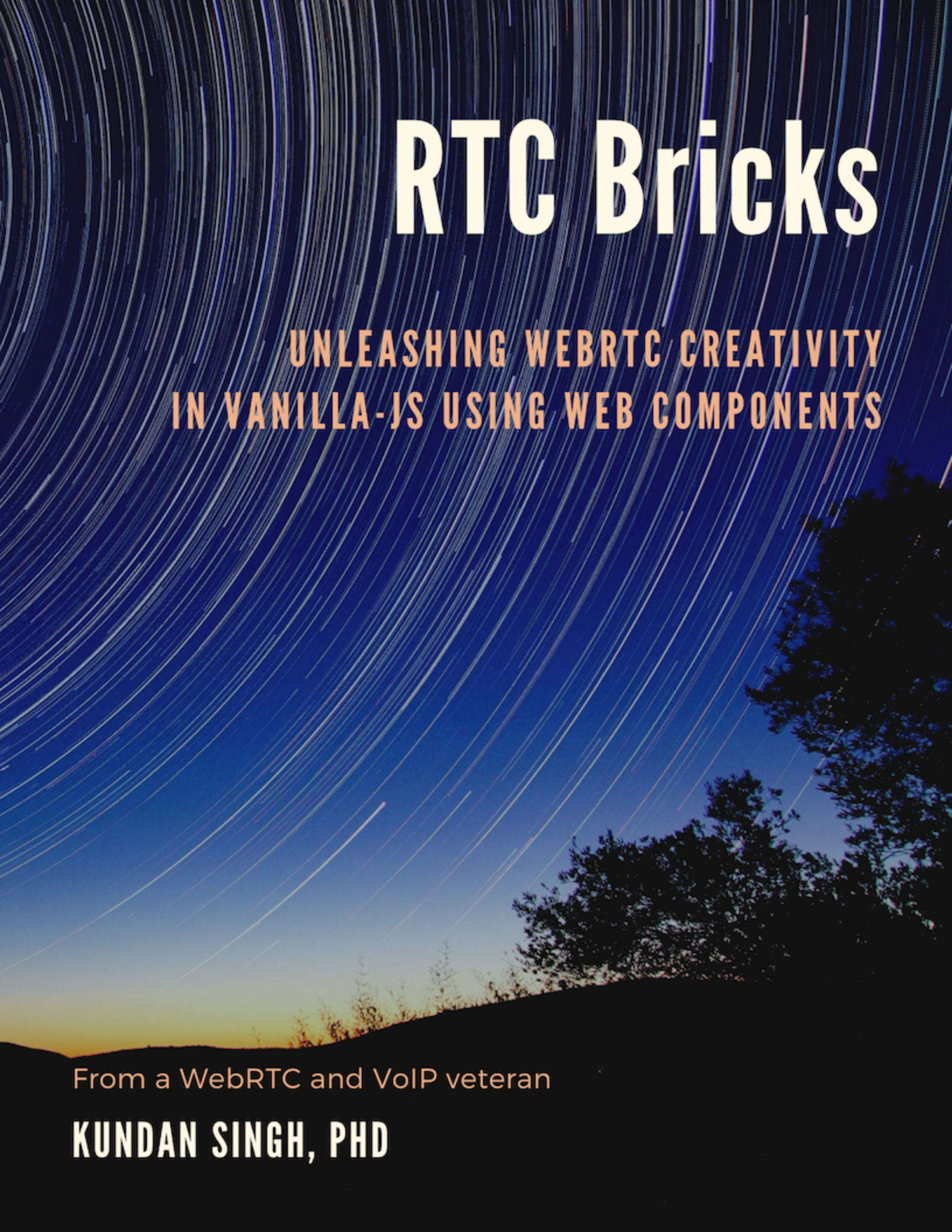


RTC Bricks

UNLEASHING WEBRTC CREATIVITY IN VANILLA-JS USING WEB COMPONENTS

From a WebRTC and VoIP veteran

KUNDAN SINGH, PHD

RTC Bricks

This project aims to unleash WebRTC creativity using web components. It has a collection of more than seventy web components for building a wide range of real-time communication and collaboration web applications.

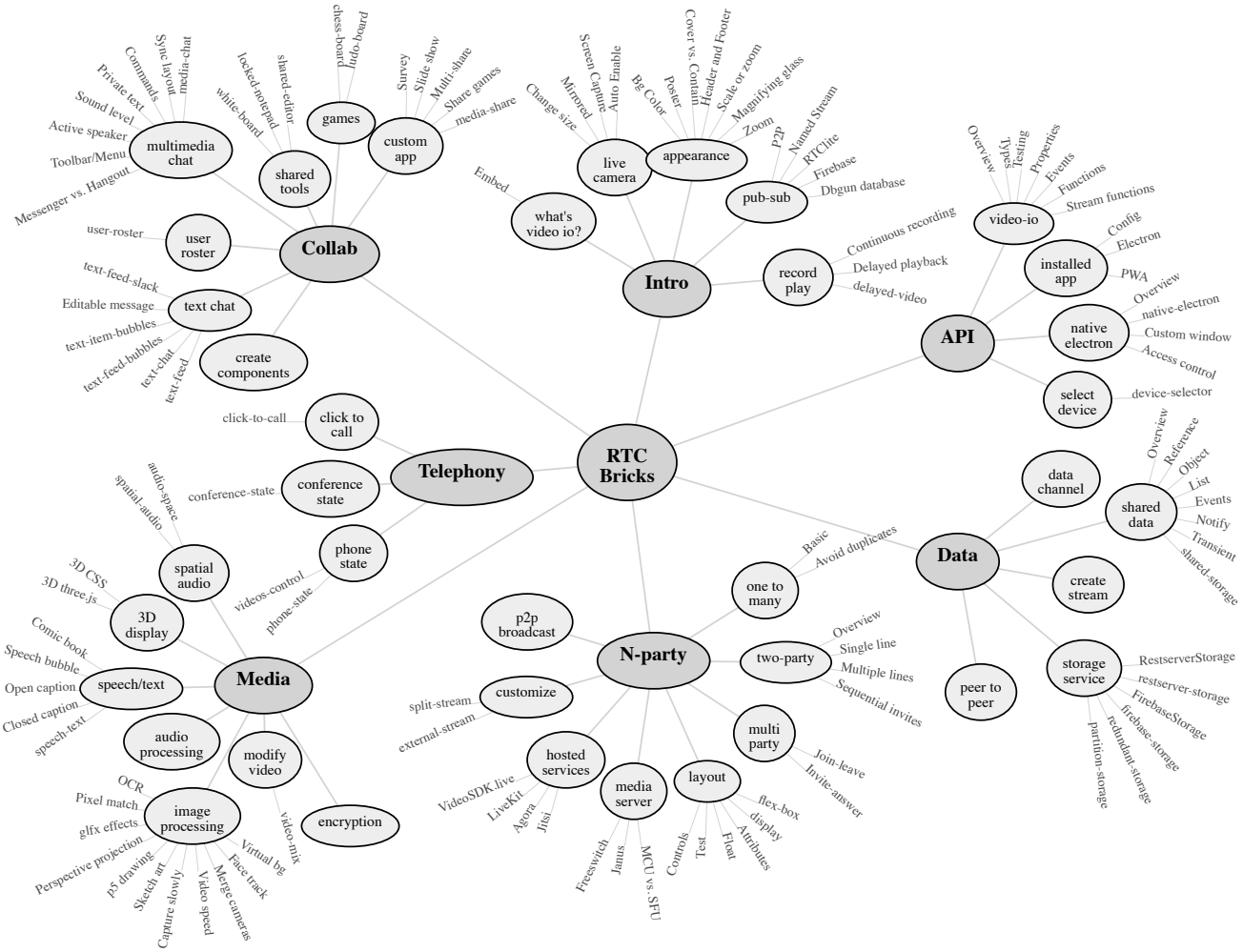
I started this project with one generic web component, <video-io>, for publish-subscribe in WebRTC apps. It has a simple video box abstraction that can be published or subscribed to a named stream. It was inspired by my earlier flash-videoio (https://github.com/theintencity/flash-videoio/) project, and implemented a subset of the ideas presented in my blog post (http://blog.kundansingh.com/2019/06/a-generic-video-io-component-for-webrtc.html). The motivation, software architecture, implementation, and various connectors of <video-io> are presented in the research paper, A Generic Web Component for WebRTC Pub-Sub (https://doi.org/10.48550/arXiv.2602.22011). In summary, it promotes reuse of media features across different applications, reduces vendor lock-in of communication features, and provides a flexible, extensible, secure, feature-rich, and end-point driven web component to support a large number of communication scenarios.

As I worked through many sample and demo web apps using this <video-io> component, I kept creating more abstractions and web components, e.g., for layout of multiple video boxes, or text chat, or speech transcription, or call signaling, and so on. The collection will keep growing, and improving, as I work on more application scenarios. But the basic foundational ideas or the theme of this project remains the same, as follow:

1. Separate any app logic from any user data.
2. Keep the app logic in the endpoint, if possible.
3. Use vanilla JavaScript, and avoid any client side framework.
4. Create flexible and extensible interfaces in HTML5 web components.

I will create a separate research paper for the motivation and software architecture. Here, I present an extensive hands-on tutorial of the various web components, or RTC Bricks. Please follow the *basic* topics below for a tutorial on how to use the `video-io` and `named-stream` web components. The tutorial is intended to be sequential. Even if you need information on a specific use case, I

recommend that you go through all the topics in sequence for the first time, under the basic category. The other advanced topics do not need to be followed in sequence. These include advanced usages such as video image manipulation and multi-party conferencing, and include other components such as `flex-box` for conference display layout and `shared-storage` for generic end-point driven software implementations of communication applications. Web components for several common scenarios are also described, e.g., `text-chat`, `locked-notepad` or `click-to-call`. A navigatable and interactive content is shown below.



Intro

First, in the basic part we go over the video-io component, its styling and appearance, and how it

is used with the named-stream component to publish or subscribe, including a few implementations of named-streams using external storage services or real-time databases such as Firebase and RTCLite. It also covers certain user interface features such as zooming, and client side recording.

API

The next part provides a complete reference for various properties, methods and events on the video-io and named-stream components, mechanics of the installed app, both PWA and native electron helper app, and the device selection related component.

Data

This is followed by the Data part that shows how to use data channel as well as shared storage for a wide range of application logic. It also covers the generic storage stream component, a few external storages beyond just named stream support including Firestore, Restserver and peer-to-peer network, and how to use the redundancy and data partition components for reliability and scalability of the real-time database.

N-party

This part is a potpourrie of several concepts such as how to use the shared storage components for two-party, multi-party, or one-to-many broadcast application logic, and to display various multi-party video layout in a flexible, adaptive and dynamic manner. It also includes various components to enable interaction with external media servers and hosted conference services such as Janus, Jitsi, Agora, LiveKit, or more, and also to support peer-to-peer media broadcast without a media server.

Media

This part includes topics related to audio/video manipulation and improvement such as virtual background, image processing, and end-to-end encryption.

Collab

There are numerous collaboration use cases and components described in this part including text-chat, multimedia conference, user roster display, and many shared tools and games such as whiteboard, shared editor or slide show. Many of these are further extended such as to support modern Slack-style enterprise messaging interface, adaptive conference layout, as well as nuanced conferencing and collaboration features.

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Finally, this part covers the telephony style application logic and use cases including call signaling and conference join models, call queues for contact center, or call distribution for campaigns, all using the generic shared storage interface.

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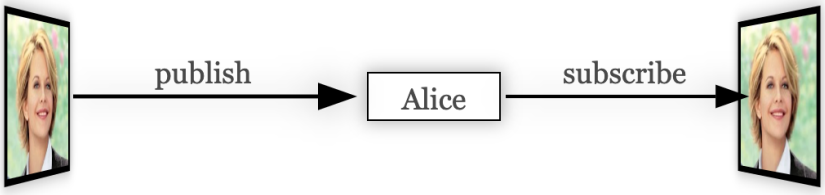
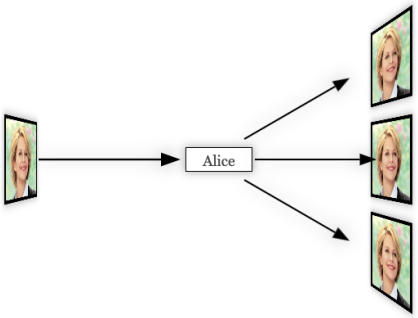
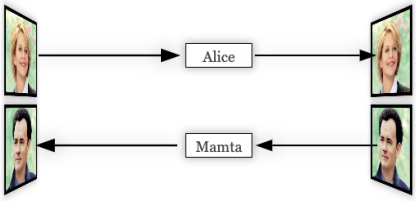
1. What is video-io?

Video-io is a web component demonstrating several generic WebRTC related use cases, e.g., live camera view, recording of multimedia messages, live video call or conferencing, in client-server as well as peer-to-peer topology. It combines the various media and connection abstractions available in WebRTC, and exposes a single *video box* abstraction. The video box can be attached to a named stream, and configured in either a publish or subscribe mode.

The basic idea is very simple. It is based on the well proven named stream abstraction previously used by Flash Player and ActionScript application developers for building real-time multimedia applications.







Consider the above example with two video boxes, both attached to the same named stream, "Alice", one to publish and the other to subscribe. When two more video boxes subscribe to the same named stream, "Alice", you get one to many video broadcast. When two video boxes come in the reverse direction attached to a different named stream, "Bob", you get two-party video call. This simple abstraction facilitates a wide range of use cases as your will see later.

1.1 Include video-io in your web-page

To include the web component, do the following in the `head` section of your HTML document.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/video-io.js"></script>
```

Although web component is now ubiquitous, to ensure compatibility across various browsers, you may want to include the light weight polyfill (https://github.com/webcomponents/webcomponents-lite) for Web components before including any of the components described in this document, as shown below.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com
/v1/webcomponents-lite.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/video-io.js"></script>
```

Alternatively, a better option is to checkout the code from the project repository (https://github.com /theintencity/rtcbricks), and host it on your own web server. Our components are vanilla JavaScript files without dependency on external frameworks, so should be pretty easy to include in any of your web application with or without your favorite framework.

In the `body` section of the HTML document, include a `video-io` element, e.g.,

```
<video-io></video-io>
```

The component instance can now be used in the script. You can also specify additional attributes such as `id` or `controls` in HTML, e.g.,

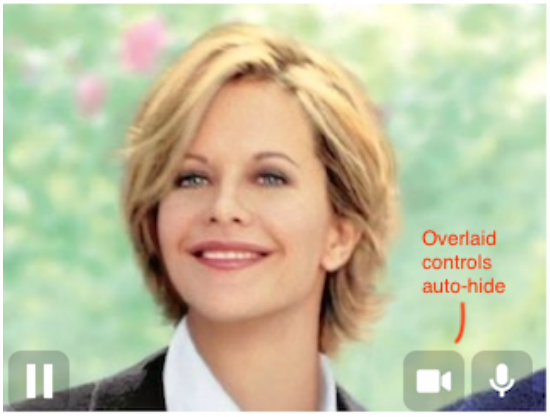
```
<video-io id="video" controls></video-io>
```

See How to use the video-io API? for a complete list of attributes and properties.

2. How to show live camera view?

One of the first things that you can do is to capture from webcam and display the video. This is done by using the `publish` attribute as follows.

```
<video-io controls publish="true"></video-io>
```



When you try the above example, you will notice a few things. The default size of the component is 320x240 pixels. The default camera capture ratio is 4:3. The `controls` attribute causes it to display the controls on mouse hover. A publisher mode component by default has three buttons - one to pause or play the video, and two for camera and microphone.

Stopping the publishing is done by resetting the `publish` property as follows.

```
<script type="text/javascript">
    video.publish = false; // stop publish
    video.publish = true;  // start again
</script>
```

By default, publish is done for both audio and video. To disable one, you can use the `microphone` or `camera` attributes.

```
<video-io controls microphone="false" publish="true"></video-io>
```

Or in JavaScript, using properties, as follows.

```
    video.microphone = false;
    video.publish = true;
```

The above example uses an external button to control the publish state. You will notice in the above example that the microphone icon is muted.

2.1 Change capture or display size

Use the CSS styles to change the display size. Use the `camdimension` attribute and property to change the camera capture size.

```
<video-io style="width: 960px; height: 540px;"></video-io>
<script type="text/javascript">
    video.camdimension = "1280x720";
    video.publish = true;
</script>
```

Although the code snippet above shows `camdimension` set as property, it can also be specified as an attribute. Many properties of the component instance are also available as attributes, that can be set in markup. See How to use the video-io API? for a complete list of attributes and properties.

2.2 Mirrored (or not?) preview

The local camera preview is mirrored by default. This can be changed to not mirror the preview video using the `mirrored` attribute to false

```
<video-io mirrored="false" publish="true"></video-io>
```

Alternatively, you can use the `--preview-transform` CSS style attribute.

```
<video-io style="--preview-transform: none;" publish="true"></video-io>
```

2.3 Screen Capture

Use the screen attribute or property to publish using screen capture instead of camera. Note that, unlike the camera preview, the screen capture preview is not mirrored.

```
<video-io screen="true" microphone="false" publish="true" style="background:
black;"></video-io>
```

Generally, for screen share, you should disable the microphone, so that sound is not captured too, and you should style the background color, so that the difference in aspect ratio is prominently shown as black.

Additionally, you can alter the other constraints such as `camdimension` or `framerate` that apply to both camera and screen capture. It is recommended to use lower framerate for screen capture, if the screen size is too big, e.g.,

```
<video-io screen="true" ... desiredframerate="3" publish="true"></video-io>
```

A lower screen share framerate is useful in keeping the bitrate in check, without losing the picture quality. Unlike camera capture, a screen capture treats `camdimension` as maximum constraint, and the actual dimension may be smaller, e.g., if the value is 640x480 but the screen size is 1280x720, then the screen capture is scaled down to 640x360 due to maximum width and height constraints.

2.4 Auto Enable

When the video is playing, the `playing` property is changed to reflect that. The pause control element of the component may be used by the user to directly change the playing state of the video. For a

publisher component, this playing state does not affect the state of the published media stream. This may cause unintended behavior, when the publisher side user pauses her video, but the subscribers continue to see and hear the live audio and video stream from the publisher.

The `autoenable` property and attribute can change this behavior. If set for a publisher component, it ties the displayed video with the published stream, i.e., when the video pauses, then the published media stream is disabled too.

3. How to change the component's appearance?

This section describes some ways to change the appearance and general behavior of the component, independent of the publisher or subscriber mode.

3.1 Background Color

The default background color of the component is transparent. This can be changed using the `background` or `background-color` CSS style attribute.

3.2 Background `poster`

Use the `poster` attribute or property to display an image before the video is loaded or played.

```
<video-io mirrored="false" poster="some-image.jpg" ...></video-io>
```

When using the `poster` attribute, it is recommended to reset the `mirrored` attribute, to prevent the poster image from getting flipped horizontally.

3.3 Cover vs. Contain

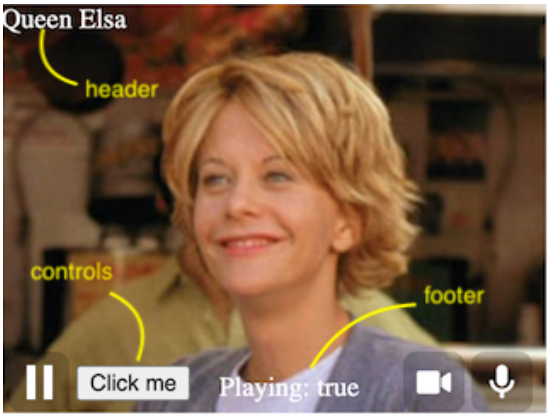
If the aspect ratio of the video in the media stream is different than the display size aspect ratio, then the `object-fit` CSS style attribute determines how the video is displayed. The default is contain. This can be changed to cover or fill.

```
<style>video-io { width: 180px; height: 240px; }</style>
...
<video-io id="video1" style="background: green;"></video-io>
<video-io id="video2" style="object-fit: cover;"></video-io>
<video-io id="video3" style="object-fit: fill;"></video-io>
```

3.4 Header and Footer

The component has three slots for header, footer and controls in the display. The header and footer are displayed as persistent overlay on top of the video element, but behind the controls if any. The controls are displayed in the middle of the built-in controls when visible. An example usage of these slots is to display the name of the person in a video call, or the status of the connection.

```
<style>video-io > span { color: white; }</style>
...
<video-io id="video">
    <span slot="header">Queen Elsa</span>
    <span slot="footer" style="margin-left: 40%; line-height: 30px;"></span>
    <span slot="controls" onclick="alert('clicked');">Click me</span>
</video-io>
<script type="text/javascript">
    ...
    video.addEventListener("propertychange", e => {
        if (e.property == "playing")
            video.querySelector('span[slot="footer"]').innerText = "Playing: " +
e.newValue;
    });
</script>
```



3.5 Scale or zoom

The controls, header or footer sizes are fixed in the component implementation, e.g., the control buttons are 36x36 pixels, irrespective of how large the component is displayed. An application may need to adjust the controls, header or footer sizes to match the display size of the component, e.g., if displaying in 160x120 then use smaller size buttons, and if displaying in 640x480 then use larger size buttons. This can be done using the CSS transform and zoom attributes.

There is also a `zoom` property in the component which can be used as follows. The default is treated as no zoom, or value of 1.0. The controls are made smaller using zoom of less than 1 and larger using zoom of more than 1. For example, using zoom value of 0.5 will make the control buttons half the size, and using 1.25 will make them 25% larger.

```
<video-io zoom="0.5" controls />
<video-io zoom="1.25" controls />
```

The following example shows the components displayed in small sizes, one without zoom and other with zoom. The header, footer and controls are enabled for all the instances for comparison.

One way to calculate the right value for zoom is as follows. Suppose the buttons appear the right size for component size of 320x240. To scale the buttons proportionally, you can derive the zoom factor using the ratio of the actual display size and this right size.

```
const desired = {width: 320, height: 240}; // right size for buttons to appear
good.
const actual = {width: 640, height: 360};  // actual size for display of
component.
video.style.width = actual.width; video.style.height = actual.height;
video.zoom = Math.min(actual.width/desired.width, actual.height/desired.height);
```

Be careful when using a small zoom value, especially on mobile or low accessibility devices, that the buttons may become too small to click.

3.6 Magnifying glass

The `magnifier` attribute or property can be used to show a magnifying glass on mouse hover for the displayed video.

```
<video-io ... magnifier="40px,2x" />
```

The example above creates a magnifying glass with diameter about 40px, and performs 2x magnification. Alternatively, the values can be specified as percent, e.g., "50%,300%" will cause the diameter to be about 50% of the component height, and magnification of 3x. Note that magnification of less than 1x is not allowed.

```
<video-io ... magnifier="50%,300%" />
```

Try the following example to experiment with the magnifier glass.

This and the next feature are useful for quickly checking some small text during screen share, when the component size is small.

3.7 Select to zoom

The `zoomable` property controls whether the user can drag-select a portion of the video and zoom.

```
<video-io ... zoomable="true" />
```

Try the following example to experiment with select to zoom. Once the publish starts, click, drag and select a rectangle on the video, to zoom in. Then click again to restore.

If already zoomed, then a mouse down on the component resets the zoom. If already zoomed, and the

component is resized, then the zoom value is preserved and the `object-fit` style is honored. To try that out, use the following example - it opens in a new tab; try resizing the window, with or without zoom on the video.

4. How to connect publisher and subscriber?

A `video-io` component instance can be in a publish or subscribe mode. Previously, we showed examples of the publish mode. The subscribe mode is relatively easy, as there is no capture device involved. For real-time media flow, a publisher instance is connected to a subscriber instance. These instances may be running on separate browsers or machines. For discussion in this section, we assume that both are running on the same web page.

There are two ways to connect the publisher and subscriber instances: point-to-point and named streams. The point-to-point connection is similar to the WebRTC peer connection abstraction, albeit unidirectional only. The named streams abstraction will be discussed in the next sub-section.

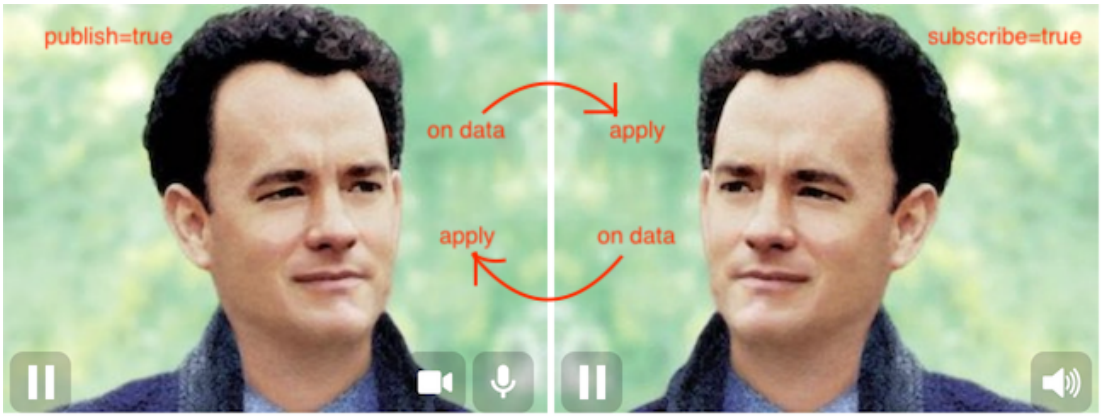
4.1 Point-to-point

In the point-to-point connection, one instance of publisher connects to one instance of subscriber. The application manages data exchange between these instances. In particular, the instance emits the data event, which must be applied to the other instance. An example follows.

```
<video-io id="video1" controls autoenable="true"></video-io>
<video-io id="video2" controls></video-io>
<script type="text/javascript">
    const video1 = document.querySelector("#video1"),
          video2 = document.querySelector("#video2");

    video1.addEventListener("data", e => video2.apply(e.data));
    video2.addEventListener("data", e => video1.apply(e.data));

    video1.publish = video2.subscribe = true;
</script>
```



The above example creates two instances of `video-io`. The first one publishes microphone and camera to the second one. The second one is in subscribe mode. The data event contains signaling data for offer/answer and ICE candidates as specified in the WebRTC APIs. If you are familiar with the WebRTC APIs, you can follow the rough sequence of events by logging the data value.

Although both the instances are shown as part of the same web page here, a real application will use some WebRTC notification service to exchange the data between the two distributed instances.

As before you can stop the publish mode, by resetting the `publish` property. Similarly, resetting the `subscribe` property stops the play. In the point-to-point mode, once the subscribe has stopped, it cannot be started again, and a new component instance must be used for any new media stream subscription.

The point-to-point abstraction should avoided unless the named stream mode is not easily applicable. Point-to-point is typically useful when integrating with existing communication service for which a named stream implementation is not available or hard to do. The named stream abstraction provides several benefits as discussed next. It also decouples the client-side app and the notification service, so that the service can be easily replaced by another in the future, while keeping the client application logic intact.

4.2 Named Stream

In this approach, at most one publisher and zero or more subscribers can be attached to a named

stream. All the subscribers receive the media stream from the publisher if present. Using named streams for connecting the publisher and subscriber is preferred to point-to-point, because of several reasons.

- It is higher level compared to the point-to-point connection abstraction.
- It allows publisher and subscribers to come and go at any time.
- It's component design enables integration with existing notification services.
- It is inspired by the once popular `NetStream` model of Flash Player

The `named-stream` component provides the bare bone necessity needed for implementing the above approach, within a single web application. In a real application, this is extended to other components that use a WebRTC notification service or a media server to allow distributed publishers and subscribers.

The following example illustrates the basic concept using the named-stream component. It uses three `video-io` components, one as publisher and two as subscribers, all attached to the same `named-stream` instance.

```
<named-stream id="stream"></named-stream>
<video-io id="video1" controls autoenable="true" microphone="false"></video-io>
<video-io id="video2" controls></video-io>
<video-io id="video3" controls></video-io>
<script type="text/javascript">
    const [video1, video2, video3, stream] = ["video1", "video2", "video3",
"stream"]
          .map(id => document.getElementById(id));

    video1.srcObject = video2.srcObject = video3.srcObject = stream;
    video1.publish = video2.subscribe = video3.subscribe = true;
</script>
```

To try the example above, click on the publish and subscribe buttons in different order and see the effect. Then try to stop and restart them in different orders.

As shown above, the `srcObject` property is used to bind a `video-io` instance to a named stream, and the `publish` or `subscribe` function is used to configure it as a publisher or subscriber. Note that if the `srcObject` is set then the application should not use the `data` event, because the named stream instance processes that internally.

If using the `srcObject` property, make sure to set the `publish` or `subscribe` property *after* setting the `srcObject`, and not to use them as attributes.

Alternatively, you can use the `for` attribute in the markup to configure the named stream as shown below. The attribute value is the ID of the DOM element of the named stream.

```
<named-stream id="stream"></named-stream>
<video-io id="video1" controls autoenable="true" for="stream" publish="true">
</video-io>
<video-io id="video2" for="stream" subscribe="true"></video-io>
<video-io id="video3" for="stream" subscribe="true"></video-io>
```

If using the `for` attribute, make sure that the named stream DOM element that `for` refers to is included before the `video-io` element, so that when the `video-io` component instance is attached to the DOM, it can find the corresponding `named-stream` in the DOM too.

The example above uses one instance of the `named-stream` component. This works only for this type of named stream component, but not for the others described below. For the other named stream components that connect to a server in some way, a separate instance of the component is needed for each `video-io` component instance.

When the publisher pauses the video, the subscriber sees black video feed. This default behavior can be changed using the `autopause` property, set on the publisher. If true, then it sends an event to the subscriber before the `playing` property is changed on the publisher. The subscriber in turn can pause and play the video, to avoid showing the black video feed during publisher side pause.

```
<named-stream id="stream"></named-stream>
<video-io id="video1" controls autoenable="true" autopause="true" for="stream"
publish="true"></video-io>
<video-io id="video2" for="stream" subscribe="true"></video-io>
```

Setting `autopause` shows consistent video behavior on publisher and subscriber side, instead of publisher paused and subscriber with black video feed.

4.3 Using `rtclite-stream` for Notification

As mentioned before, a real application will likely use a WebRTC notification service to exchange the signaling data among the different distributed instances of the `video-io` components running in different user browsers.

My earlier open source project rtclite (https://github.com/theintencity/rtclite) has a light weight notification server based on named streams. The concept is first explained in a blog post on WebRTC notification system (http://blog.kundansingh.com/2019/06/webrtc-notification-system-and.html), but extended to named stream with the server code in streams.py (https://github.com/theintencity/rtclite/blob/master/rtclite/app/web/rtc/streams.py) file and an example client is in streams.html (https://github.com/theintencity/rtclite/blob/master/rtclite/app/web/rtc/streams.html).

First, follow the instructions there to install and run the notification server, and try out the example

client code. I run the notication service for local testing as follows, using Python 2.7, on TCP port 8080.

```
python -m rtclite.app.web.rtc.streams -l tcp:0.0.0.0:8080 -d
```

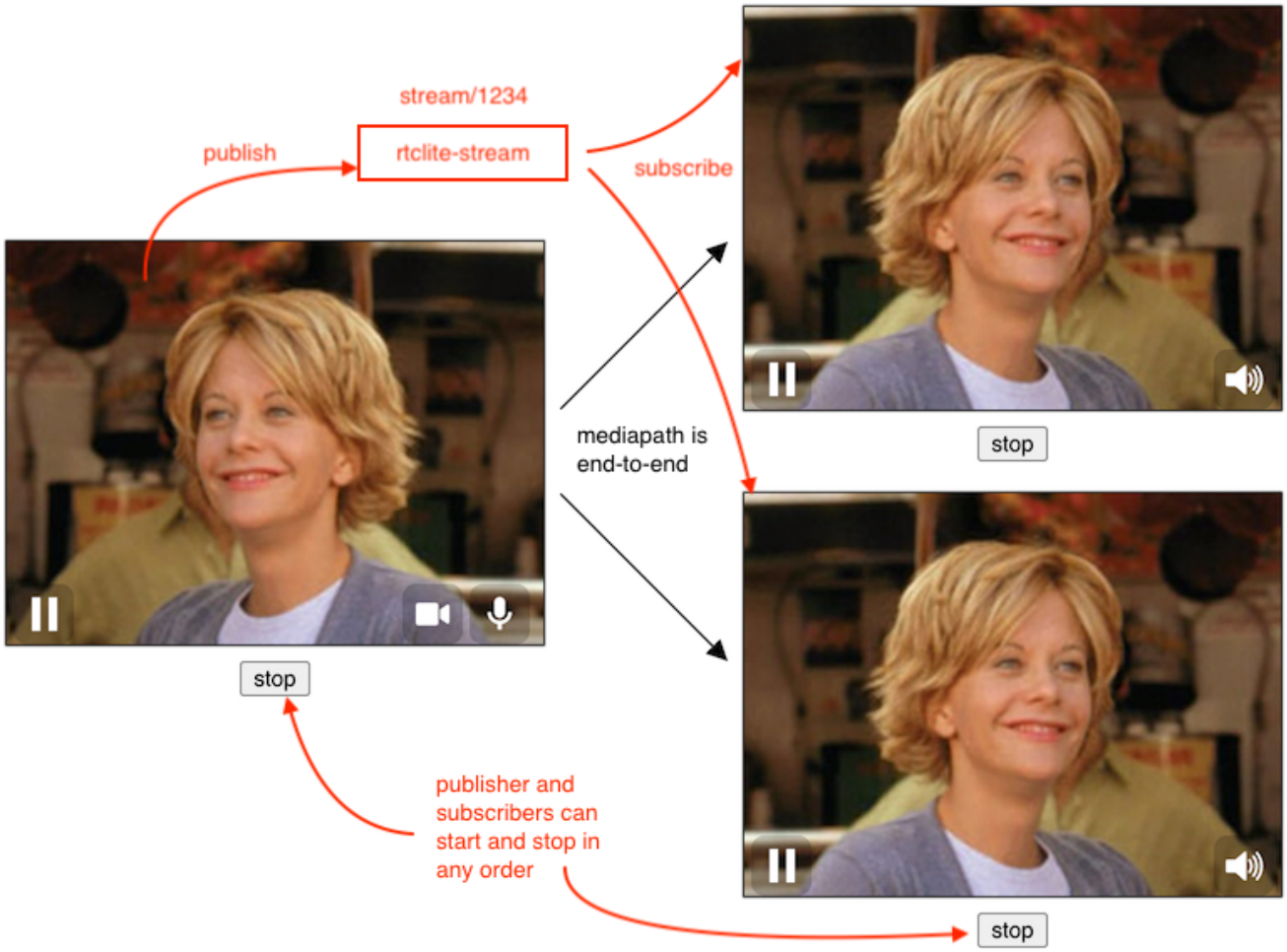
I have also ported that notificaion server to NodeJS, and included in this project for convenience. I run this notification server for local testing as follows, after installing the dependencies.

```
cd srv
npm install
node streams.js -p 8080 -d
```

Default port is already 8080, so the `-p` option above is redundant. Default log level is `info`, and `-d` option creates verbose log, whereas `-q` is for the quieter mode with only error logging.

Next, use the `rtclite-stream` component instead of the default named-stream, and try it out below. Note that the named streams in separate web pages refer to the same stream at the notification server, if the same `src` attribute is used.

```
<!-- in <head> -->
<script type="text/javascript" href="https://rtcbricks.kundansingh.com
/v1/rtclite-stream.js"></script>
...
<!-- in <body> -->
<rtclite-stream id="stream" src="ws://localhost:8080/stream/1234"></rtclite-
stream>
<video-io id="video" controls autoenable="true" for="stream"></video-io>
<script type="text/javascript">
    const video = document.querySelector("#video");
    ...
    video.publish = true;
    ... // or
    video.subscribe = true;
</script>
```



Note that this `rtclite-stream` component provides a one-to-one mapping to the stream publish or subscribe operation, and hence, each such stream instance may be attached to only one `video-io` instance.

Please note that the notification server described above does not have any access control. It may be extended to add some form of authentication and access control for your need on top of the basic connection.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the websocket server URL to connect to the rtclite's stream service, and any parameter or path for stream identifier, e.g., "ws://localhost:8080/stream/1234"

4.4 Using Firebase for Notification

I have created another component, `firebase-stream`, that uses the Firebase (https://firebase.google.com/) project to implement the notification system. Unlike the previous `rtclite-stream` component, which requires a separate stream object for attaching to each `video-io` instance, the single `firebase-stream` object may be attached to multiple `video-io` instances in your web app. Behind the scenes, the component provides a proxy to reach and manipulate data on the Cloud Firestore (https://firebase.google.com/docs/firestore) database. So it does not matter whether you use a single or separate `firebase-stream` objects for all the `video-io` instances on the web page.

First, signup for the Firebase account, create a sample app, and add the Cloud Firestore feature to the app. Second, include the relevant scripts in your web application as shown below. Next, use the `firebase-stream` component instead of the default named-stream. Then, configure the component by providing your app's details such as apiKey, projectId and appId. Other fields are not needed. After that, this component instance may be used with `video-io` as shown in other examples previously.

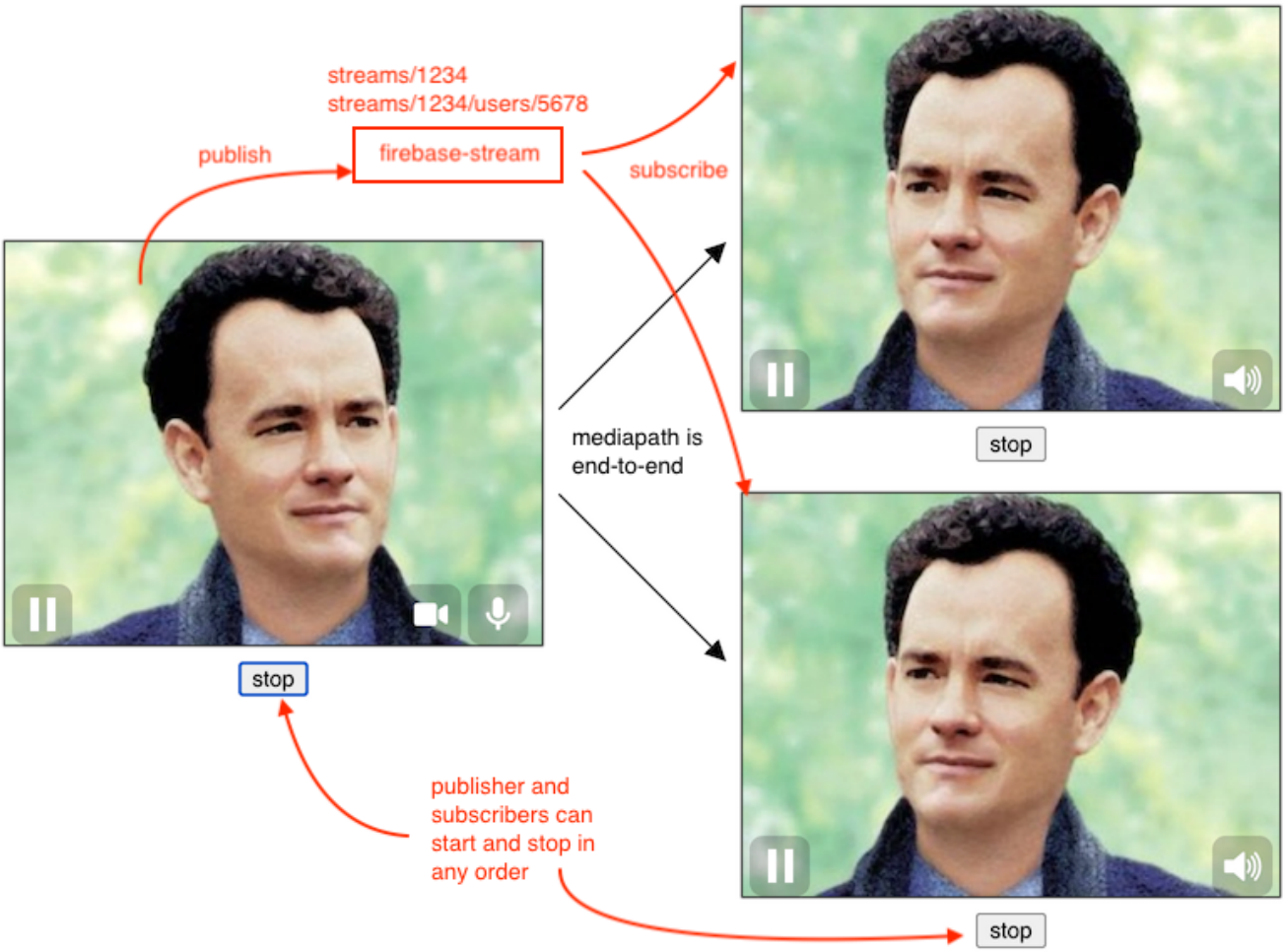
```
<!-- in <head> -->
<script type="text/javascript" href="https://www.gstatic.com/firebasejs/12.9.0
/firebase-app-compat.js"></script>
<script type="text/javascript" href="https://www.gstatic.com/firebasejs/12.9.0
/firebase-firestore-compat.js"></script>
<script type="text/javascript" href="https://rtcbricks.kundansingh.com
/v1/firebase-stream.js"></script>
...
<!-- in <body> -->
<firebase-stream id="stream" src=""></firebase-stream>
<script type="text/javascript">
document.querySelector("#stream").src = "id:123456?config=" +
encodeURIComponent(JSON.stringify({
    apiKey: ..., projectId: ..., appId: ...
}));
</script>
```

I use the legacy API with chaining, as I find it easier to understand and program with. You are free to update the firebase-stream.js component file to use the modular API.

To make sure that the following sample uses the right configuration, first set the apiKey, projectId and appId in your localStorage, using the JavaScript console. Keep the console open to see any error or warning when you try the example later.

```
localStorage["firebase-stream"] = JSON.stringify({
    apiKey: "...", projectId: "...", appId: "..."
});
```

Try the following example which opens one publisher and two subscribers, and allows you to start or stop the publisher and subscriber.



Please note that the notification server described above may require privacy protection of the keys. Please read the Firebase and Firestore documentation to secure your application by adding appropriate authentication, and access control on your database. Also, take measures to secure the app credentials.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required

Set the stream name and firebase configuration with JSON object containing projectId, appId and apiKey, e.g., "id:1234?config=...

4.5 Use the Graph Universe Node database for notification

Graph Universe Node database is an open source project (https://github.com/amark/gun) for fast and distributed data storage and synchronization. To use this, first follow the simple instructions of that project to install the node locally. Next, use our `dbgun-stream` web component as the named stream implementation as shown below. It takes the stream name, and a config with list of peers and other options.

```
<!-- in <head> -->
<script type="text/javascript" href="https://cdn.jsdelivr.net/npm/gun/gun.js">
</script>
<script type="text/javascript" href="https://rtcbricks.kundansingh.com/v1/dbgun-
stream.js"></script>
...
<!-- in <body> -->
<dbgun-stream id="stream"></dbgun-stream>
<script type="text/javascript">
  document.querySelector("dbgun-stream").src = "id:1234"
    + "?config=" + encodeURIComponent(JSON.stringify({
      peers: [ 'http://localhost:8765/gun', ... ], // may include others
      localStorage: false, radisk: false,
  }));
</script>
```

Try the following example which opens one publisher and two subscribers, connected to the locally running database as mentioned above.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description

`src` string, property and attribute, required
: Set the stream identifier and other config, e.g., "id:1234?config=...". The config parameter is JSON object containing peers as array of peer URLs, and other attributes such as localStorage or radisk.

Use of other databases to implement the notification service is discussed in How to create a stream using shared data? Use of external media servers such as Janus or FreeSwitch is discussed later in How to work with a media server?

5. How to record and play a video message

Use the `record` attribute or property to enable recording of the published or subscribed stream. Note that the recording is done on the client side by default. Use the `recorddata` property to access the recorded blob. This can then be converted and assigned to the src URL of a media element, or downloaded locally. An example follows.

```
<video-io record="true" publish="true"></video-io>
<video autoplay></video>
<script type="text/javascript">
    const video = document.querySelector("video-io");
    video.record = false; // to stop recording
    const blob = video.recordeddata;
    if (blob) {
        const url = URL.createObjectURL(blob);
        ... // play this url in <video> element or download it
        const player = document.querySelector("video");
        player.src = url;
    }
</script>
```

There are few other properties that can alter the behavior. The `recordmode` controls whether the recorded data is overwritten (default) or appended ("append") for subsequent recordings in the same component instance. In the example above, this should be set before the first recording, to ensure that it takes effect on subsequent recording. The `recordtype` controls the content type of the recorded data. Supported content types depend on the browser.

Playing the recorded data, converted to a URL, can be done in the standard `video` element as shown in the example above.

5.1 Continuous recording

The `recordmax` property controls the maximum duration of recording in seconds. If a negative value is supplied, then the last that many seconds are accessible in `recordeddata`. In this mode, the

`recordeddata` value may be a promise, and must be resolved to access the actual data.

```
video.recordmax = -10; // last 10s of recordings
...
const blob = video.recordeddata; // it may be a blob or a promise
Promise.resolve(blob).then(blob => {
    if (blob) {
        const url = URL.createObjectURL(blob);
        ... // play this url in <video> element or download it
        const player = document.querySelector("video");
        player.src = url;
    }
});
</script>
```

Try the following example to record the subscribed stream, instead of the published, and to allow playing the last 30 seconds at any time.

You can use an `audio` elements instead of `video` to only play sound of the last N-seconds. The `recordmax` is set to 30 seconds in the above example, but if there is not enough recorded data, the played recording will be smaller. You can also use `currentTime` on the media element to play the last 10s for example, even if the recording is for last 30s.

5.2 Delayed playback

Some applications need delayed playback of audio and video instead of in real-time. For example, in real-time captioning, live events with moderation, or ability to look at your back or side in a video mirror. Such delayed video can be played using the recording feature shown earlier.

A naive approach can setup a periodic timer, say for 10s, and access the `recordeddata`, and play in a `video` element. The code snippet is shown below. This uses the continuous recording with default `recordmode`, where the recording is restarted after the `recordeddata` property is accessed.

```
<video-io record="true" publish="true"></video-io>
<video autoplay></video>
<script type="text/javascript">
    const video = document.querySelector("video-io");
    const player = document.querySelector("video");
    setInterval(() => {
        player.src = URL.createObjectURL(video.recordeddata);
    }, 10000);
</script>
```

This works, with a problem, that everytime the video elements `src` is updated with the last recorded segment of 10s, there is flicker.

5.3 delayed-video

To solve the issue, a new `delayed-video` component is used. Internally, it employs two `video` elements, and two `MediaRecorder` instances, running in parallel. It switches the display to the video element that has started playing recently, thus avoiding any flicker. The following example shows how to use it.

```
<video-io id="video" record="true" publish="true"></video-io>
<delayed-video for="video" delay="10"></delayed-video>
```

Instead of specifying the `for` attribute with value as the identifier of the `video-io` instance, you can set the `input` property as the `video-io` instance, or the `srcObject` property as a `MediaStream` instance. The following are equivalent, assuming that the stream exists.

```
player.setAttribute("for", "video");
player.input = document.getElementById("video");
player.srcObject = document.getElementById("video").videoStream;
```

Try the following example. You can change the delay value before starting.

The `delayed-video` component has attributes for `delay`, `controls`, and `for`. It has properties for `input` and `srcObject` in addition to `delay` and `controls`. Only one of `for`, `input` or `srcObject` must be specified, in addition to a valid `delay`, for the recording and delayed playback to start. These attributes and properties are summarized below.

Name	Type and description
`for`	attribute, optional Set to the id of the source video-io element. The video-io element must be present in DOM at the time this attribute is set.
`input`	property, optional Set to the video-io element DOM object.
`srcObject`	property, optional Set to the MediaStream instance. See localStream or videoStream of video-io.
`delay`	property and attribute, required Set to a positive number, indicating delay in seconds.
`controls`	property and attribute, optional If attribute is present, or property is set, then displays the controls of the internal video element.

6. How to use the video-io API? (complete reference)

Previously, we have shown several examples of attributes and properties. Here we formally define those and enumerate and describe all the available values.

6.1 Overview

An attribute is accessible and settable in the HTML markup of the component. A property is readable and/or writable in the JavaScript code. Generally every attribute in our component is available as a property too, but not the reverse.

Some properties are also reflected as an attribute, which means that the current value of the property is updated in the component attribute. Unless marked as such, this is not the default. Thus, if a property is updated via attribute, but accessed via property, it will get the last update from attribute. But, if the property is updated via JavaScript property setter, and accessed via attribute, its value will not be correct. If the property is marked as "reflected as attribute" in the table below, then its value will be correct. Note that only a non-default property value is reflected as attribute, because a missing attribute indicates the default property value.

Following example shows the camera attribute and property.

```
<video-io ... camera="true" ...></video-io>
<script type="text/javascript">
    let video = document.querySelector("video-io");
    video.camera = false; // access the property
</script>
```

6.2 Types

A property can have one of the four types - bool (for boolean), string, number or object. The corresponding attribute is always a string in the HTML markup, but can represent the correct value in string, e.g., `camera="true"`.

Some boolean attributes may be treated differently - their presence may indicate a value of true, and absence a value of false, e.g., the `controls` attribute.

For a number-type property, typically the JavaScript `NaN` indicates that the property is not yet set, whereas an empty string in the attribute value indicates the same. For a string-type property, typically an empty string indicates an unset value both in property and attribute.

Generally, a number-type property defaults to JavaScript `NaN` and a string-type property defaults to an empty string. For several number-type properties, setting the value to NaN does not do anything. For example, even though the default `volume` on launch of the component is 1, once it is set to say 0.5, setting it next to NaN keeps it at 0.5 instead of reverting to original default of 1. Similarly for other number properties such as the `desiredframerate` property.

Some properties are read-only, some are write-only, but most of them are read-write properties.

A write-only property is useful for invoking a function, e.g., `getstats` is set to true, to have the component populate the quality metrics such as the `lost`, `bitrate` and `framerate` properties. This avoids the need to periodically capture the quality metrics, and only updates them when the trigger property, `getstats`, is set.

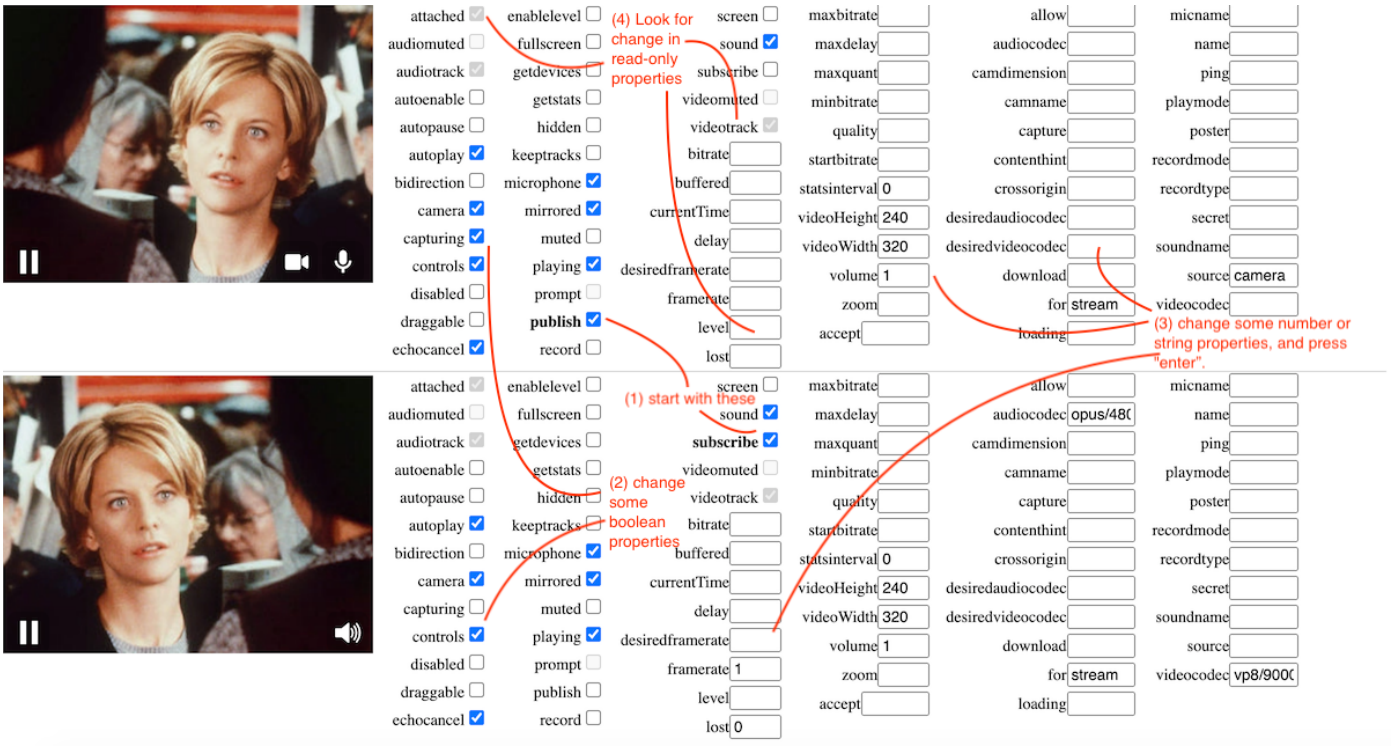
Setting an attribute in the markup initializes the property, if it is not read-only. A read-only property cannot be set and has no effect even if the corresponding attribute is set.

While setting a property as an object is trivial for primitive types of bool, number or string, it is not so for an object type. We assume JSON formatted string value for the attribute when setting an object type property via the attribute.

6.3 Testing

You can try out the various properties and attributes below, and test the publish-subscribe behavior of the component. It includes two `video-io` components, and allows you to control various properties, and view their changes. Although not shown in the screenshot below, it allows read/write of object properties as well. Note that some properties must be set before `publish` or `subscribe` is set for them

to take any effect. Try enabling the publish checkbox on first and the subscribe on second to get started.



6.4 Properties

Some of the properties below are not yet implemented, and are marked so. Some of the properties are related to some other properties, and are marked so.

Name	Type and description
`attached`	bool (read-only), default is false Indicates whether the component instance is attached to DOM or not? This is set to true when connectedCallback is called, and false when disconnectedCallback is called. Certain other properties such as "for" are processed only when attached, and postponed otherwise. See `for`, `publish`, `subscribe`

`audiomuted` — bool (read-only), default is false

Indicates whether audio track is muted on a subscribed component. This is set to true on mute event and to false on unmute event on the received media stream track.

See `audiotrack`, `videomuted`

`audiotrack` — bool (read-only), default is false

Indicates whether audio track exists on a subscribed component.

See `audiotrack`, `videotrack`

`autoenable` — bool, default is false

If set to true, then the component will automatically enable or disable the outbound tracks when the video is played or paused, respectively. This is applicable only for the published component.

See `autoplay`

`autopause` — bool, default is false

Controls the auto pause of video by having the publisher inform the subscriber about its playing state so that the subscriber can pause or play the video to avoid black video on publisher side pause. This does not affect the subscriber if the publisher is already paused before setting this property.

See `playing`

`autoplay` — bool, default is true

Controls the autoplay attribute of the underlying video element, and is applicable only for the published component.

See `autoenable`

`bidirection` — bool, default is false, reflected as attribute, attribute presence means true *(not implemented)*

If set to true, then the component can be used in both subscribe and publish mode at the same time.

`camera`	bool, default is true Controls the use of video capture device and outbound video track in a published component. See `microphone`, `keeptracks`, `publish`
`capturing`	bool, default is false Controls and indicates whether the published component's outbound tracks are enabled or not. See `camera`, `microphone`, `playing`
`channel`	bool, default is false Controls whether the underlying data channel is established or not. This must be set before the publish or subscribe is initiated. If the underlying data channel is created, it allows the application to use the send function to send some text data from the publisher to all the subscribers, and from the subscriber to the publisher. The receiver gets the message event with the received data. See `publish`, `subscribe`
`controls`	bool, default is false, reflected as attribute, attribute presence means true If set to true, the publish/play user interface controls are displayed. The controls automatically hide if content is playing, and mouse is not over the display.
`disabled`	bool, default is false, reflected as attribute, attribute presence means true If set to true, the user interface controls are disabled in the component. See `hidden`
`draggable`	bool, default is false, reflected as attribute, attribute presence means true If set to true, the component can be dragged to another place, or other

	content can be dragged to the component. The content is available in JSON (text), URL and HTML formats, representing the component state. Unlike other boolean attributes, this one requires explicit value of "true".
`echocancel`	bool, default is true If set to true, then microphone capture enables echo cancellation. This is applicable only for the published component. See `microphone`
`enablelevel`	bool, default is false If set to true, then the level property is periodically updated to represent the current microphone audio activity level on publish or received stream's audio activity level on subscribe. This allows the component to not listen for the audio activity level if not needed by the application. See `level`, `microphone`
`fullscreen`	bool, default is false Controls and indicates whether the component is in full screen mode or not.
`getstats`	bool (write-only), default is false If set to true, then calls getStats on all the peer connections and updates the related properties such as bitrate, quality, audiocodec, etc., similar to what is done when statsinterval is set, but done only once. See `statsinterval`
`hidden`	bool, default is false, reflected as attribute, attribute presence means true If set to true, then the component is not shown. This is useful for audio-only component. See `disabled`

`keeptracks`	bool, default is false If set to true, then changing the camera or microphone property only enables and disables the outbound track, instead of adding or removing the track. This is applicable only for the published component. See `camera`, `microphone`, `publish`
`microphone`	bool, default is true Controls the use of the audio capture device and outbound audio track in a published component. See `camera`, `sound`, `keeptracks`, `publish`
`mirrored`	bool, default is true If set to false, then the published camera view is not mirrored. See `camera`
`muted`	bool, default is false, reflected as attribute, attribute presence means true Controls and indicates the microphone or sound mute state. This is related to the microphone and sound properties. See `microphone`, `sound`
`playing`	bool, default is false Controls and indicates the media play state, for both published and subscribed components. See `subscribe`, `capturing`
`prompt`	bool (read-only), default is false Indicates whether the device capture permissions prompt is current shown or not. See `publish`
`publish`	bool, default is false Controls whether this is a published component or not. The component can be either published or subscribed. This is processed only after the

	component is attached to DOM. See `subscribe`, `camera`, `microphone`, `screen`
`record`	bool, default is false Controls and indicates the current recording state of the published or subscribed component. See `publish`, `subscribe`, `recordtype`, `recordmode`, `recordmax`, `recordeddata`
`screen`	bool, default is false Controls the use of the desktop or application sharing and outbound video track for that in a published component. See `publish`, `camera`
`sound`	bool, default is true Controls and indicates the use of audio play device. If set to false, audio play is muted. See `microphone`, `volume`
`subscribe`	bool, default is false Controls whether this is a subscribed component or not. The component can be either published or subscribed. This is processed only after the component is attached to DOM. See `publish`
`talking`	bool (read-only), default is false Indicates whether the active talking is detected from the local microphone or received stream. This is updated only when enablelevel is set to true. See `enablelevel`, `level`
`videomuted`	bool (read-only), default is false Indicates whether video track is muted on a subscribed component. This is set to true on mute event and to false on unmute event on the

	received media stream track. See `videotrack`, `audiomuted`
`videotrack`	bool (read-only), default is false Indicates whether video track exists on a subscribed component. See `audiotrack`, `videomuted`
`zoomable`	bool, default is false If set to true, the video can be zoomed using drag-select. If already zoomed, then clicking on the video resets the zoom. When zoomed, the selected portion is displayed as much as possible. See `magnifier`
`bitrate`	number (read-only) Indicates the current total bitrate in kb/s. See `quality`, `delay`, `statsinterval`
`buffered`	number (read-only) *(not implemented)* Indicates the current buffer size in seconds. See `quality`, `delay`, `statsinterval`
`currentTime`	number (read-only) *(not implemented)* Indicates the current play time in seconds.
`delay`	number (read-only) *(not implemented)* Indicates the current media delay in seconds. See `quality`, `lost`, `statsinterval`
`desiredframerate`	number Controls the desired video framerate in fps (frames per second) for a published component. The actual framerate may be different. See `framerate`, `publish`, `camera`
`framerate`	number (read-only)

Indicates the current video framerate in fps (frames per second).
See `desiredframerate`, `quality`, `statsinterval`

`gain` number

Controls and indicates the sound level of the microphone. Supported value is between 0.1 to 10 (geometric), corresponding to -20dB to +20dB (linear), and 1 indicating no change. It is ignored if some other source is used.
See `microphone`, `level`, `volume`

`level` number (read-only)

Indicates the current audio activity level. This is updated only when enablelevel is set to true.
See `enablelevel`, `gain`, `volume`

`lost` number (read-only)

Indicates the cumulative packet lost count.
See `quality`, `delay`, `statsinterval`

`maxbitrate` number

Controls the maximum bitrate in kb/s to be generated by the video track for a published component. The actual bitrate may be different.
See `minbitrate`, `startbitrate`, `publish`, `camera`

`maxdelay` number *(not implemented)*

Controls the maximum delay allowed in a subscribed component.

`maxquant` number

Controls the maximim video encoder quantization parameter for a published component. This only applies to VP8 video encoder. Lower value such as 30 or 40 gives better picture quality, and higher value such as 50 or 60 uses lower bitrate.
See `publish`, `camera`

`minbitrate` number

Controls the minimum bitrate in kb/s to be generated by the video track for a published component.

See `maxbitrate`, `startbitrate`, `publish`, `camera`

`quality` number (read-only) *(not implemented)*

Indicates the quality of published or played stream, as a number 0 (worst) to 1 (best). This uses several other metrics and statistics data to create a single metric of quality.

`recordmax` number

Controls the maximum duration of recording allowed in seconds. A positive number keeps the recording from the beginning of the session, whereas a negative number interprets it from the end. For example, use 300 to record first five minutes, or use -60 to keep record of most recent one minute.

See `record`

`startbitrate` number

Controls the starting bitrate in kb/s to be generated by the video track for a published component.

See `maxbitrate`, `minbitrate`, `publish`, `camera`

`statsinterval` number, default is 0

Controls the interval in seconds to periodically call getStats internally. The getStats is called to update certain related properties such as audiocodec, bitrate, quality, etc. Setting this to 0 or NaN or negative value stops any calls to getStats and any updates of these properties.

See `getstats`, `stats`, `audiocodec`, `videocodec`, `bitrate`, `framerate`, `lost`, `delay`, `quality`

`videoHeight` number (read-only)

	Indicates the height in pixels of the video currently playing, in published or subscribed component. See `videoWidth`, `playing`
`videoWidth`	number (read-only) Indicates the width in pixels of the video currently playing, in published or subscribed component. See `videoHeight`, `playing`
`volume`	number Controls and indicates the sound level of the audio play. See `sound`, `level`, `gain`
`zoom`	number Controls the zoom or scale of the controls, header or footer. Does not affect the component size itself. Less than 1.0 makes the controls smaller, and more than 1.0 makes them larger. See `controls`
`answer`	object Controls the constraints used for creating answer SDP in WebRTC negotiation. This cannot be changed after peer connection is initiated. See `subscribe`
`configuration`	object (write-only) Controls the optional configuration used for creating peer connection, e.g., {"iceTransportPolicy":"relay"}. This cannot be changed after peer connection is initiated.
`constraints`	object (write-only) Controls the optional constraints used for creating peer connection, e.g., {"googDscp":true}. This cannot be changed after peer connection is initiated.

`devices` object (read-only)

Returns a promise that resolves to a list of devices. The device name from this list may be used to set the camname, micname or soundname properties.

See `camname`, `micname`, `soundname`

`input` object

Set this to an external video, canvas, video-io or video-mix instance as source for media stream on publish. This avoids camera and microphone capture. The source property is set to input.

See `publish`, `subscribe`, `source`

`offer` object

Controls the constraints used for creating offer SDP in WebRTC negotiations. This cannot be changed after peer connection is initiated.

See `publish`

`recordeddata` object (read-only)

Contains the blob or a promise that resolves to a blob of recorded data so far for this component instance. If the recordmode is not "append", then the recorded data is reset immediately after access. A promise is returned only when recordmax was set to a negative value, and the recorded data was spliced at the beginning to accommodate the limit. If the property is accessed without stopping record, then last one second of recording may be missing in the value.

See `record`

`servers` object

Set this to a list of ICE servers needed for creating peer connections in this component. This cannot be changed after peer connection is initiated.

See `publish`, `subscribe`

`snapshot` object (read-only)

Contains a snapshot image as a data URL string, captured from the currently displayed video at the time this property is accessed.

See `publish`, `camera`

`srcObject` object

Set this to a named stream component instance to use that stream for this component. Alternatively, use the "for" attribute.

See `publish`, `subscribe`, `for`

`stats` object (read-only)

Returns a promise that resolved to the result of getStats on all the peer connections as an array of arrays.

See `getstats`, `statsinterval`

`video` object (read-only)

A reference to the underlying video element that is used to display the published or subscribed video.

See `display`, `poster`

`accept` string, reflected as attribute *(not implemented)*

Controls the content type that can be played or recorded by this component. This is similar to the accept attribute of the input element of type file.

See `capture`

`allow` string, reflected as attribute *(not implemented)*

Controls the features that are allowed for this component. This is similar to the allow attribute of the iframe element.

`audiocodec` string (read-only)

Indicates the audio codec in use for a published or subscribed component, e.g., "opus/48000". If multiple peer connections are present, then multiple comma separated values may be present, e.g.,

"opus/48000,pcmu/8000".
See `desiredaudiocodec`, `videocodec`, `microphone`, `publish`

`camdimension` string
Controls the camera capture size for a published component. This is the desired size, the actual may be different. For example 640x360
See `publish`, `camera`

`camlabel` string (write-only)
Search for the desired camera label match for a published component, and set camname to its ID if found.
See `camera`, `camname`, `devices`

`camname` string
Controls the desired camera ID for a published component. If it cannot be obtained, then camera capture may get disabled.
See `publish`, `camera`, `devices`

`capture` string *(not implemented)*
Controls which type of capture device should be used. This is similar to the capture attribute of the input element of type file.
See `accept`

`contenthint` string
Controls the contentHint attribute of the outbound audio and/or video track for a published component. Allowed values are "speech", "speech-recognition", "music" for audio, and "motion", "detail", "text" for video. A comma separated string can specify for both if needed, e.g., "speech,motion".
See `publish`, `camera`, `microphone`

`crossorigin` string, reflected as attribute *(not implemented)*
Controls the cross origin resource sharing behavior of the component. This is similar to the crossorigin attribute of the video or script

element.

`desiredaudiocodec` string

Controls the audio codec preference for a published or subscribed component, respectively, e.g., "pcmu" to allow only PCMU, or "opus/16000,*" to prefer OPUS at 16kHz, but allow others too.

See `desiredvideocodec`, `audiocodec`, `microphone`, `publish`

`desiredvideocodec` string

Controls the video codec preference for a published or subscribed component, respectively, e.g., "vp9" to allow only VP9, or "h264;42e01f,*" to prefer H264 and profile-level-id of 42e01f, but allow others too.

See `desiredaudiocodec`, `videocodec`, `camera`, `publish`

`download` string, reflected as attribute *(not implemented)*

Controls the download resource name. This is similar to the download attribute of the anchor element.

See `record`, `recordeddata`

`for` string, reflected as attribute

Set this to the id of a named stream component instance, which will be used by this component. This is processed only after the component is attached to DOM.

See `srcObject`, `publish`, `subscribe`

`loading` string, reflected as attribute *(not implemented)*

Controls the eager vs lazy loading policy. This is similar to the loading attribute of the iframe element.

`magnifier` string

Controls whether to show magifier on mouse hover. The value controls the size of the magnifier and magification level, e.g., "30px,4x" indicates the magnifier circle of 30px diameter centered at the mouse

position, with 4x magnification within the circle. Alternatively, percent may be used, e.g., "40%,300%" where magnifier diameter is 40% of component height, and maginification is 3x. If the supplied magnification level is less than 100% or 1x then a minimum 1x is assumed.
See `zoomable`

`miclabel` string (write-only)
Search for the desired microphone label match for a published component, and set micname to its ID if found.
See `microphone`, `micname`, `devices`

`micname` string
Controls the desired microphone ID for a published component. If it cannot be obtained, then microphone capture may get disabled.
See `publish`, `microphone`, `devices`

`name` string, reflected as attribute
The name attribute has its standard semantics.

`ping` string
Controls the webhook URLs, space separated, that will receive the events about the component. This is similar to the ping attribute of the anchor element. At this time, the events reported are only publish, subscribe or stop contained in the body of the POST request to indicate the start or stop of the publish or subscribe event. Use this with caution, as it will leak the application URL containing sensitive data to the third-party pinged service via the referer header.

`playmode` string *(not implemented)*
Controls the play mode of a subscribed component. Possible values are live or web.
See `playing`, `subscribe`

`poster` string

Controls the picture to be displayed before the first frame of the video is played, for a published or subscribed component. This is similar to the poster attribute of the video element.

`recordmode` string

Controls whether the recorded data is overwritten or appended for subsequent recordings of a component. Default is to overwrite. If set to "append", then it is appended. In the append mode, access to the recordeddata property does not clear the past recording. This property should be set before starting to record. If the property is modified during active recording, the recording is restarted, ignoring previous recorded data.

See `record`, `recordeddata`

`recordtype` string

Controls the content type of the recorded data. Support for a content type depends on the browser. Default is to use "video/webm" if supported. For audio-only recording, change this to "audio/ogg?codec=opus" or similar, if supported. This property should be set before starting to record. If the property is modified during active recording, the recording is restarted, ignoring previous recorded data.

See `record`

`secret` string

Enables the end-to-end encryption using insertable streams, and sets the value as encryption key.

See `publish`, `subscribe`

`soundname` string

Controls the desired speaker or audio output device ID for a subscribed component. If it cannot be obtained, then sound may get disabled.

	See `playing`, `devices`
`source`	string (read-only) Indicates that the media source is one of "input", "screen", or "camera", or not assigned yet "". This is applicable only for a publish component. See `input`, `camera`
`videocodec`	string Indicates the video codec in use for a published or subscribed component, respectively. It is of the form "vp8/90000" or "h264/90000;profile-level-id=42001f" to include extra parameters when needed. If multiple peer connections are present, then multiple comma separated values may be present, e.g., "vp8/90000,vp9/90000". See `desiredvideocodec`, `audiocodec`, `camera`, `publish`

The table above is the complete reference for the properties and attributes of the video-io component.

6.5 Events

Previously, we used the "data" event from the component instance. In addition, there are some other events dispatched by the component as shown below. The "propertychange" event is the most important.

Event	Example and description
`propertychange`	{"type": "propertychange", "property": "camera", "oldValue": false, "newValue": true} Dispatched when any property changes. This is not dispatched for a write-only property. Application will often need to listen to this, and filter specific property change events, to update the user interface or other application behavior.
`data`	{"type": "data", "data": {.. some JSON object ..}, "pc": ... peer connection ...}

	Dispatched when the component generates WebRTC signaling negotiation data that needs to be dispatched to the other instance. If the data object has "candidate" attribute, then it is an ICE candidate object. Otherwise the data object must have a "type" attribute of either "offer" or "answer", along with other attributes, for an SDP object in WebRTC. The same data object format is accepted by the apply function of the component. See method `apply`
`play`	{"type": "play"} Dispatched when the underlying video element dispatches the play event.
`pause`	{"type": "pause"} Dispatched when the underlying video element dispatches the pause event.
`message`	{"type": "message", data: "..."} Dispatched when some end-to-end data is received on the underlying data channel. See the channel property earlier, and the send function below. See property `channel`, method `send`

6.6 Functions

Previously, we used the "data" event from the component instance to deliver to another component instance via the `apply` function, when creating a point-to-point publisher-subscriber connection. Furthermore, we used a few implementations of named streams to connect with the component instance. Here, we go through the video-io component and named stream APIs that are useful for such interactions, including the functions in the components.

Function	Signature and description
`metadata`	Object.keys(video.constructor.metadata.properties).forEach(...)

	This class property represents an object containing information about all the properties, events or methods of the component, including a brief description of the property. The properties table shown previously used this property to display the table.
`apply`	video.apply({... JSON object ...}) The supplied data to the function is in the same format as the data object of the "data" event described previously.
`createPeerConnection`	video.createPeerConnection(...) Create a new peer connection based on the information available in the component instance. The named stream implementation typically calls this function.
`pc`	video.pc.forEach(...) An array of zero or more peer connection instances stored for this component instance. By default, it uses one peer connection in the array. But some named streams may implement differently, e.g., the named-stream and rtclite-stream components use one peer connection in a subscribed component, and zero or more in a published component depending on how many subscribers are subscribed to this named stream. The janus-stream component does not use this property to store the peer connections.
`localStream`	(read-only) Although this is a property, it is more applicable to the interface with the named stream, and hence is described here, instead of in the properties table. It represents the local capture stream for a published component, that can be used by the named stream implementation to send on an outbound peer connection.
`remoteStream`	(write-only) Although this is a property, it is more applicable to the interface with the named stream, and hence is described here, instead of in

	the properties table. When the named stream implementation detects a newly received remote stream, it supplies it to the video-io component by setting this property.
`send`	video.send("... some text ...") By default, an underlying data channel is created when the component is published or subscribed. The send function can be used to send some text data from the publisher to all the subscribers, or from the subscriber to the publisher. This feature can be disabled by resetting the channel property before publish or subscribe is initiated.

6.7 Stream functions

Sample implementations of three named streams are available from us. If you want to implement another named stream component, e.g., to use a different signaling or notification channel for your WebRTC application, you can use the following interface to do so. A named stream component must implement the following functions. The video-io component instance invokes these functions on the attached named stream component instance.

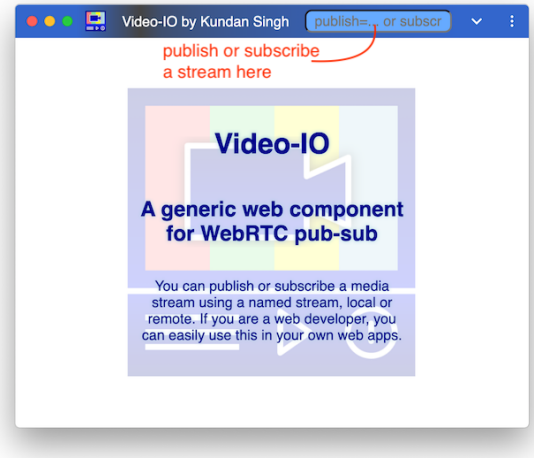
Function	Signature and description
`publish`	stream.publish(video) This is called when the video-io component wants to publish a stream. It supplies its own reference. The implementation will likely create peer connections for outbound streams.
`subscribe`	stream.subscribe(video) This is called when the video-io component wants to subscribe a stream. It supplies its own reference. The implementation will likely create peer connections for inbound streams.
`stop`	stream.stop(video)

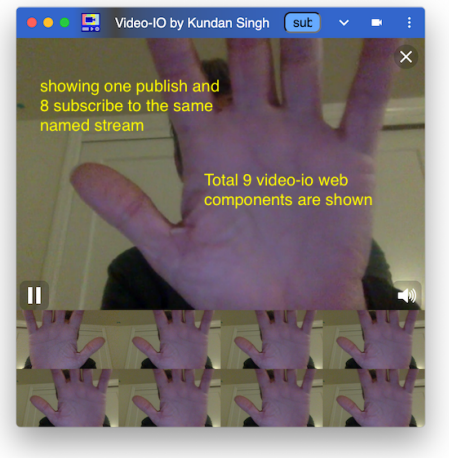
	This is called when the video-io component wants to stop publish or subscribe. It supplies its own reference. The implementation will likely close the peer connections.
`addTracks`	(optional) stream.addTracks(tracks) This is called, if available, when the video-io component wants to add new tracks to the published stream. The implementation will likely update the tracks for the outbound peer connections. On the other side, it should update the video-io component when the received remote stream changes using the remoteStream property. See property `remoteStream`
`removeTracks`	(optional) stream.removeTracks(tracks) This is called, if available, when the video-io component wants to remove existing tracks from the published stream. The implementation will likely update the tracks for the outbound peer connections. On the other side, it should update the video-io component when the received remote stream changes using the remoteStream property. See property `remoteStream`

Please see the `named-stream.js` or `rtclite-stream.js` file for examples of how to implement a named stream component.

7. How to use the video-io installed app?

We have also created a standalone web app named video-io that can show zero or more video-io web components wrapped in a flex-box component. Although the video-io web component shows a single video in publish or subscribe mode, many video conferencing related use cases require showing multiple video elements at the same time. The flex-box web component, which is described later How to customize multi-video layout?, is used to layout multiple video-io or other elements.





7.1 Progressive web app (PWA)

This video-io standalone web app can be installed as a progressive web app (PWA), on desktop or mobile. To use the installed app, first launch the web app in the browser, then use the browser's prompt or the install button near the address bar to install it locally. Try the following to launch the web app with a local camera preview, and a local subscribed view of the same, and then click the install button near the address bar.

```
https://rtcbricks.kundansingh.com/v1/video-io.html?publish=...&subscribe=...
```

Note that the PWA manifest file for this app expects the web page of the app to be at `/v1/video-io.html`. So if your testing is not on this path, it may not allow or show the install button. Alternatively, you can edit the video-io.json file for another path as per your hosting.

The user interface allows publish or subscribe of the named streams, e.g., by entering publish=alice or subscribe=alice it uses the local named-stream components, and it attaches a video-io component to each such stream. For testing with external named streams, you need to specify the full description, e.g., `publish=rtclite:ws://localhost:8080/streams/1234` will publish to that named stream using the rtclite-stream component. A list of publish and subscribe parameters can also be supplied on launch. It can also be launched on desktop, if not already open, to add a new stream using its URL protocol handlers: `web+ezpub` or `web+ezsub`, for publish or subscribe, respectively. Note that the protocol handler feature is not supported on mobile. If a user opens a URL web+ezpub:rtclite:ws://localhost:8080/streams/1234, it adds a video-io web component instance, and an attached rtclite-stream web component. It then connects to the presumed rtclite service at localhost port 8080, over a websocket transport, and publishes camera/mic media to the named stream, `streams/1234`.

The flex-box component allows dynamically adjusting the layout, e.g., double clicking on a video to put it in presenter mode, or resize videos based on available size and aspect ratio of the window. It allows drag-and-drop of the video elements, e.g., to re-order them in the display, or to pop out a video to a separate window or tab, or to move or copy a publish or subscribe video stream from one app instance to another.

7.2 Configure attributes and styles

Besides the publish and subscribe URL parameters, it also accepts config parameter, and the corresponding `web+ezcfg:` protocol handler. The config parameter value can be used to set the attributes or styles on all included or individual video-io elements. Consider the following example of the URL parameter:

```
?publish=...&config=video1.screen%3Dtrue%26video.style.object-fit%3Dcontain
```

Note that the parameters are parsed and processed sequentially. It creates a publish video-io first after processing the publish parameter, and labels it as `video1`. Then the config parametre is parsed, to interpret two actual values as follows. Note that the full parameter value is escaped.

```
video1.screen=true
video.style.object-fit=contain
```

The first one is applied to the individual video-io instance labeled `video1`, and causes it to use screen share to publish, instead of the default camera video feed. The second is applied generically to all video-io instances including the previously created as well as those that will be created in the future in this instance of the app. In this case it changes the `object-fit` style of the video-io component to `contain` instead of default `cover`, so that sides in the video are not cut-off, and a padding is used instead.

The config parameter can also be used to set the attribute or style on the flex-box container. Consider the following example, which turns the flex-box display to pip or picture-in-picture mode, and uses the second video as the background.

```
...&config=box.display%3Dpip%26video2.float%3D (same as below)
box.display=pip
video2.float=
```

All the properties and styles of the video-io components are detailed in the previous chapter, How to use the video-io API? Additionally, standard CSS styles can be used too.

The goal of this video-io app, separate from the video-io web component, is to create a generic user interface for web video conferencing applications, where the conferencing app logic can reside in external software, which invokes this app to display, capture, publish and subscribe various media streams using the protocol handler. The extensive video-io component API can be used to further customize its behavior using the URL parameters.

7.3 Electron app

We have also built a native Electron app, which uses the same code as the PWA, but wraps it in the Electron packager. The protocol handlers are ezpub, ezsub, and ezcfg without the "web+" prefix. It supports the same set of configurations as the PWA.

The sample app can built, tested and packaged as follows:

```
cd 11-electron-app
npm install
npm start ezpub:one ezsub:one
npm run make
```

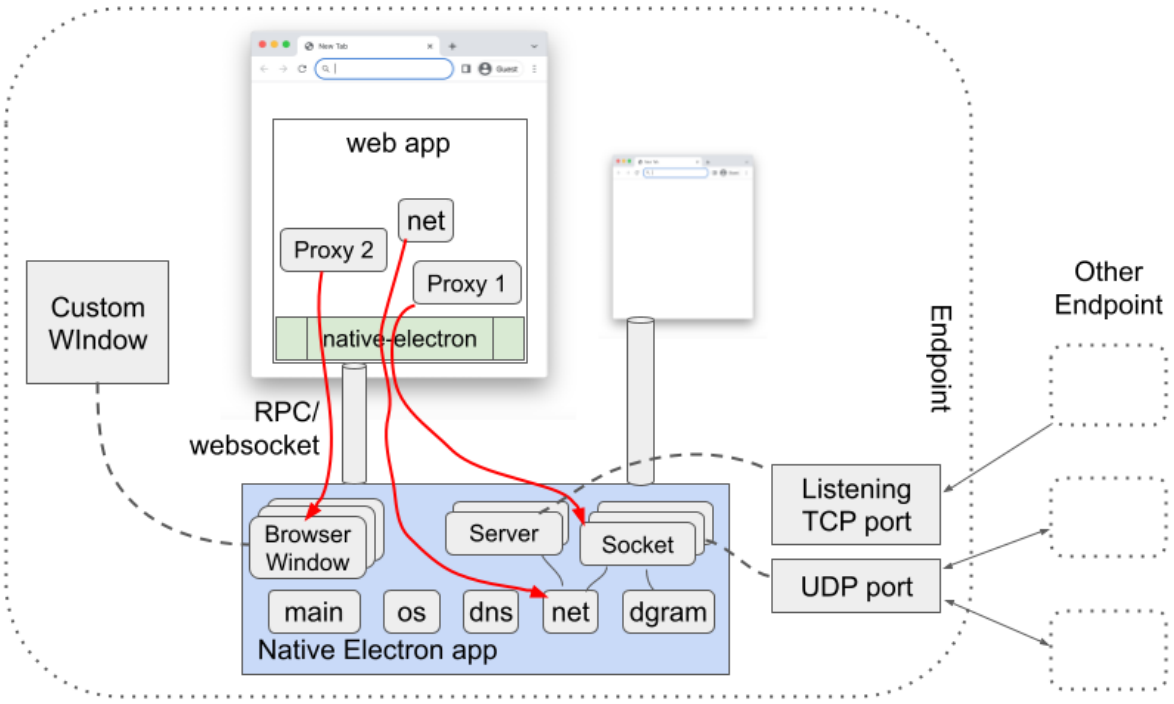
The main app logic is in main.js, which parses the command line or launch parameters, and opens the external video-io.html web app. To enable screen sharing or desktop capture from the electron app, it uses preload.js and renderer.js to replace getDisplayMedia with custom desktop capturer. There is also an example package.json file for building the app. These are only for trial purpose, and a real world app will need to edit and customize these.

8. How to use the native Electron features?

The Electron app and the progressive web app described in the previous chapter behave almost the same. In general, a progressive web app is preferred to an Electron app, for similar functionality. However, the native Electron can provide many additional features that are not available in a web app. In this chapter, we describe a separate native Electron app that enables a wide range of features and constructs that are not available in a web app.

8.1 Overview

The architecture is shown below, where the native Electron app acts as a plugin to enable and expose several Electron APIs such as for opening a native window, getting system information, DNS resolver, and TCP and UDP sockets. The basic idea is inspired by my earlier project, flash-network (https://github.com/theintencity/flash-network/) (see more here (https://theintencity.kundansingh.com/flash-network/)), that used a native AIR (Adobe Integrated Runtime) app to expose certain network APIs to web apps, including for my SIP-in-JavaScript (https://github.com/theintencity/sip-js) project.



These Electron features are exposed using a web component, `native-electron`, from a web app. This allows the web app to use, say, UDP or TCP socket, for implementing advanced networking applications such as peer-to-peer or application level multicast, or for implementing custom window behavior, such as to open a transparent or frameless browser window for a more immersive video conferencing display, or for drawing on the screen or showing the mouse pointer of the other participants during a screen share enabled video collaboration.

To use these feature, first build the native app as follows, and run it on the local machine.

```
cd 12-native-electron-app
npm install
npm start
npm run make
```

You may enable it to bind to all the interfaces, instead of only the local interface by default, using the -h option shown below. If no port, using -p, is specified, then it uses the default port of 9090. You may also want to edit the package.json or other source files to customize your native app.

```
cd 12-native-electron-app
npm start -- -h 0.0.0.0 -p 9090
```

Once the native electron app is running locally, use a `native-electron` web component in the web app to connect to the native app as shown below.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/native-electron.js"></script>
...
<native-electron src="ws://localhost:9090/native-electron"></native-electron>
```

When the `src` property is set, it attempts to connect to that service, using websocket, assuming it as a locally running Native Electron app. This websocket connection is then used as a channel for various RPC (remote procedure call) interactions between the client (web app's native-electron component

instance) and the server (locally running Native Electron app).

Although the native app is expected to run on the local machine, it is not a requirement. The web component can connect to a remotely running native app as long as such connections are allowed. The native app itself may restrict incoming connection to be from only a localhost, by binding to the local IP interface (default) instead of all.

The local native app assigns an identifier to each channel, so that it can corelate the various APIs and proxy objects related to that channel. The web app can supply this identifier, using the id parameter, or let it be generated by the client side web component, as follows. The component internally replaces "{id}" in the URL with its own randomly generated identiier.

```
<native-electron src="ws://localhost:9090/native-electron?id={id}"></native-
electron>
```

The native features exposed by this component are grouped into five modules. These are os, dns, net, dgram and main, corresponding to the similarly named modules in NodeJS, except that main is used for the browser window related APIs. The client side component just exposes these as proxy objects, so that the web app can invoke any method on those.

For example, if the web app calls a method, say, dns.lookup("www.google.com"), as shown below, then the web component serializes the method request and all the parameters, and sends it to the native app.

```
const {dns, os, dgram} = document.querySelector("native-electron");
const platform = await os.platform(); // "darwin", "win32", or "linux"
const result = await dns.lookup("www.google.com"); // e.g., {"address":
"142.250.189.154","family":4}
```

When the native app receives this, it deserializes the request, runs the command using the NodeJS module, and returns the response or error, again after serialization. The web component then returns that response, after deserialization, as the resolved value of the promise returned by that method,

dns.lookup.

Some NodeJS APIs such as dgram.createSocket return an object that are only valid in the native app, not in the web app. For such cases, the serialization and deserialization step ensures that a proxy object is exposed in the web app, with a unique identifier, so that further method calls or usage of that proxy object in the web app, results in the corresponding action on the real object in the native app. Such implementations are well known and thoroughly researched in RPC literature.

In the following example, the socket variable is actually a proxy object. Further method such as send on that object ensures that the native app uses the right underlying socket object. Setting the event handler, allows the web app to receive that event.

```
const socket = await dgram.createSocket({type: "udp4", ...});
socket.onmessage = (msg, rinfo) => { ... };
await socket.send("testing", 8123, "192.168.1.2");
```

Try the following example to test some APIs including opening a window, doing DNS lookups, create TCP and UDP server and client sockets, and sending messages. The test takes several seconds to complete successfully. Use the JS console of the browser to see any errors ourside the component.

When the channel that created the proxy object is closed, the proxy object is automatically deleted and cleaned up by the native app. This avoids leaking memory, and automatically closes any windows or sockets when the connected web page closes.

The native-electron component is agnostic to the full set of APIs supported in these modules, and those are actually determined by the connected native app. If an API is not supported, e.g., due to mismatch in platform or version of the NodeJS used in the native app, it responds with an appropriate error.

Because of the nature of such RPC-based APIs, all the methods on the various modules or various proxy objects must be asynchronous, using promise based syntax in the web app, as illustrated above. Note that all the proxy objects in the web component receive all the relevant events from the native app, and depending on which event has a handler installed, only those are triggered or dispatched by

the component. This may change in the future to optimize, e.g., to receive only the events with installed handlers from the native app, instead of all the events.

Property access in JavaScript is synchronous, whereas our RPC-based API requires asynchronous interaction to get or set a property. Hence, our proxied objects or modules do not provide any direct property access. However, if the property access is via a method call, such as address() on net.Socket, then those are supported. This may change in the future, to proactively get the property values and keep them updated in the proxied object in the web component.

8.2 native-electron

The following table describes all the properties of the component.

Name	Type and description
`src`	string, default is "ws://localhost:9090/native-electron" A websocket URL to connect to the locally running Native Electron installed app. Set this to start the connection, and reset to stop.
`state`	string (read-only) The connection state of the component, is one of there: idle, connecting, connected, disconnected, or waiting.
`debug_level`	number, default is 2 Logging level on JavaScript console: 0 none, 1: error, 2: warn, 3: info, 4: debug, 5: trace.
`useprompt`	boolean, default is false Controls whether to use the built-in JavaScript prompt for access code. If set to false, then it uses DOM-based user interface for access code.
`hasprompt`	boolean (read-only), default is false Indicates whether a prompt for access code is being shown or not.

`main`	object (read-only) A proxy object to invoke native Browser Window (main) related APIs, e.g., main.createWindow(...)
`os`	object (read-only) A proxy object to invoke native OS (os) APIs, e.g., os.networkInterfaces()
`dns`	object (read-only) A proxy object to invoke native DNS (dns) APIs, e.g., dns.lookup(...) or dns.resolve(...)
`net`	object (read-only) A proxy object to invoke native Network (net) APIs, e.g., net.createServer(...) or net.createConnection(...)
`dgram`	object (read-only) A proxy object to invoke native Datagram (dgram) APIs, e.g., dgram.createSocket(...)

The following table shows all the events dispatched by the component instance.

Event	Example and description
`prompt`	{type: "prompt", visible: true} Dispatched when prompt for access code is shown or hidden
`statechange`	{type: "statechange", oldValue: "idle", newValue: "connecting"} Dispatched when the state property changes

As mentioned earlier, the native app defines what APIs are supported in the various modules, os (https://nodejs.org/api/os.html), dns (https://nodejs.org/api/dns.html), dgram (https://nodejs.org/api/dgram.html), net (https://nodejs.org/api/net.html) and main, as well as on various proxied objects such as net.Socket, net.Server, dgram.Socket or BrowserWindow (https://www.electronjs.org/docs/latest/api/browser-window). These APIs are well documented in NodeJS and/or ElectronJS as referenced above.

Our native electron app also has a subset list of supported APIs as described here. In particular, these global methods on the modules are supported. These are documented in the NodeJS and/or ElectronJS references.

Module	Methods
`dns`	getServers, lookup, resolve, resolve4, resolve6, resolveAny, resolveCaa, resolveCname, resolveMx, resolveNaptr, resolveNs, resolvePtr, resolveSoa, resolveSrv, resolveTlsa, resolveTxt, reverse
`os`	arch, cpus, endianness, freemem, hostname, loadavg, machine, networkInterfaces, platform, release, totalmem, type, uptime, version
`net`	connect, createConnection, createServer, isIP, isIPv4, isIPv6
`dgram`	createSocket
`main`	createWindow, getAllWindows, getFocusedWindow, fromId

The following methods on the proxied objects are supported. These objects are either created by the modules methods, or received in an event or method of another proxied object. These are documented in the NodeJS and/or ElectronJS references mentioned above.

Object	Methods
`net.Server`	address, close, getConnections, listen
`net.Socket`	address, connect, destroy, end, pause, pipe, resetAndDestroy, resume, setEncoding, setKeepAlive, setNoDelay, setTimeout, getTypeOfService, setTypeOfService, write
`dgram.Socket`	addMembership, addSourceSpecificMembership, address, bind, close, connect, disconnect, dropMembership, dropSourceSpecificMembership, getRecvBufferSize, getSendBufferSize, getSendQueueSize, getSendQueueCount, remoteAddress, send, setBroadcast, setMulticastInterface, setMulticastLoopback, setMulticastTTL, setRecvBufferSize, setSendBufferSize, setTTL

`BrowserWindow`	destroy, close, focus, blur, isFocused, show, showInactive, hide, isVisible, isModal, maximize, unmaximize, isMaximized, minimize, restore, isMinimized, setFullScreen, isFullScreen, setSimpleFullScreen, isSimpleFullScreen, isNormal, setAspectRatio, setBackgroundColor, setBounds, getBounds, getBackgroundColor, setContentBounds, getContentBounds, getNormalBounds, setEnabled, isEnabled, setSize, getSize, setContentSize, getContentSize, getMinimumSize, setMinimumSize, getMaximumSize, setMaximumSize, setResizable, isResizable, setMovable, isMovable, setMinimizable, isMinimizable, setMaximizable, isMaximizable, setFullScreenable, isFullScreenable, setClosable, isClosable, setAlwaysOnTop, isAlwaysOnTop, moveAbove, moveTop, center, setPosition, getPosition, setTitle, getTitle, flashFrame, setSkipTaskbar, setKiosk, isKiosk, isTabletMode, getMediaSourceId, loadURL, reload, setOpacity, getOpacity, setIgnoreMouseEvents, setContentProtection, isContentProtected, setFocusable, isFocusable

Note that some method results are redacted, e.g., the MAC address field is redacted in the result of os.networkInterfaces. Some methods have restrictions, e.g., net.Socket's listen or dgram.Socket's bind does not allow Unix path, and must use a port, and it does not allow listening or binding to port number less than or equal to 1024 for some protection.

Try the following example to view most of the APIs, and try them in real time.

The test example above allows you to edit the parameters of various methods, and invoke them in any order. It also shows when an event handler is called. It has extensive test setup for TCP and UDP socket, as well as browser window.

8.3 Custom window

A major benefit of using the native electron app is that the web app can implement browser window features that are not available to the web app. The BrowserWindow object in ElectronJS is versatile and flexible to accomplish a number of use cases, such as transparent background, frameless window,

semi-transparent overlay, and so on. We demonstrate two such use cases below.

The first example uses the rtclite stream to connect a publisher and subscriber to the same locally running service, but displays each video-io component in its own transparent window, with rounded shape to display the videos in circle. Those windows have no visible controls, and are displayed with always-on-top flag enabled. They can be dragged around on the screen to move, or dragged to resize near the corner.

Make sure that the rtclite streams service and the Native Electron app are running locally. Then try the following example to launch the two video-io instances.

The second example allows drawing on the screen. It uses a transparent full size window and loads the overlay-draw.html web app in that window. This web app is a simple drawing application that uses SVG and user mouse input to draw lines. You can first try the web app as follows. Click on the color picker to pick a pen color. Then click-and-drag the mouse within the web app area to draw lines.

Next, to test drawing with the overlay transparent window, make sure that the Native Electron app is running locally on the default port. Then try the following example. Then click the Start button to start drawing, and double click anywhere to stop. Click anywhere and drag to draw. The drawing disappears 8s after completing the last continuous drawing. Use Shift key when completing a drawing to change the disappearance timer to 60s.

A color picker is shown by default on top-left of the screen when the drawing is enabled. Click the picker to change the pen color if needed. You can also long press and drag the picker to a different position on the screen.

Internally the above example loads a generic overlaw-draw.html web app in a transparent window.

The Native Electron app's menu includes options to launch these windows: a self camera preview in a circle shape, and the drawing overlay described above.

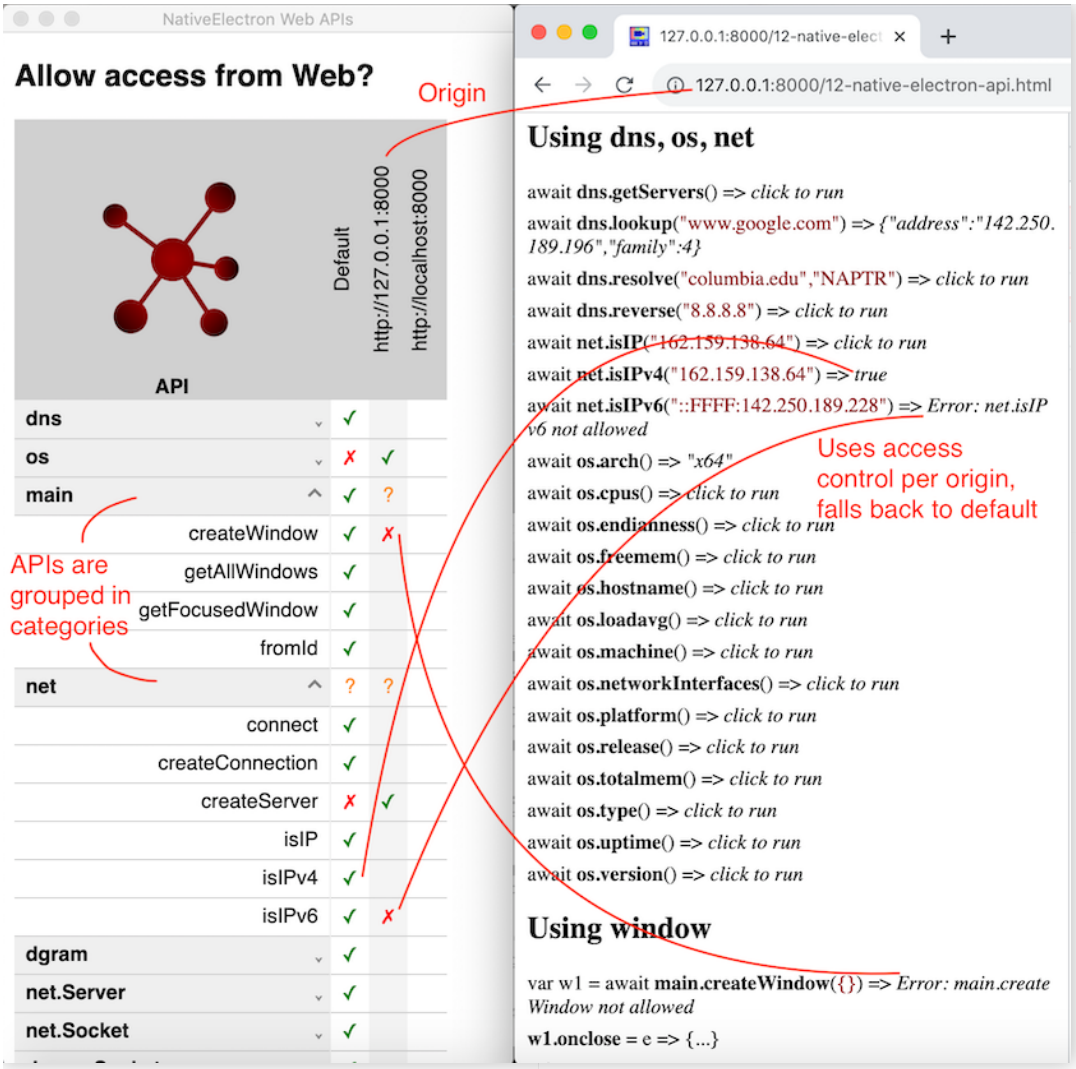
8.4 Access control

The web APIs exposed by the native-electron component in conjunction with the locally running Native Electron app are very powerful. If misused, they can cause damage to the local system such as by exploiting vulnerability in Electron, NodeJS or their dependencies. Thus, such APIs should be allowed only from trusted web pages or apps.

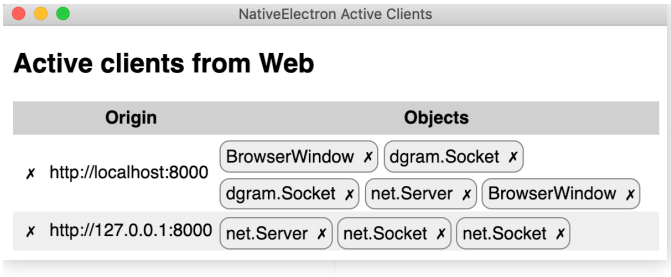
The Native Electron app implements a simple authentication to ensure that the web apps cannot connect to the native app for the first time without a user interaction and input. This mechanism attempts to keep the end user in control of the authentication and authorization phases. Here, we describe how it works.

When the native-electron web component, used in a web app, attempts to connect to the local app, on WebSocket, the native app checks the HTTP Origin header of the request, and the access code in the connection URL parameter. If the access code is missing, or if the native app already has an access code for this origin but is different from the access code supplied in the URL parameter, then the native app displays the access code prominently on the screen, and responds with an error. The access code disappears after a brief timeout, of say, 5s. The native-electron web component, on an error, prompts the end user to enter the access code. If the user cancels the prompt, the connection is no longer re-attempted. If the user manually enters the access code in the prompt, and continues, it is reattempted. It causes the native-electron web component to retry the WebSocket connection, with the new access code in the URL parameter. If the access code is successfully verified by the native app, it allows the WebSocket connection to proceed. This authentication process is similar to what was used in my earlier flash-network project mentioned before. Subsequent RPC on this connection are further controlled based on API access control described later.

The Native Electron app has three user interface windows for access control, that can be shown directly using the application menu of the locally running native app. The first one is for access code management for various origins, such as to edit or delete them. The second one for web API access control, which allows the end user to disable some APIs from certain origins, or from all. And the third one is for listing and controlling all the active connections from the web app. This interface also shows all the created proxy objects such as TCP or UDP sockets and windows, and allows the end user to close an individual object, or the whole connection from that web app to the native app.



The above screenshot shows the native app's web API access control window on the left, and the test web page opened in the browser on the right. It also shows how the various permissions on the APIs affect the tests, e.g., isIPv6 is blocked for the origin of the web page, but isIPv4 has no override permission so it falls back to the default, which is allowed. The access control window shows the API methods grouped in high level categories, and allows setting the access control for the whole category, or the individual method in that category. Access control can be set for the web page origin, or if not set, then it falls back to the default column as shown above.



The above screenshot shows the native app's active client window, with various active connections from web apps, and their created objects. The cross button in the row closes the connection from that web app, and the cross button next to the object type closes that object. Note that our native-electron web component is designed to reconnect automatically, so closing the connection usually results in an immediate reconnect. To really block the web app, you should also delete or change the access code in the first user interface described earlier.

9. How to select devices?

The `device-selector` component can be used to display a user interface to allow selecting media devices. It allows selecting microphone, speaker and camera devices. When this component is attached to another target `video-io` component, it automatically sets the devices on the target. The controls in this component automatically adjust on resize.

Try the following example to explore device selection. Give it a try from a machine that has multiple devices such as two webcams or two microphones.

9.1 device-selector

The following table describes all the properties of the component.

Name	Type and description
`audioinput`	object Currently selected microphone device object. The object contains kind, deviceId, label and groupId attributes. It can be set to the deviceId string, instead of an object, in which case it is assigned internally to the right device

object for that deviceId if found, or throws an error if not.
See `microphone`

`audiooutput` object
Currently selected sound device object. The object contains kind, deviceId, label and groupId attributes. It can be set to the deviceId string, instead of an object, in which case it is assigned internally to the right device object for that deviceId if found, or throws an error if not.
See `sound`

`videoinput` object
Currently selected camera device object. The object contains kind, deviceId, label and groupId attributes. It can be set to the deviceId string, instead of an object, in which case it is assigned internally to the right device object for that deviceId if found, or throws an error if not.
See `camera`

`microphone` boolean, default is true
Controls whether to show microphone device selection and microphone level. If set to false, it unselects the microphone and resets the audioinput property. If set again to true, it re-selects the same microphone device, and reverts the audioinput property to its previous value.
See `audioinput`

`sound` boolean, default is true
Controls whether to show sound device selection and sound test. If set to false, it unselects the sound and resets the audiooutput property. If set again to true, it re-selects the same sound device, and reverts the audiooutput property to its previous value.
See `audiooutput`

`camera` boolean, default is true
Controls whether to show camera device selection and preview. If set to false,

it unselects the camera and resets the videoinput property. If set again to true, it re-selects the same camera device, and reverts the videoinput property to its previous value.
See `videoinput`

`preview` boolean, default is true
Controls whether to show selected camera preview, microphone level and sound test controls. This is useful to reduce the CPU overhead of camera preview and microphone level indicators.

`mirrored` boolean, default is false
If set to true, then the selected camera preview is mirrored. Mirrored preview appears more natural to people during camera tests. Note that the video-io component also has a mirrored property, which defaults to true, unlike the mirrored property of this component.
See `preview`, `camera`

`autosize` boolean, default is false
Controls how the size of component versus internal elements are adjusted. If set to true, then the component size is automatically set based on the internal elements such as based whether camera, sound or microphone are enabled or not. In that case the width is locked at 180px. If set to false, then the size of internal elements are adjusted based on the component size, and a minimum width of 180px and height of 320px is imposed.

`selected` boolean, default is true
Controls whether to auto-select a device in each category, or if false, allow empty selection as default. When the property is set to true, previous selection is not altered, but a new item of "Not selected" is added in each device category. When the property is set to false, and the previous selection was a valid device, then the selection is not altered. But if previously, no device was selected, then the first device in each category is implicitly selected.

`save` boolean, default is false

Controls whether to save the selection in localStorage, and re-use it next time. The localStorage key of device-selector is used.

`showsave` boolean, default is false

Controls whether to show a save button at the top. Clicking on the save button dispatches the save event, which can be used by the application to save the selected devices. Using the save button is not required, e.g., if using the for or target property, using the current selection on close, or when detecting the change in selection using the change event.

`for` string

Set to the id of the target video-io element to which device selection is applied. The camname, micname and soundname properties of the target are updated on device selection. The video-io element must be present in DOM at the time this attribute is set.

See `target`

`target` object

Set to the target video-io instance to which device selection is applied. The camname, micname and soundname properties of the target are updated on device selection. When this attribute is set, the initial device selection, if any, of the device-selector is applied to the target, and if no device selection, then camname, micname and soundname properties from the target, if set, are indicated in the device-selector. This has implication on the behavior based on the order of component initialization, device selection and assignment of the target attribute.

See `for`

The following table shows all the methods of the component.

Function	Signature and description
`setdevices`	selector.setdevices(await navigator.mediaDevices.enumerateDevices()) *(not implemented)*

Set the list of devices in similar to that returned by navigator.mediaDevices.enumerateDevices. This alters the list of devices shown in the component, and selection is only allowed from that list.

The following table shows all the events dispatched by the component instance.

Event	Example and description
`change`	{type: "change", kind: "microphone", deviceId: "...", label: "..."} Dispatched to indicate that a selected device changed. The new device details (deviceId and label) are included. If the device selection is reset, then those details are empty strings. See `audioinput`, `audiooutput`, `videoinput`
`prompt`	{type: "prompt"} Dispatched to indicate that device permission prompt is active. If this event is dispatched, then another "ready" event will be dispatched when the permission is granted or denied. Note that if the permission is pre-granted or pre-denied, then it will not prompt. See event `ready`
`ready`	{type: "ready"} Dispatched only after the user grants or denies the permission and previously the "prompt" event was dispatched. Note that if the permission is pre-granted or pre-denied, then it will not dispatch prompt or ready. See event `prompt`
`save`	{type: "save"} Dispatched when the save button is clicked. See property `showsave`

The user interface of the component can be customized using the following styles.

Style	Description and default

`--color-indicator`	Default `darkgreen` color of the microphone level indicator
`--bgcolor-indicator`	Default `lightgrey` background color of the microphone level indicator
`--bgcolor-preview`	Default `lightgrey` background color of the camera preview video

10. How to use the data channel?

The `channel` property of the `video-io` component can be used to enable the underlying data channel between publisher and subscribers, similar to the media path, but bi-directional.

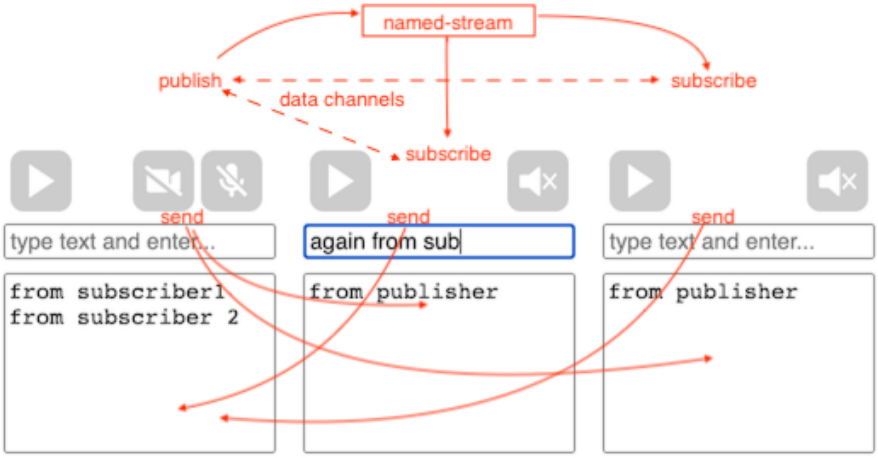
```
<video-io id="video1" channel="true" publish="true"></video-io>
<video-io id="video2" channel="true" subscribe="true"></video-io>
```

This then allows you to send some text data using the `send` method, which is then received and delievered via the `message` event on the other end.

```
video1.send("... some text ...");
video2.addEventListener("message", event => {
    // event.data is the text data received.
});
```

The data channel is established along with the media path, when the component is published or subscribed. Hence, the channel property must be set before publish or subscribe is initiated. A data-only path may be achieved by disabling `camera` and `microphone` properties of the publish side. In the full mesh or peer-to-peer case, the data channel, like the media path, is between the publisher and all the subscribers. Thus, it allows sending data from the publisher to the subscribers, and from the subscriber to the publisher. It does not allow sending data among the subscribers, as the peer connection is only between the publisher and the subscriber, but not between two subscribers. However, the application can implement higher-level logic to facilitate data routing at the publisher, by receiving from one subscriber and sending back to all, such that the original subscriber ignores the reflected data.

Try the following example to explore how the bi-directional data path works.



The example does not enable audio/video by default, but uses the video-io component display to show the shared image files, if any. To enable audio/video, you need to click to enable publish and subscribes, and the camera/microphone on the publisher. Similar to the underlying WebRTC data channel, the component can support sending text string, `Blob`, `ArrayBuffer` or `ArrayBufferView`. The image file send in the above example uses a `Blob`, and if that fails, it falls back to `ArrayBuffer`, because `Blob` support was added only recently in Chrome's data channel.

When a media server such as Janus is used in the media path, then the data channel is between the publisher and the media server, and between the subscriber and the media server. Thus, unless the media server supports the data channel and implements the message routing logic, you will not have publisher to subscriber or subscriber to publisher data path using this mechanism. This is similar to the media path requirement at the media server.

Later, we will see how this feature can be combined with the `speech-text` component to implement captioning and other features. Although, the channel feature is useful, it is not enough to implement several communication use cases such as discovering participants in a call or registering to receive incoming call. For that we need some other application logic such as based on shared data, described next.

11. How to use shared data?

The ability to access and modify shared data is crucial in a distributed application such as two-party call, multi-party conference or online panel discussion. Furthermore, the clients can get notified when a piece of shared data is modified, and can update the client display state. For example, participants list or user's presence information can be stored as shared data. And user's client can modify and get notified on modification of such, to implement the entire application logic in the endpoint.

This type of resource-oriented software architecture has been researched and has matured already, e.g., in my previous work on `restserver` and `vvowproject` (https://github.com/theintencity/vvowproject), as well as with the popular Firebase real-time database.

11.1 Overview

The `SharedStorage` class in this project has an implementation of the shared data abstraction for local testing and demonstrations. The individual subclass implementations further extend this for real world applications by using specific server side storage, such as in `restserver-storage.js`. This section shows how to use the base `SharedStorage` class for initial testing, and to replace it with others if needed.

To get started, include the implementation script, and create a `SharedStorage` instance as follows.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/shared-storage.js"></script>
<script type="text/javascript">
    const db = new SharedStorage("local");
</script>
```

The constructor parameter in the above example causes it to use an internal `LocalSharedStorage` implementation, using the browser's `localStorage`, and is good only for local demonstrations. The shared-storage implementation can be extended to support other specific storage implementations using this mechanism as shown below.

To construct the shared storage with a specific implementation such as in restserver-storage.js, use the following.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com
/v1/restserver-storage.js"></script>
<script type="text/javascript">
    const db = new SharedStorage(new RestserverStorage(...));
</script>
```

Alternatively, the `shared-storage` component can be included as follows by supplying the string source attribute.

```
<shared-storage id="storage" src="..."></shared-storage>
```

If `src` is "local", then it uses `localStorage` internally. If `src` is a websocket URL such as "wss://...", then it uses restserver-storage with the supplied server information.

The `id` attribute of the `shared-storage` instance identifies the shared storage element on the web page, and can be used by other components to link to this data storage. Such other components are described later in this document including in the collaboration and telephony topics. Those components accept the storage element identifier using the `for-storage` attribute as shown below.

```
<text-feed-data for-storage="storage" ...></text-feed-data>
```

11.2 Reference

There are two types of data structures allowed in such storage - single object or a list of objects. Such data is identified by an hierarchical path on that storage, e.g., "users/alice/contacts" may represent the contacts list of user Alice. The following example shows how to get reference to an object or a list, or a nested object or list.

```
const uref = db.list("users");
const vref = db.object("version");
const sref = db.object("version").object("software");
const cref = db.list("users").object("alice").list("contacts");
```

As you can see, the data is organized hierarchically. An object's parent may be another object or a list. A list's parent may not be another list. Hierarchical structure allows storing and managing data in a scope for access control and cleanup. Those familiar with Firestore will find that object here is like a document, and list here is like a collection, except that our list is implicitly ordered.

Getting the reference can be done via a nested path directly. The two lines in each of the following blocks of code are identical.

```
const sref = db.object("version").object("software");
const sref = db.object("version/software");
```

```
const cref = db.list("users").object("alice").list("contacts");
const cref = db.list("users/alice/contacts");
```

11.3 Object

Following data operations are allowed on an object reference: create, read, update or delete. Every function in the following example returns a promise. The difference between create and update is that create will fail if the object already exists, whereas update will not. If the object does not already exist, then create and update will have the same effect. Moreover, update can be used to perform partial update of the object value, e.g., to add, change or delete some attributes. In particular, using `undefined` as attribute value deletes an existing attribute.

```
await ref.create({name: "Bob", email: "bob@office.com", phone: "+12123334444"});
const data = await ref.read();
await ref.update({name: "Bob Smith", phone: undefined}); // change name, remove
phone, unchanged email
await ref.delete();
```

When creating a new object, if you do not care about whether the object existed previously, then use the update function, instead of create. You can use create to implement some form of lock or mutex actually. For example, a client does a create on a object path. If that succeeds, it continues performing some contentious operation, otherwise it does not. After completing the operation, it deletes the object path.

11.4 List

Following data operations are allowed on a list reference: add, getall, removeall. Every function in the following example returns a promise.

```
const id = await ref.add({name: "Alice", email: "alice@home.com"});
const list = await ref.getall();
await ref.removeall();
```

The `getall` function allows filtering, ordering and limiting the result. Note that the list children are ordered in their natural creation order, i.e., the order in which the children are created either using `add` on the list reference or using `create` or `update` on the child object reference. Some examples of filtering, ordering and limiting the result follows.

```
const sorted = await ref.getall({order: 'name'});
const page2 = await ref.getall({offset: 10, limit: 10}); // zero-based index
10-19
const result = await ref.getall({filter: data => data.name.match(/kundan/i)});
const count = await ref.getall({reduce: (data, sum) => (sum+1), initial: 0}); //
returns count
```

11.5 Events

In addition to the data operations on the object or list reference, you can also perform event subscription and notification. The `onchange` handler on the object reference is called whenever the object value at that path is created, updated or deleted. The `onchange` handler on the list reference is called whenever its child object is created, updated or deleted. Additionally, any application level event data may be dispatched on any object or list reference using the `notify` function, which invokes the `onnotify` handler of that object or list reference. To unsubscribe to receive events, just reset the handler to null.

With remote shared object, the event handlers are crucial in detecting changes in the shared data structures of the application. For example, a contact list application sets the `onchange` handler on the contacts list, to detect any change in that data, and to show the updated list. Some examples of `onchange` are shown below.

```
oref.onchange = ({type, value}) => { // on object reference
    // type is one of "create", "update" or "delete"
    // data is the updated object value for create or update, and previous value
for delete.
};
lref.onchange = ({type, value, id}) => { // on list reference
    // type and value are as before.
    // id the child object's id.
};
```

Note that if both `getall` and `onchange` is used on a list reference, then there may be duplicates either due to race condition, timing of when the item is added to the list, or a nuance of the actual storage implementation. The application should check for duplicates, e.g., by using unique item identifier in the list.

11.6 Notify

Some examples of `onnotify` and the corresponding `notify` function are shown below. The notify

function returns a promise that resolves to the count of receivers that received the notification. If the count is 0, that means the notification was not really delivered to any, such as when were no listeners. Note that the notification is not stored for later delivery. This may require the application to use other ways to find out if the notification was sent before it installed the listener.

```
ref.onnotify = ({data, from}) => {
    // data is whatever serializable object was supplied in notify.
};
const count = await ref.notify({type: "message", value: "Hello there!"});
```

Each client is associated with a unique identifier. The identifier may change when the client is reconnected. This identifier is also carried as part of the event so that the handler can check who originated the change in data, or who dispatched the notification. Note, however, that the semantics of this client identifier is implementation dependent, and may not align with the application's interpretation.

The `notify` and `onnotify` examples do not require that the object or list reference have any real data stored there. This allows constructing data paths to exchange events even without storing any data in the storage.

11.7 Transient

Unlike other real-time databases, this shared object abstraction allows transient objects. A transient object is deleted automatically and immediately when the client which created that object is disconnected. Other clients that listen to the event on that object path will receive the delete event. This allows readily implementing presence and real-time events when needed.

By default, the `create` and `add` functions create persistent object. An object or list reference can be marked as transient, to create a transient object as shown below. The `update` function generally preserves the existing persistent or transient mode of the object. If update is called to actually create a previously non-existent object, then the object reference's mode is used similar to create. Moreover, for the transient mode, the update function changes the anchor of when the transient object will be

deleted, to that of the client that invoked the update, instead of the one that previously invoked a create, if any.

```
await oref.transient().create({name: "Bob"});
await lref.transient().add({name: "Alice"});
```

11.8 shared-storage

The details of the shared-storage web component API is summarized below.

The following table describes all the properties of the `shared-storage` component.

Name	Type and description
`src`	string Name of the implementation with default connection, or an URL to determine the implementation and connection to the service. Reset to null to close this storage.
`ready`	bool, default is false Whether the storage is ready, i.e., implementation is determined.
`connected`	bool, default is false Whether the underlying implementation is ready and connected.
`impl`	object The underlying implementation object derived from SharedStorageImpl. A derived component may prevent setting this property directly.

The following table shows all the methods of the `shared-storage` component.

Function	Signature and description
`close`	ss.close() Close and reset the underlying implementation.

`toString`	console.log("storage " + ss) String representation for logging.
`object`	ss.object("path/to/some/object") Return an object reference to the supplied path.
`list`	ss.list("path/to/some") Return a list reference to the supplied path.
`create`	await ss.create("path/to/some/data", true, {id: 1234}) Create a resource at the supplied path, and fail if it exists. This returns a promise.
`read`	let data = ss.read("path/to/some/data") Read a resource at the supplied path, and fail if not found. This returns a promise that resolves to the content of the resource.
`update`	await ss.update("path/to/some/data", true, {id: "A123"}) Update a resource at the supplied path, or create if not found. This returns a promise.
`delete`	ss.delete("path/to/some/data") Delete a resource at the supplied path. This returns a promise.
`add`	let id = await ss.update("path/to/some", true, {id: "5678"}) Add a resource at the supplied path, always creating a new child resource. This returns a promise that resolved to the identifier of new child resource.
`getall`	let data = await ss.getall("path/to/some") Get zero or more child resources of the parent resource at the supplied path. It returns a promise that resolves to an array of objects.
`removeall`	await ss.removeall("path/to/some") Remove immediate child resources of the parent resource at the supplied path.It returns a promise

`notify`	await ss.notify("path/to/some", {type: "join"}) Send notify message on the supplied resource path. It returns a promise that resolves to a number that indicates the number of listeners the notification was sent to.
`getListeners`	let handlers = ss.getListeners("notify", "path/to/some") Get a list of listeners for events such as change or notify on the supplied resource path.
`addListener`	ss.addListener("notify", "path/to/some", function (..) { ... }) Install a listener for events such as change or notify on the supplied resource path.
`removeListener`	ss.removeListener("notify", "path/to/some") Uninstall the listener for events such as change or notify on the supplied resource path.

The following table shows all the events dispatched by the `shared-storage` component.

Event	Example and description
`close`	Indicates that the storage is closed.
`ready`	Indicates that the storage is ready.

12. How to store data externally?

When the shared storage component uses a "local" source, it enables demonstration of this named stream within a single application, using the localStorage of the browser. Here, we describe how to attach external storage services to the shared storage, such as using RestserverStorage or FirebaseStorage.

12.1 RestserverStorage

As mentioned before, the shared storage component can be an external storage service such as `RestserverStorage`, e.g., by specifying a "ws:" or "wss:" URL in the `src` attribute. Developers are refered to the vvowproject (https://github.com/theintencity/vvowproject) for installing and running the Python or PHP-based `restserver`.

I have also ported that resource server to NodeJS, and included in this project for convenience. This ported server implements a subset of the features, e.g., it supports only the in-memory database, instead of MySQL, PostgreSQL and SQLite3 supported by the earlier the Python or PHP implementations. I run this resource server for local testing as follows, after installing the dependencies.

```
cd srv
npm install
node restserver.js -p 8080 -d
```

Default port is already 8080, so the `-p` option above is redundant. Default log level is `info`, and `-d` option creates verbose log, whereas `-q` is for the quieter mode with only error logging.

Try the above example, after running the resource server locally, on the default port 8080. This tests the various APIs of the resource server.

12.2 restserver-storage

The `restserver-storage` web component extends the `shared-storage` element, to force use

RestserverStorage internally, and behaves as if the shared storage's `src` attribute is set to websocket URL. The `impl` property cannot be set directly in this web component.

```
<restserver-storage id="storage1" src="ws://localhost:8080/restserver">
</restserver-storage>
```

Try the following example, after running the resource server locally, and check the code and JavaScript console.

The following table describes all the attributes and properties of the component. Additional properties and methods are in the shared-storage base class.

Name	Type and description
`src`	string, property and attribute Set the URL to the resource server including any authentication credentials, as a websocket URL.
`impl`	object, property, read-only Underlying implementation object. Cannot be set, since it forces use of an internal RestserverStorage implementation.

12.3 FirebaseStorage

I have also implemented a basic `FirebaseStorage` component that can attach to the shared-storage web component and use the Cloud Firestore behind the scenes. This can be done by specifying a "firebase-storage:..." value in the `src` attribute, with the JSON string containing your firebase configuration.

```
<!-- in <head> -->
<script type="text/javascript" href="https://www.gstatic.com/firebasejs/12.9.0
/firebase-app-compat.js"></script>
<script type="text/javascript" href="https://www.gstatic.com/firebasejs/12.9.0
/firebase-firestore-compat.js"></script>
<script type="text/javascript" href="https://rtcbricks.kundansingh.com/v1/shared-
storage.js"></script>
<script type="text/javascript" href="https://rtcbricks.kundansingh.com
/v1/firebase-storage.js"></script>
...
<!-- in <body> -->
<shared-storage id="storage1" src="firebase-storage:..."></shared-storage>
```

Alternatively, you can directly assign the implementation, `impl`, to the shared-storage component, as follows.

```
<shared-storage id="storage" src=""></shared-storage>
<script type="text/javascript">
  document.querySelector("#storage").impl = new FirebaseStorage({
    apiKey: ..., projectId: ..., appId: ...
  });
  document.querySelector("#storage").dispatchEvent(new Event("ready"));
</script>
```

The actual Firestore APIs, even though operate on similar hierarchical data store, are not quite compatible with the shared-storage component. In particular, Firestore has no concept of transient resources, i.e., ability to automatically remove some resources on client disconnect, the change listener also retrieves the full data set, and there is a constraint of alternating collection and object in the resource path.

This required some changes in my implementation to work around the restrictions using timeouts, soft state for transient resources, explicit cleanups on beforeunload and initial connection, and ignoring initial data set retrieval on the change listener. Moreover, generic notification on a resource path, without actual data storage is not available, so my workaround uses a temporary short-lived

resource to emulate a notification This can potentially cause double notifications, or duplicates when `onchange` and `getall` are used together on the same list resource. Item identifier is used to detect duplicates. The `storage-stream` component that does not use alternate list and object resources by default, has a `fixpath` property to enable a workaround to support this constraint.

My implementationof FirebaseStorage is primitive, good for demonstration purpose, but not ready for production. Moving parts of the implementation to service worker may mitigate some of the problems in the future.

To make sure that the following demonstration uses the right configuration, first set the apiKey, projectId and appId in your localStorage, using the JavaScript console. Keep the console open to see any error or warning when you try the example later.

```
localStorage["firebase-stream"] = JSON.stringify({
    apiKey: "...", projectId: "...", appId: "..."
});
```

Try the following example to see some shared-storage APIs in action, using firebase-storage for actual data storage and notifications.

12.4 firebase-storage

The `firebase-storage` web component extends the `shared-storage` element, to force use FirebaseStorage internally, and has a convenient `config` property to set the configuration as an object. Try the following example, and check the code and JavaScript console.

```
<firebase-storage id="storage1" src=""></firebase-storage>
<script type="text/javascript">
  let storage1 = document.querySelector("#storage1");
  // storage1.src = "local"; // throws an error
  // storage1.impl = ...;    // throws an error
  storage1.config = { apiKey: ..., projectId: ..., appId: ... }; // works
</script>
```

This web component can be used in place of `shared-storage` when needed, as a storage attached to an internal FirebaseStorage, instead of having to attach the specific implementation to that storage.

The following table describes all the attributes and properties of the component. Additional properties and methods are in the shared-storage base class.

Name	Type and description
`src`	string, property and attribute Set the Firebase configuration as JSON string prefixed with "firebase-storage:". Alternatively, use the config property.
`config`	object, property Set the Firebase configuration as an object. Only one of src or config should be set.
`impl`	object, property, read-only Underlying implementation object. Cannot be set, since it forces use of an internal FirebaseStorage implementation.

12.5 redundant-storage

The `redundant-storage` web component, and the corresponding `RedundantStorage` implementation enable storage redundancy for reliability. Notethat the RedundantStorage object is internally used automatically in the web component, and is not available to app directly.

The implementation is primitive, only supports restserver-storage currently, and may be improved in

the future. The following example shows how to use the component to include two separate restserver-storage so that data is stored at two servers, and any of them can be used to read. If one server is terminated or crashes, the app continues to work.

```
<!-- in <head> -->
<script type="text/javascript" href="https://rtcbricks.kundansingh.com
/v1/restserver-storage.js"></script>
<script type="text/javascript" href="https://rtcbricks.kundansingh.com
/v1/redundant-storage.js"></script>
...
<!-- in <body> -->
<redundant-storage id="storage1">
    <restserver-storage src="ws://localhost:8080/restserver"></restserver-
storage>
    <restserver-storage src="ws://localhost:8082/restserver"></restserver-
storage>
</redundant-storage>
```

Internally, this component modifies some of the data access and notification APIs, to ensure that data stored on all the storage services are consistent. For many of the write APIs such as `create`, `update`, `read`, `delete`, `removeall` it just invokes the similar API on all the included components. For the read APIs such as `read` or `getall` it invokes the similar API on all the included components, and succeeds if any of them reponds -- the first response is used. One write API to list, `add`, is non-trivial, because invoking this on all the included components will create separate identifiers for the new object in the list. Since this identifier is used by the app logic, this is not derirable. Hence, the component attempts to `add` the object on one of the active included storage component first, and then uses that returned identifier to `create` that object on all the other included components. This opens door for race conditions, that should be detected and worked around by the application.

Internally, the component sends any notification to all the included components, but detects and avoids duplicates when a notification is received. This may be improved in the future to use sequential notification sending, to avoid unnecessary traffic, for `notify` and `onnotify`. However, duplicate avoidance is still needed for `onchange` notifications, unless the actual service is updated to

avoid sending such change notifications.

12.6 partition-storage

The `partition-storage` web component can be implemented for scalability, e.g., by sharding based on the resource path of the collection (list), and requiring that collection and object are alternating in the path. This is needed to ensure that the a list resource and the objects of that list resource are both handled by the same partition.

The following example shows three `restserver-storage` destinations included in the partition storage, so that on average each storage will handle one third of the resource paths.

```
<partition-storage id="storage1">
    <restserver-storage src="ws://localhost:8080/restserver"></restserver-
storage>
    <restserver-storage src="ws://localhost:8082/restserver"></restserver-
storage>
    <restserver-storage src="ws://localhost:8084/restserver"></restserver-
storage>
</partition-storage>
```

The following example shows how to combine the partition (scalability) and redundant (reliability) storage. Here, the same three destinations are used, but each destination also acts as a backup to another destination. Thus, each resource path gets stored at two servers, depending on ther primary and secondary redundant storage in that partition.

```
<partition-storage id="storage1">
    <redundant-storage id="storage1">
        <restserver-storage src="ws://localhost:8080/restserver"></restserver-
storage>
        <restserver-storage src="ws://localhost:8082/restserver"></restserver-
storage>
    </redundant-storage>
    <redundant-storage id="storage1">
        <restserver-storage src="ws://localhost:8082/restserver"></restserver-
storage>
        <restserver-storage src="ws://localhost:8084/restserver"></restserver-
storage>
    </redundant-storage>
    <redundant-storage id="storage1">
        <restserver-storage src="ws://localhost:8084/restserver"></restserver-
storage>
        <restserver-storage src="ws://localhost:8080/restserver"></restserver-
storage>
    </redundant-storage>
</partition-storage>
```

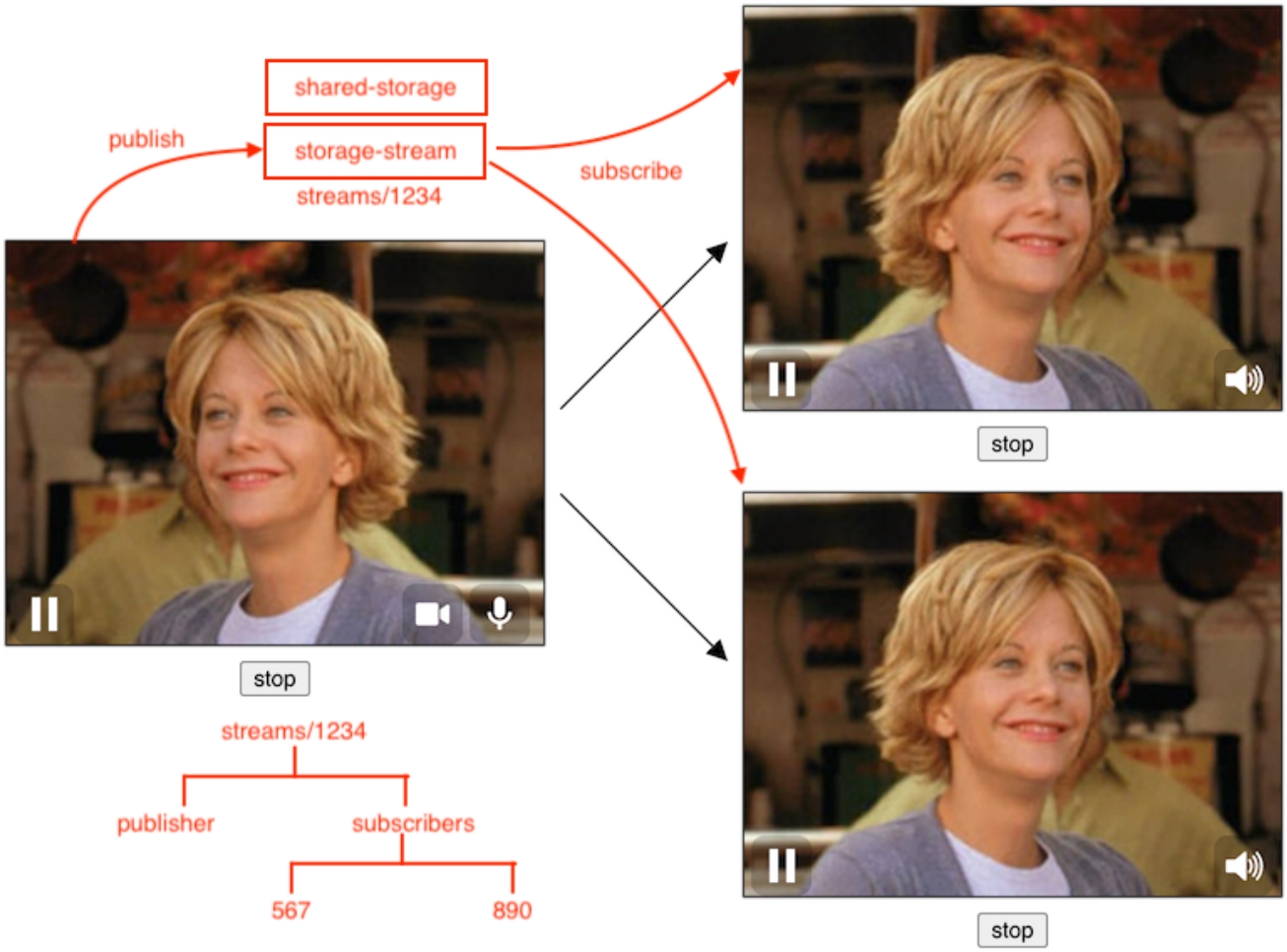
As we will see in the next few sections, the shared storage abstraction can be used to implement a wide range of application scenarios.

13. How to create a stream using shared data?

A new named stream component, `storage-stream`, is implemented using the `shared-storage` component. This enables use of single application service for both shared data and publish-subscribe named stream, such as when using the `RestserverStorage` implementation.

Similar to the `named-stream` or `rtclite-stream` component, the `storage-stream` enables full-mesh media path from publisher to each subscriber. The example code below is almost identical to the named stream examples shown previously. Depending on the specific shared storage implementation, additional dependencies are needed, as mentioned earlier.

```
<!-- in <head> -->
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/shared-storage.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/storage-stream.js"></script>
...
<!-- in <body> -->
<shared-storage id="storage" src="..." ></shared-storage>
<storage-stream id="stream" for-storage="storage" path="streams/1234"></storage-stream>
<video-io id="video" controls autoenable="true" for="stream" ... ></video-io>
```



When the path attribute is set on the component, it extends it to define the storage paths for the one publisher, and zero or more subscribers. For example, if the path is set to "streams/1234" then the publisher object's path becomes "streams/1234/publisher", and the subscribers list's path becomes "streams/1234/subscribers", to which subscribers are added as child objects using randomly assigned unique identifiers. Once this structure is established, the full mesh media path is created by exchanging signaling data between the publisher and each subscriber, via a series of notify messages. The publisher and subscribers can join or leave in any order, similar to other named streams described earlier. The publisher's path is used to send a message to the publisher, and the subscribers child path is used to send a message to that subscriber.

The following table describes all the attributes and properties of the `storage-stream` component.

Additional properties and methods are in the named-stream base class.

Name	Type and description
`path`	string, default is `""` Storage path of the list data representing the publishers and subscribers.
`fixpath`	bool, default is false Workaround for firebase store that requires odd for collection, and even for document.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following example uses external restserver as described in the previous section, for shared storage implementation.

Try the above example, to test the storage stream implemented using resource server, after running the resource server locally, as described in the previous chapter. If you run the resource server on another publicly accessible machine, edit the `src` attribute of the web components in the above example first.

Try the above example, to test the storage stream implemented using Cloud Firestore service, after setting the Firebase configuration in localStorage as described earlier.

Try the following example to test the `redundant-storage` component for reliability, after running

two instances of the resource server locally on ports 8080 and 8082. During the session, try terminating one instance, and see how the client behaves for subsequent tests.

Try the following example to test the `partition-storage` component for scalability, after running two instances of the resource server locally on ports 8080 and 8082. Each run uses a new random stream name, which may get assigned to the first or the second server. Notice that only one of the server will be used, depending on which partition the resource path maps to.

14. How to use peer-to-peer storage?

My other project, Ezcall (https://github.com/theintencity/ezcall), uses a peer-to-peer network and storage for video conferencing. The peer-to-peer implementation is part of this project, in `peer-storage.js`. It has two classes, `PeerNetworkImpl` and `PeerStorageImpl`, as implementations of a P2P network node, and the associated shared data storage, respectively. The details of the implementation, a research paper showing the motivation and architecture, as well as a demonstration are available on the project website linked above.

Our shared-storage component has a well defined interface to implement the actual data storage logic, and the `PeerStorageImpl` class can provide the peer-to-peer storage implementation for that interface, similar to how the `RestserverStorage` class provides the resource server storage implementation. It needs to work with external call signaling, and data channel for the actual transfer and synchronization of data among the peers, as described in the above project.

Note that shared-storage is a web component, but other classes are not, and must be plugged into this web component to change the component's storage implementation. The storage-stream, which is also a web component, only uses the shared-storage abstraction, and does not care about the specific storage implementation. The following example shows how to plug in the peer-to-peer storage, and use the storage-stream with video-io as before. Note that the `src` attribute of shared storage is not set, but the `impl` property is explicitly updated to plug in the storage implementation.

```
<!-- in <head> -->
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/shared-storage.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/peer-storage.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/storage-stream.js"></script>
...
<!-- in <body> -->
<shared-storage id="storage"></shared-storage>
<storage-stream id="stream" for-storage="storage" path="streams/1234"></storage-stream>
<video-io id="video" controls autoenable="true" for="stream" ... ></video-io>
<script type="text/javascript">
  const storage = document.querySelector("shared-storage");
  const id = "..."; // unique id of this peer
  storage.impl = new PeerStorageImpl(id);
  storage.net = new PeerNetworkImpl("fullmesh", id);
  storage.impl.net = storage.net;
  storage.dispatchEvent(new Event("ready"));
</script>
```

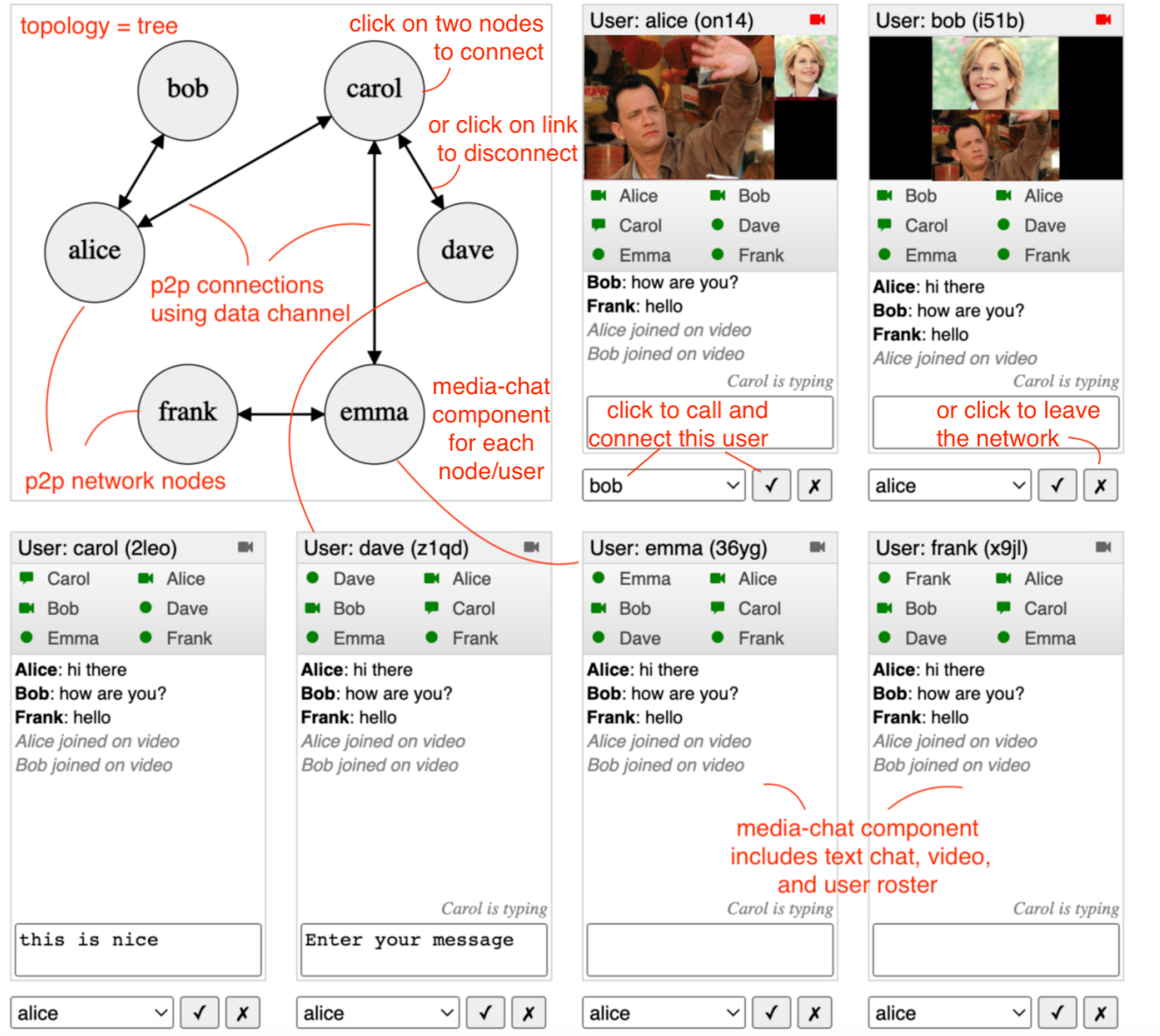
The `PeerNetworkImpl` currently supports two network topologies: fullmesh and tree. The fullmesh topology assumes a full mesh connection among all the peers, where the tree topology assumes a spanning tree topology. This distinction is useful in the underlying implementation for message routing or flooding for data transfer or synchronization in the peer-to-peer network. The class also includes a convenience function to connect the shared-storage instances, and is useful for local demonstrations, as the following example show.

```
<shared-storage id="storage1"></shared-storage>
<shared-storage id="storage2"></shared-storage>
<shared-storage id="storage3"></shared-storage>
<script type="text/javascript">
  const storages = [...document.querySelectorAll("shared-storage")];
  PeerNetworkImpl.connectall("fullmesh", ...storages);
</script>
```

The `peer-storage` web component extends the `shared-storage` component, and includes both PeerStorageImpl and PeerNetworkImpl. It is configured using `topology` and `peerid` attributes or properties. Internally, it is just a convenient way to wrap multiple objects in a single component, and can be used in place of `shared-storage` as shown below.

```
<peer-storage id="storage1" topology="fullmesh" peerid="first"></peer-storage>
```

Try the following example to emulate a peer-to-peer network among users, connected via the media-chat component, which is described later.



You can launch the above example in a separate window, and pass the URL parameter, say, `?users=10` to emulate 10 users instead of the default 6. It can emulate up to 30 users or nodes for local testing of text chat, and peer-to-peer network and storage, but the media conference will get overwhelmed with more than 4 simultaneous video users.

The following table describes all the attributes and properties of the component. Additional properties

and methods are in the shared-storage base class.

Name	Type and description
`src`	do not use Cannot be set, instead use peerid and topology.
`peerid`	string Unique peer identifier of this node in the network and storage.
`topology`	string Topology is either "fullmesh" (default) or "tree" for spanning tree.
`impl`	object, property, read-only Underlying implementation object. Cannot be set, since it forces use of an internal PeerStorageImpl implementation.
`net`	object, property, read-only Underlying network implementation object. Cannot be set, since it forces use of an internal PeerNetworkImpl implementation.

15. How to do one-to-many video broadcast?

The techniques described in How to connect publisher and subscriber? is sufficient to establish one-to-many broadcast. The various `video-io` instances publish or subscribe to some named stream to facilitate this.

15.1 Basic

An application can also show a list of all the publishers, and allow the user to subscribe to one, similar to tuning a radio station. The shared storage described earlier can be used, e.g., using a shared list, say, "stations". A publisher picks a name, and adds it in that list. Using a transient object ensures that the object is removed when the publisher is closed.

```
db.list("stations").transient().add({name: "channel one"})
```

A subscriber can show the list to the user to select. It also keeps track of changes in the list.

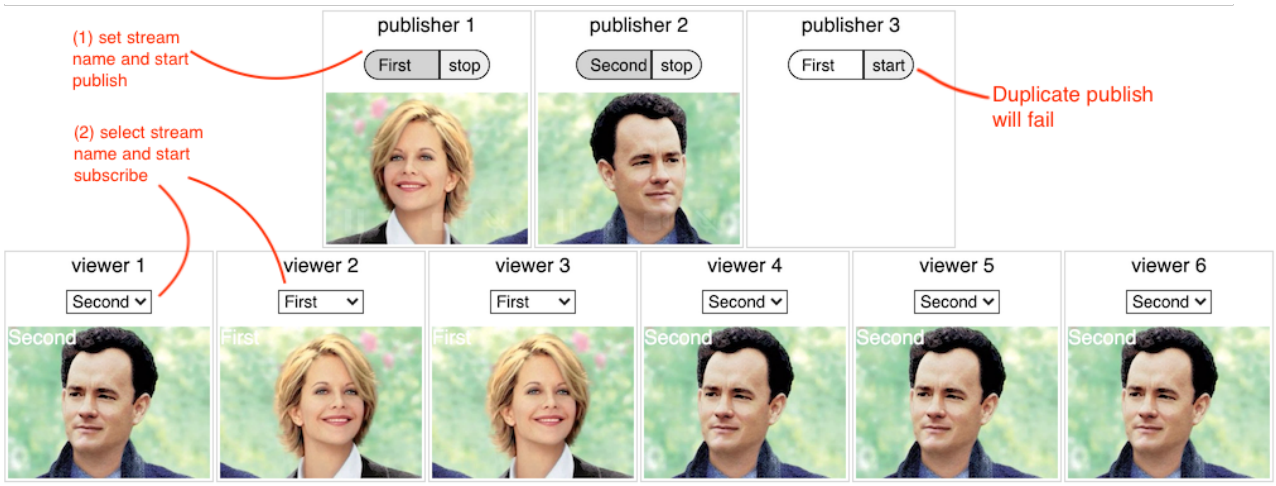
```
const items = await db.list("stations").getall();
// use items to show list of stations.
// each item is an array with key-value: ["..id..", {name: ...}]
```

```
db.list("stations").onchange = event => {
    // event.type is "itemcreate" or "itemdelete" (or "itemupdate")
    // update display list based on event.id and event.newValue
};
```

The above example allows you to publish some streams, and view them. There can be more than one viewers for the same stream. When the published stream is stopped, all the viewers are also stopped.

15.2 Avoid duplicates

If the application needs to avoid duplicate names, it can use the name as object identifier in the path. In that case it must also check if another client is publishing on the same channel before publishing self, using the `create` method on the object reference.



The above example shows that same name will not be published twice, because the shared object's create will fail. To sanitize the name to shared object path segment, all non-alphanumeric letters are changes to "-", and all alphanumeric characters are converted to lower case, for comparison.

The named stream may be replaced by other implementations such as rtclite-stream or janus-stream, for a real distributed application. Later we will see how to use peer-to-peer for such broadcast.

16. How to do two-party video call?

The techniques described in How to connect publisher and subscriber? along with an external call signaling protocol is sufficient to establish a two-party call or multi-party video conference. The call signaling can be implemented using the shared storage described earlier.

16.1 Overview

For a two party call, each party creates two `video-io` components, one to publish and the other to subscribe. The two parties choose and share the named stream information with each other as shown below.

The call signaling protocol is used for three things: (a) to register a user name, so that others can discover and reach this user, (b) to send an intent to call, so that the other user can answer or decline, and (c) to exchange the named stream information so that both the clients can launch the `video-io` components.

These can be accomplished using the shared storage described before. For example, data path of the form "users/{name}" can represent the user's presence. The user's client can listen for events on this, and other users can send notification to this data path. One example follows:

Caller	**Receiver**
1. Register user to receive any call response.	1. Register user to receive any call intent.
2. Start publish video-io component on stream1.	
3. Notify receiver of call intent. Mention stream1.	
	4. On notification, prompt the user to answer or decline.
	5. And start subscribe video-io component on stream1.
	6. On answer, start publish video-io component on stream2.

	7. And notify caller of call answer. Mention stream2.
8. On notification, start subscribe video-io component on stream2.	

This is just one example. Order of some steps may be altered, e.g., step 2 and step 5 may be postponed after call is answered. Following is another example. The important thing is to understand the three phases - call intent, video-io component, and stream name exchange.

Caller	**Receiver**
1. Register user to receive any call response.	1. Register user to receive any call intent.
2. Notify receiver of call intent. Mention stream1.	
	3. On notification, prompt the user to answer or decline.
	4. On answer, notify caller of call answer. Mention stream2.
	5. Start subscribe video-io component on stream1.
	6. Start publish video-io component on stream2.
7. On notification, start subscribe video-io component on stream2.	
8. Start publish video-io component on stream1.	

16.2 Single line

The specific steps of sending and receiving call intent or answer can be codified using `SharedStorage` as follows. Let's assume the client can be in four states: idle, inviting, invited or active. We will use notification "invite" to send the call intent, and "answer" to respond. Other notifications such as "cancel", "decline" or "end" will also be used with their intuitive meanings.

Suppose, the caller is user "alice" and receiver is user "bob". Both the clients listen for incoming notifications on their respective shared object. For example, the receiver side code looks like the following.

```
db.object("users/bob").onnotify = event => { ... }
```

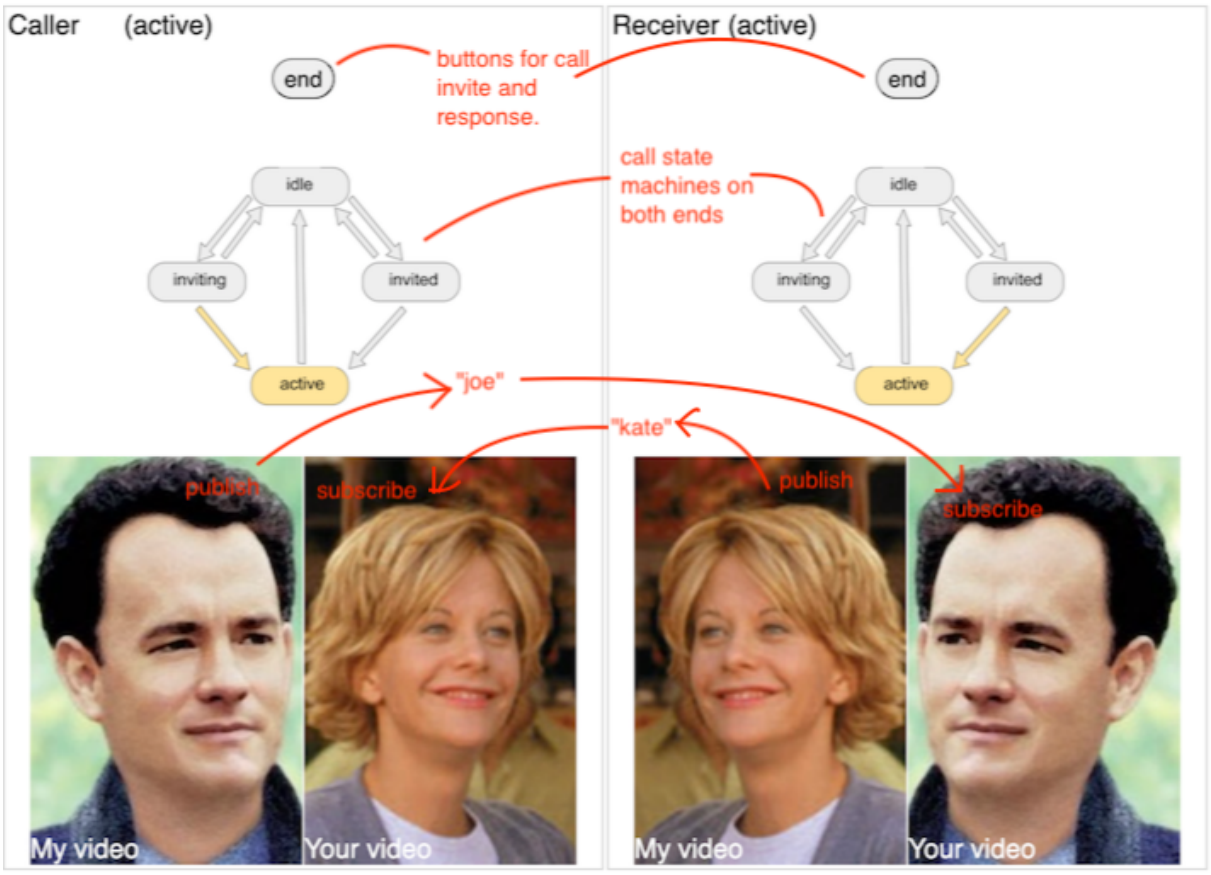
When the caller initiates a call, it sends a notification "invite" with additional details such as caller's named stream and caller name, triggered on the receiver user's shared object, as follows. It then changes the state to "inviting".

```
db.object("users/bob").notify({type: "invite", from: "alice", stream: "abc1"});
```

When the receiver gets this notification, it prompts the user about the incoming call, and changes the state to "invited". If the user answers the call, it changes the state to "active", and sends back a notification "answer" to the caller as follows. It includes additional details such as receiver's named stream.

```
db.object("users/alice").notify({type: "answer", stream: "xyz2"});
```

When the caller receives this notification, it changes the state to "active" too. The complete code path can be tried below, and looked up in the code sample there. It also covers other notifications such as to "cancel", "decline" or "end" the call.



The example above shows the state transition of the caller and receiver clients on different events such as button clicks to invite or answer.

16.3 Multiple lines

The above example shows a very simple call signaling protocol using the shared storage. A real call application will likely be much more complex to handle some or all of these requirements:

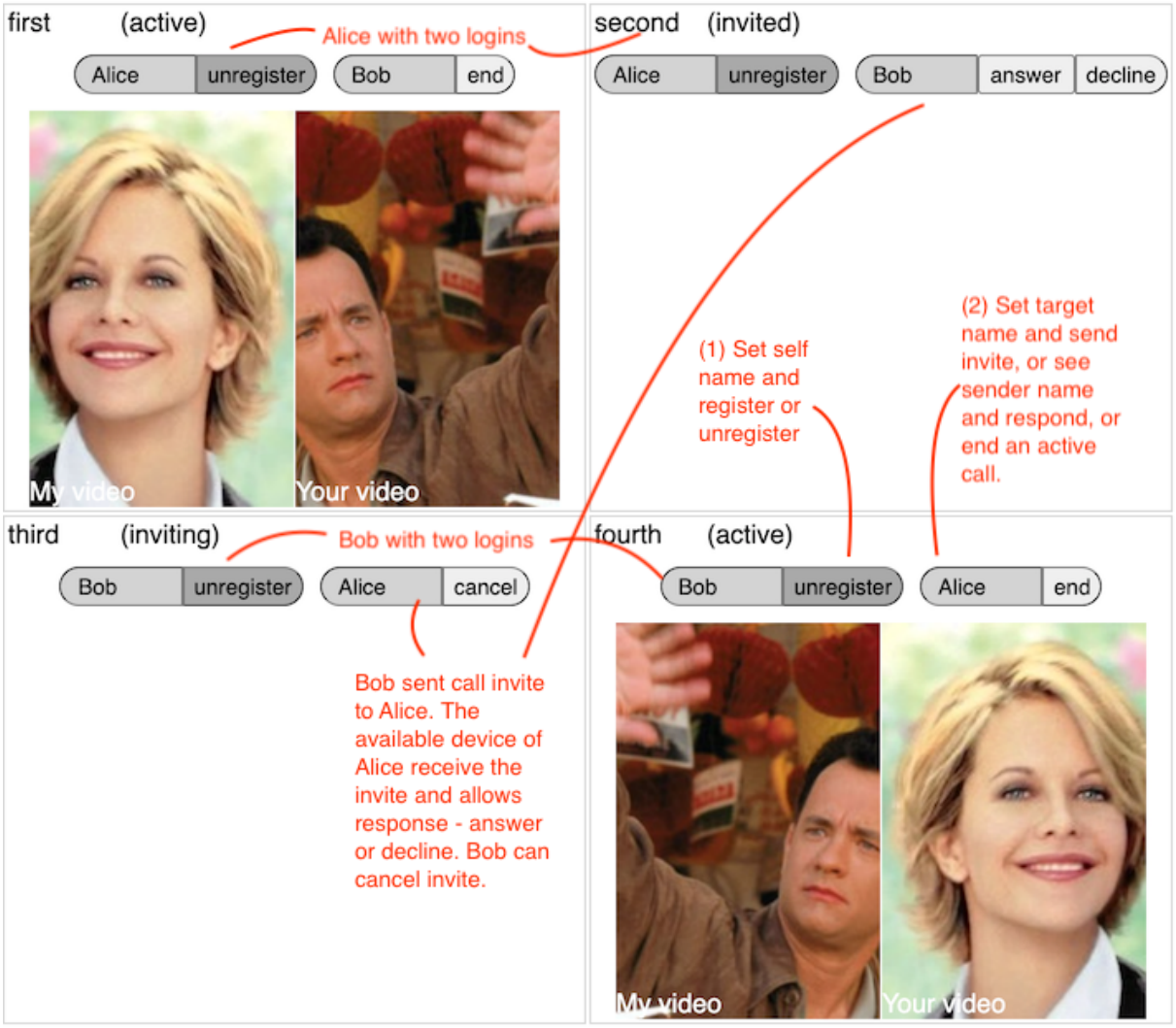
1. Ability to register multiple devices for the same user such that any one can pick the call, similar to multiple line presence of the home phone system.
2. Allow multiple call invitations at the same time, even if there is at the most one active at any time.
3. Search the user by name or other attributes either before placing the call, or when multiple users

are found for the same target.

4. Gracefully handle timeout, unreachability or other unreliability in the system.
5. Call transfer, hold, call park or other telephony features that people are familiar with.

The first two requirements can be implemented as follows. Each call "invite" includes an unique invitation identifier. This is included in all related notifications of "answer", "decline" or "cancel". It is not needed in "end". Additionally, when a call is answered or declined from one device of the receiver, the caller sends a "cancel", so that all other devices in pending incoming invitation state can clean up and stop ringing. Moreover, another response besides "decline" may be needed, to stop ringing of only the local device, but not others. These ideas are similar to the SIP forking proxy behavior of an INVITE request.

The implementation is demonstrated below. You can try registering two clients with the same name, and have the third client call that name. A new state of "ready" is included, to distinguish from unregistered "idle" state. The example includes four clients for further experimentation.



Here are the experiments you can try in the above example. Register the four clients with their default names, Alice and Bob, two clients per name. Invite from first client of Alice to Bob, and notice both of the Bob's clients receiving the invite. Answer from one of the Bob's clients, and notice that the other client stops incoming call state, and the two party call is established between the first client of Alice and the answering client of Bob, with two-way video. Note that the sound is disabled in the above example, to avoid local audio feedback loop. Click on the end button to stop the two-party call, which also stops the two-way video. Now repeat the above call, but decline from one client of Bob. Next, repeat the above with two-way video, and then attempt another call from the second client of Alice to Bob, and note which client receives the invitation, and how two separate calls are possible

between these users on separate clients. Next, unregister the clients from their users, and register only some, to see that call invitation is not received on unregistered client. Try registering with other names, and calling others names, including non-existent names, to see the behavior.

The display controls are updated in the above example to reflect the internal state of the client. The behavior is similar to a typical softphone from traditional VoIP system. Some behavior can easily be added or altered such as for missed call notification, ringing sound, or when to show the videos.

16.4 Sequential invites

An alternate implementation can be done as follows. Instead of a shared receiver object at "users/bob", the receiver user can add its device contact as a transient object in the list "users/bob /devices". When the caller user attempts to send a call invite, it locates all the items of the list, and sends the notification to each. This allows the caller to manage separate receiver devices and their call state independently, e.g., for sequential forking, parallel forking, or a mix of two. Folks familiar with VoIP or SIP (Session Initiation Protocol) can see similarity with them, and that is expected. In fact, for a full fledged phone system, the call signaling will likely become similar to the existing signaling protocol.

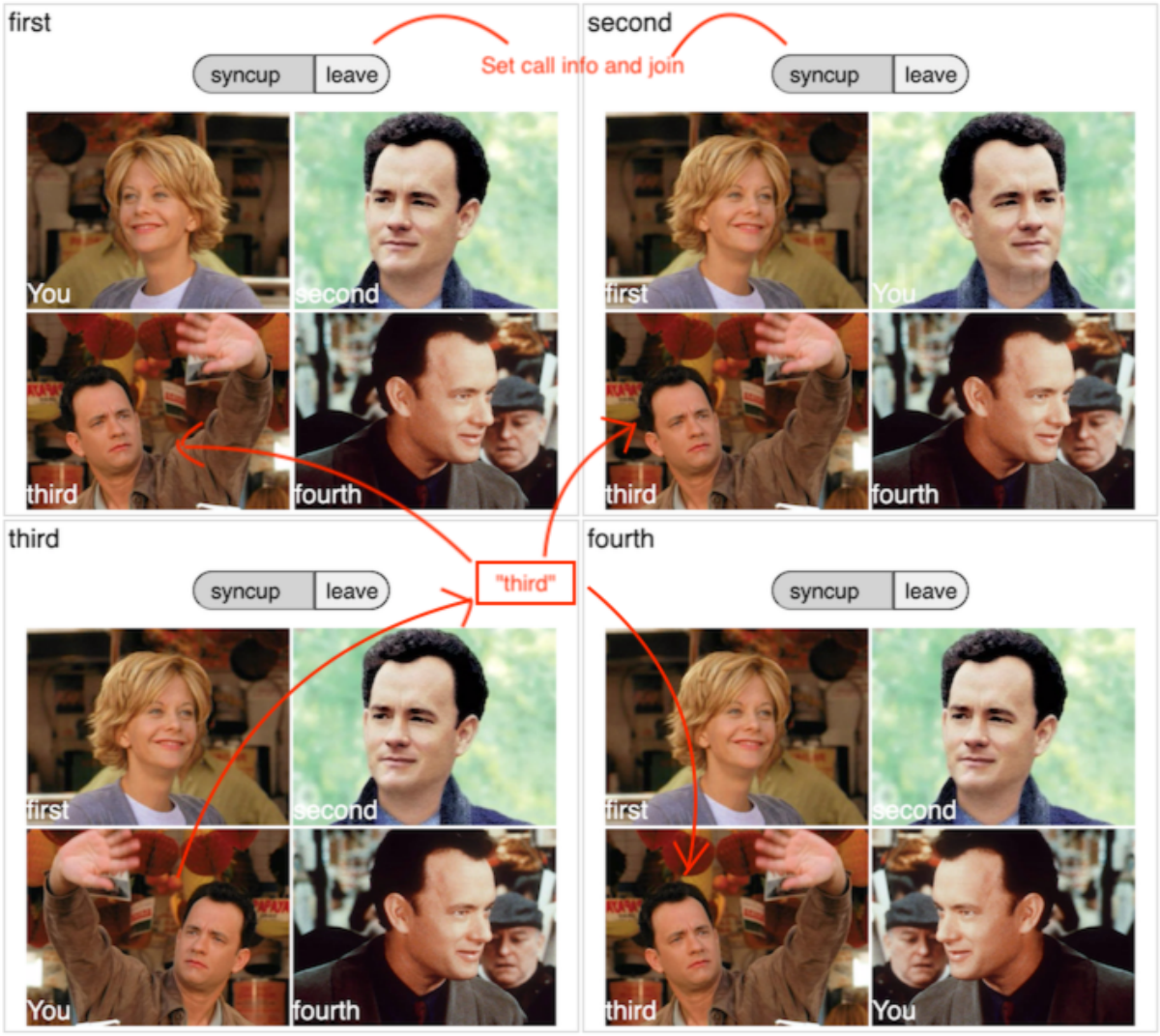
17. How to do multi-party video conference?

Generally, there are two models of signaling used for multi-party calls:

- Join-leave: where participants know the unique call identifier, and can dial-in to the bridge using that identifier. Invitation is out-of-band to convey that identifier or join instructions.
- Invite-answer: similar to the two-party call, where a caller can invite more than one receivers in the call, or a receiver can merge an incoming caller to her existing call.

17.1 Join-leave

For the join-leave model, we can use the shared storage, to store the participants of a call, e.g., "calls/1234/users/alice" represents the user "alice" in a call with call identifier "1234". For this to work, the call identifier must be known to all the participants. The participants can discover each other by listening to any change in shared list of "calls/1234/users". For simplicity, we can assume the participant identifier, e.g., "alice", to be same as her published stream name. Thus, in an N-party call, each participant has one publish `video-io` component and N-1 subscribe `video-io` components.



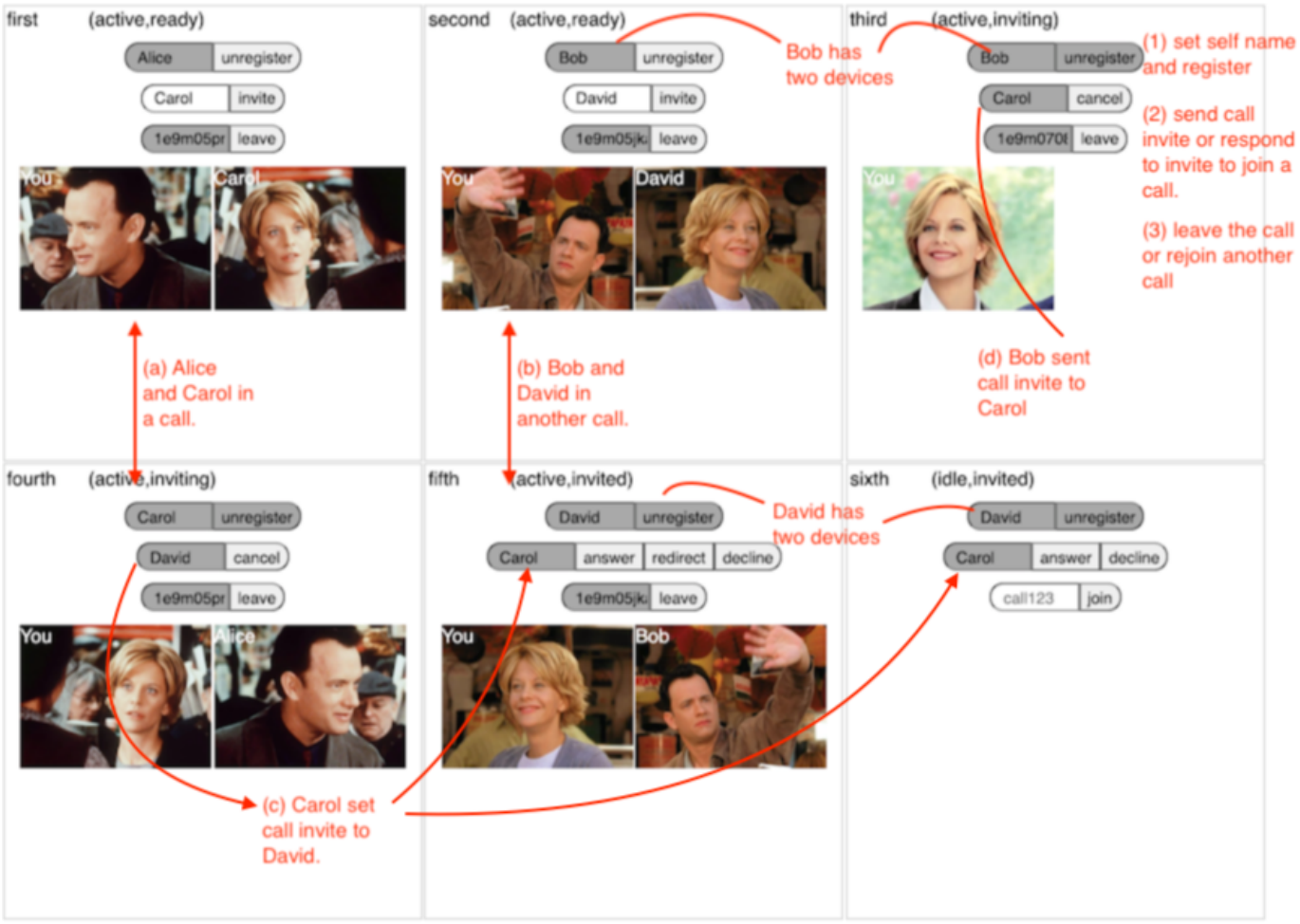
In the example above, you can try joining the different clients in different order, or change some call identifier to have some clients join a different call. For simple layout of videos, each publisher has the same fixed position in each client viewer, and the layout is fixed for a four-party call.

17.2 Invite-answer

The invite-answer model is well suited for a telephone style system. It turns out that we can build a system that combines both the models, described earlier as the two-party call and join-leave

conference. The idea is to keep join-leave as default, but be able to convey the call identifier via invite-answer notification. Once the call is joined, user can only leave, but cannot force another user to end too via call signaling. Thus, unlike the previous two-party call signaling, the "end" notification is not used anymore. All the other notifications of "invite", "cancel", "answer" and "decline" are still valid. Additionally, a new notification of "redirect" is used, similar to decline, but it redirects the caller to another call, and it is up to the caller whether to join the new proposed call, if it is not already in the original call, or do not join the new call, if it is already in the original call with other folks. The state machine is also altered so that it allows multiple invites, but at most one pending.

The combined model uses both types of shared data - for call signaling use "users/alice", and for call membership use "calls/1234/users/alice".



In the example above, you can try various sequence of events by registering, inviting, or joining to see the expected behavior. For example, after registering the users on their devices, call from Alice to Bob, and Carol to David, and click answer to be in a call. Then call from Alice to Carol, and select to answer. This will cause Carol's device to switch to the incoming call, and leave the original call with David. Then call from David to Bob, and select to redirect. This will cause David's client to leave the original call without any other participant, and join Bob's call. The redirect is not processed on the caller if it is in a call with another person.

For simplicity, only a maximum of four videos, including one self preview, are shown. If there are more than four participants in the call, only three others plus self will be shown. The first video is

always reserved for self preview. You will also notice that the video layout is not adjusted when participants leave. That is covered in the next section.

18. How to customize multi-video layout?

The `flex-box` web component is a container to display multiple videos, images or other content.

18.1 flex-box

The existing CSS display styles of flex or grid are powerful and can be used in a variety of scenarios to achieve the desired layout. However, they often need to be tweaked for a video conferencing display and user experience. This component internally uses those CSS styles, and allows customizing the display using a few attributes, while catering to a wide range of display scenarios suitable for video conferencing.

Try the example below for join-leave style multi-party conference, but using the `flex-box` container for video layout. It allows seeing the behavior as the window size changes, or the video orientation is altered for a participant.

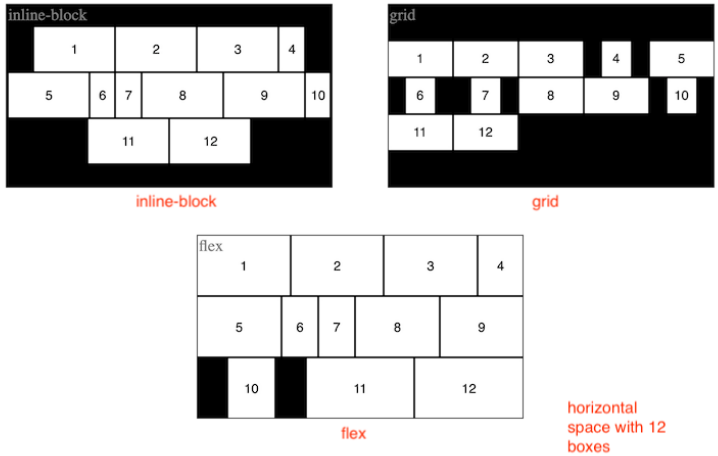
The basic usage of the `flex-box` component is shown below. In this example the container `flex-box` contains three `div` elements. The *container* controls the overall layout. The child *items* control the item attributes such as the natural size of the item, whether to layout in landscape or portrait mode, and how flexible the aspect ratio should be.

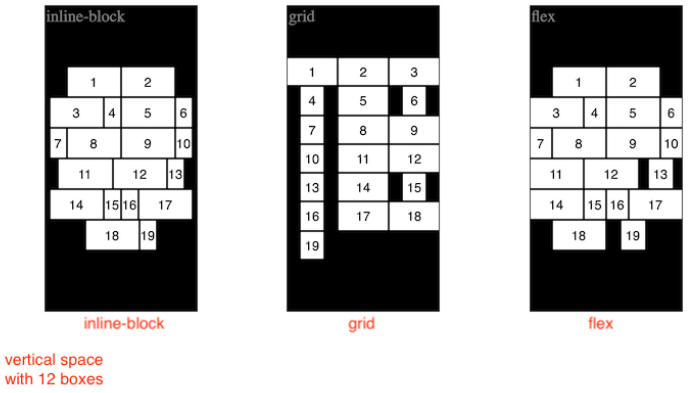
```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/flex-box.js"></script>
<flex-box display="grid">
    <div width="320" height="240" min-ratio="1:1" max-ratio="16:9"></div>
    <div width="320" height="180" min-ratio="4:3" max-ratio="16:9"></div>
    <div width="240" height="320" min-ratio="9:16" max-ratio="3:4"></div>
</flex-box>
```

18.2 display

The container can display the items in different layouts. Some examples are shown below. Here the container itself is in two different sizes or dimensions: landscape vs. portrait, showing three different

layouts in each dimension: inline-block, flex and grid.





The container component's `display` attribute controls the overall layout of the items in the display, and can take one of these values.

display	Description
`inline-block`	(default) Items are in their natural sizes, scaled to fit while reducing empty space. This is the default value that appears as inline-block CSS display. The items are laid out one after other in their natural sizes specified using the `width` and

	`height` attributes.
`flex`	Items are altered to change the aspect ratios, to minimize the empty space. This uses the CSS `flex` display internally, positioning the items in multiple rows, such that heights of all the items are same, but widths are flexible. The `min-ratio` and `max-ratio` attributes of the item help in determining the actual size and position of the item, and `use-border` determines how to adjust size and position within these ratios.
`grid`	Items are laid out in NxM grid, while reducing outside empty space. This uses the CSS `grid` display internally, such that the bounding box is of the same size for each item. The component's `ratio` attribute helps in determining the actual size of the item's bounding box.
`pip`	One item is in background, and all other items are overlaid on top, near a side. The picture-in-picture (PIP) display shows one item in full size in the background, and all other items overlaid on top in a row or column. All the overlaid items are arranged in a line, either a row or a column, and attach to one of the four sides. If float item's fraction or factor is specified, then non-float items can overflow the view, and can be viewed on scrolling.
`page`	Some items may overflow the displayed page, and can be viewed on scrolling. This allows scrolling through the items, instead of cramping all the items in displayed view of the container. This is particularly suitable for keeping a minimum size of the item, even when large number of items are present.
`line`	Items are displayed horizontally or vertically, with scrolling enabled. This is like page display, but has only one row or one column, depending on the width and height or the container. This allows scrolling through the items. This is suitable for keeping the container user interface narrow with either horizontal or vertical alignment, such as a side bar or bottom bar of video

elements.

The following example allows you to see the different display values as the window size changes, and as the items are added or removed from the container. The items are randomly added with landscape or portrait orientation. The window sizes are randomly modified periodically.

A few things to note in the above example: first, the `flex` display gives a more fuller experience, while reducing the empty space not occupied by any item. Second, except for the `inline-block` display, the item's aspect ratio may be altered to fit in the layout. The item can specify the range of aspect ratios within which it may be altered. Third, the `inline-block` display avoids the extra padding within the item, especially for the portrait mode items.

The `pip` display is suitable for small number of items, and always has a `float` item, and that appears in the background. By default, the display attempts to squeeze all the non-float items to be displayed on a side. However, if the fraction or factor is specified on the float item, e.g., "4x" or "80%", then the non-float items are forced to occupy that much space, and hence can overflow. In that case, scrolling can be used to view the overflow or hidden non-float items. It can also be used to move the non-float items out of view if needed, to avoid overlapping with the float item.

The `page` display is suitable for keeping a minimum display size of the items, so that if not all items can be shown, then you can use scrolling to see the other items. It shows the items similar to grid, attempting to show 9 or more items, but does not scale up to fill empty space if needed. If a float item is present, then it is similar to the flex display, with one line of non-float items, while showing up to 3 or more non-float items by default depending on the scaling factor.

18.3 Attributes

Besides the mandatory `display` attribute, there are other attributes that control the display behavior of the component. Some of there are described below.

The `transition` attribute on the component defaults to use a CSS linear transition with 0.3s duration for all changes in position or size of the child items. It also does the fade-in or fade-out effect using

the transition on the opacity CSS attribute when the child item is added or removed, respectively. One side effect of this is that when a child item is removed from this container, the actual removal is delayed until the fade-out effect is completed. These transitions or animations can be disabled by setting the `transition` attribute value to "none".

```
<flex-box display="flex" transition="none" />
```

The `ratio` attribute on the component is an estimate of the child items aspect ratio, and is used to guess the initial layout before arriving at an optimized layout internally. It defaults to "16:9" for HD-ratio. It is generally ignored for the `inline-block` display.

```
<flex-box display="grid" ratio="4:3" />
```

In the `page` display, without any float item, the `min-count` attribute can be used to change the minimum number of boxes shown, and can affect the size of the boxes relative to the container size. The default value is 9, and using a larger number can give more number of items per page. Note, however, that the actual items per page may be larger than the specified number. When a float item is present then the float property value of that item controls the size of float and non-float items.

```
<flex-box display="page" min-count="12" />
```

The `debug` attribute when set to true allows you to see the layout positions and sizes using a rectangle overlay, and be able to debug them using browser's dev tools. Without this, internally, the implementation hides the actual layout calculations and just sets the absolute positions and sizes of the container items.

```
<flex-box display="..." debug="true" />
```

As shown previously, the container item can have attributes to control the display.

- **width**: (required, number) Actual width of the item, e.g, videoWidth or naturalWidth.
- **height**: (required, number) Actual height of the item, e.g., videoHeight or naturalHeight.
- **max-ratio**: (string or number) Value should be a number such as 1.25, or a string of format "4:3", or a keyword of "fixed" or "auto".
- **min-ratio**: (string or number) Value should be a number such as 0.8 or a string of format "2:3", or a keyword of "fixed" or "auto".
- **use-border**: (present or absent) If present then it uses border size to accommodate aspect ratio within min and max ratios. Default is to use only other CSS attributes of left, top, width and height.
- **float**: (string) Indicates that this item is to be displayed larger than other items. More details are below.

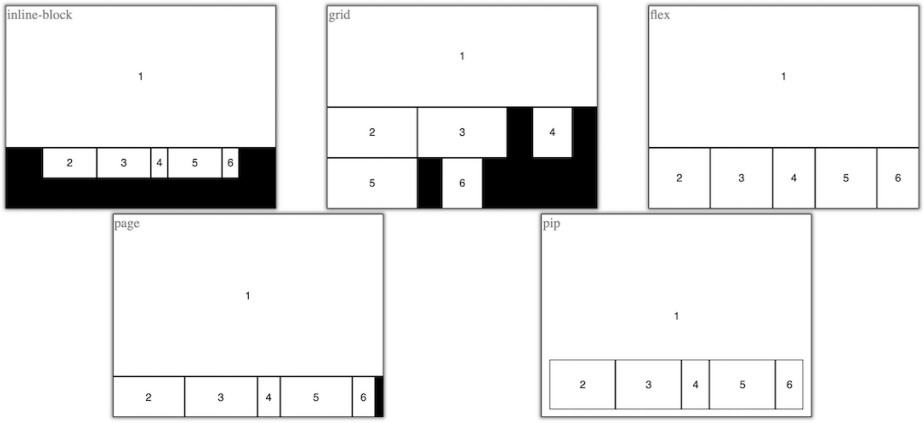
Note that the `width` and `height` attributes are required on the item for layout.

The `applyPosition` method can be called on this component to force update its layout. This is useful when the component width and height are dynamically updated in JavaScript instead of using CSS, based on any change in the container size. The argument, if true, causes a slight delay in layout update, to allow accommodating multiple calls, e.g., in response to continuous resize events.

```
var box = document.querySelector("flex-box");
box.applyPosition();     // update layout immediately
box.applyPosition(true); // update layout after brief 50ms delay
```

18.4 Float

The `float` attribute of the item is quite flexible in positioning the item outside the defined `display` layout of the container. In a video conferencing application, for example, it can be used to show large video of the screen share, presenter or talker. The different values of `display` attribute have different behavior for float vs. non-float items. At the high level, except for the `grid` display, the available space is divided into two parts - one for float item, and the other for all the non-float items.



The `float` attribute value can be empty, or a fraction or factor, along with an optional desired position. For example, "80%" indicates that the float item takes roughly 80% size on the main axis. The main axis is usually determined by the difference in aspect ratios of the container and the float item. The percentage or fraction value is typically used for the `flex`, `inline-block`, `pip` or `page` display, but not for the `grid` display. Typically, a minimum 50% fraction value is imposed for the float item, when in `flex`, or `inline-block` display. For the `grid` display, a factor such as "3x" is used, indicating that the float item is 3-times larger than the non-float item. For a `pip` or `page` display, either fraction or factor may be used. For a `pip` display, a fraction 80% is same as factor 5x, indicating that the non-float items will take 20% or 1/5th the space compared to viewable float background item, since the non-float item is overlapping the float item. For a `page` display, a fraction 80% is same as factor 4x, indicating that the non-float items will take 20% of 1/5th the same compared to the remaining space of 4/5th of float item, since the float item is not in background but non-overlapping with non-float item.

Position can be specified for the float item, for example, as "bottom left" or "top" or "right" or default of "top left". When using two values, the implementation is flexible in picking one of the two, based on the aspect ratios of the available space vs. the float item, so as to reduce the empty space and change in aspect ratios. These fraction or factor and position values can be combined, e.g., "70% top right", which allows the float item to take roughly 70% of available space and be attached to either top or right side of the available space.

For the `pip` display, the float item is always full size in the background, but its position value allows

positioning the other non-float items. For example, if "top left" is specified, then non-float items are on bottom or right

The following example compares the different displays when default float attribute is set on one of the item.

Empty value is interpreted in the context of the `display` attribute. For grid, it assumes "3x top left" and for others "80% top left" or "70% top left" depending of whether the non-float boxes are less than five or not, respectively. To position the active speaker video in large size on top or left, you can specify the fraction, e.g., 80%, to be used by the speaker video, and the position, e.g., "bottom left" to prefer bottom or left in "flex" or bottom-left in "grid".

By default, only one item can have the float attribute set in a container. If another item's float is set, the previous item's float attribute is implicitly removed.

18.5 Test

Try the following example to experiment with various attributes. It starts with the flex display with one window size. You can change the display, window size or other attributes to see how the component behaves. There are buttons to add or remove boxes to see the behavior of different attributes with different number of boxes in the container.

The above can be used as a test tool for trying out various displays, their attributes, float vs. non-float items, and interaction with user via built-in controls.

18.6 Controls

The component has several user interaction controls triggered via mouse, as follows:

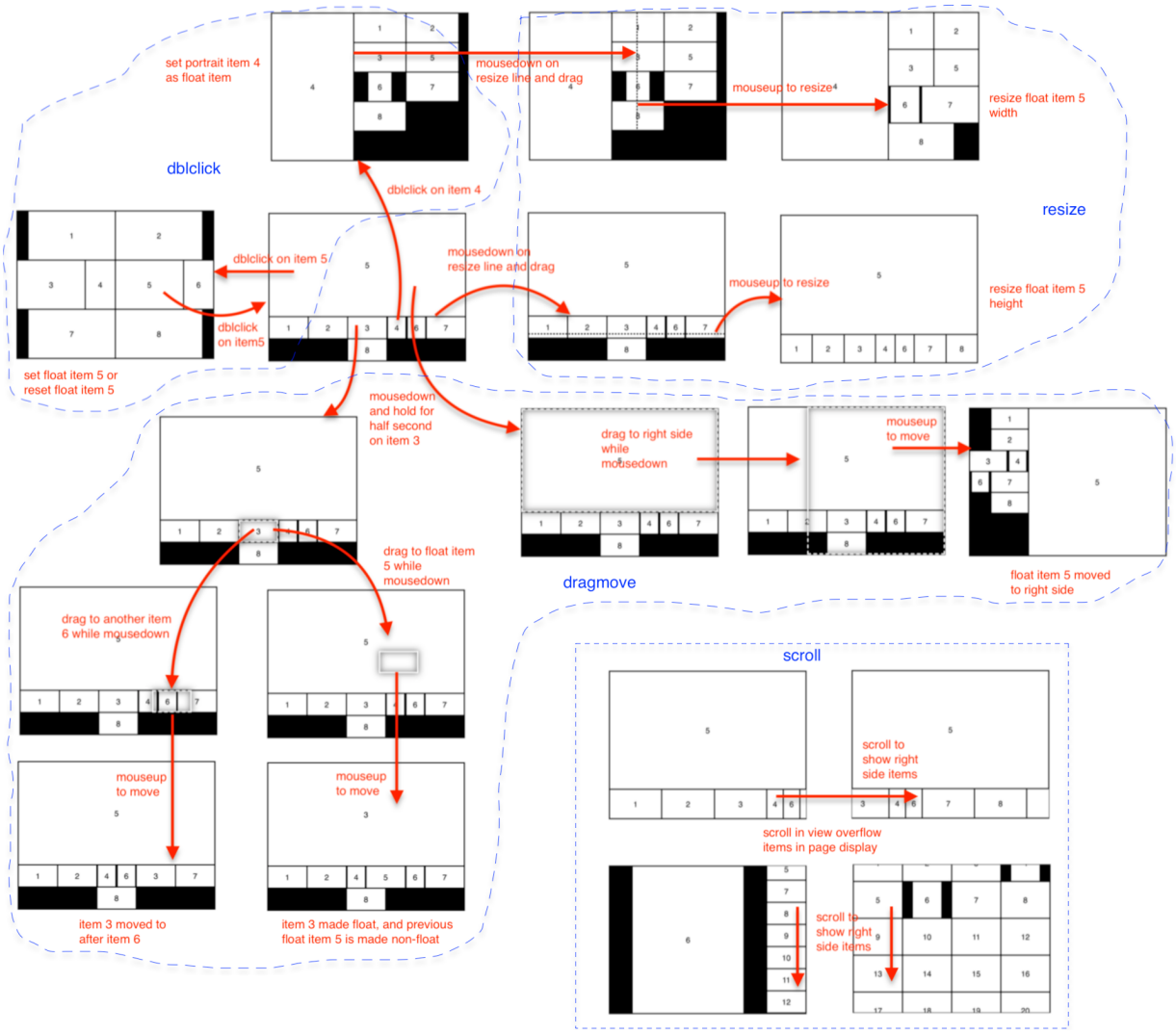
Interaction	Description
`dblclick`	To toggle item's float behavior, or to change the float item. Double clicking on a box makes it float with the last float attribute value if any, or default "top left". Double clicking on a float box removes its float attribute. Note that the `pip` display must have a float item, so removing the float attribute is not allowed in that display.
`dragmove`	To re-position a non-float item, or to attach float item to a side. You can also drag-move an item to a different place. Click and hold the left mouse button briefly to see the move cursor. Then drag the box over to another item. If the target item is another non-float item then the dragged item is moved to the position based on the order of that target item. If the target item is a float item, then the dragged item is made float instead. If the float item is dragged, it can be

moved to one of the four sides, to attach the float item to that side. This is not available in `grid` because in that display the float item does not attach to a side.

`resize` To change size ratio of float item vs. non-float area.
When you hover the mouse over the border of the float and other boxes, you will notice a divider. Click drag on the divider to change the ratio of the space taken by the float item and the other boxes, similar to setting the float attribute. This is not allowed in the `grid` display.

`scroll` To scroll through all the items if overflow in page or pip display.
In `page` display, or in `pip` display with fraction or factor specified on the float item, if there are more items than what can be shown in the container's view, then the user can scroll to see other items. The scrolling behavior is like line scrolling instead of page navigation.

These interactions are illustrated below.



These user interaction controls can be disabled using the disallow attribute on the container component as follows, using comma separated values to disable.

```
<flex-box ... disallow="dblclick,dragmove,resize,scroll"></flex-box>
```

You can use the `scrollTo` function shown below, to show an item programmatically when scroll is disallowed. This only works when the display is set to `page`.

```
let flexbox = ..., item = ...; // some item added to flex-box
flexbox.scrollTo(item);
```

When a container item is made visible or hidden due to scrolling in the page, then the container component dispatches a `change` event with the details. This is also dispatched when the display attribute changes to or from `page` and scrolling get enabled. After the display change to page, until this event is received, you can assume that all child items are getting displayed. The event object contains list of child items that were made visible and hidden, as shown below.

```
let flexbox = ...;
flexbox.addEventListener("change", event => {
    // event.detail.visible and .hidden arrays contain zero or more child
elements.
});
```

In the context of multi-party video conference display, the range of aspect ratio adjustment is important. Typically, for webcam videos, adjusting the ratio, and perhaps, zooming in, is desirable. For screenshare or other content video, keeping the original aspect ratio is preferred.

Later, we describe how to use 3D layout for the `video-io` components, in a multi-party call. The `flex-box` component also dispatches a `change` event whenever position or size of any of the container item changes, or when the size of the container changes, which may trigger a change in layout. This is used by spatial audio as discussed later.

The following table describes all the attributes of the component.

Name	Type and description
`debug`	bool, default is true Controls whether to enable layout related logging and visual debugging.
`display`	string, default is "inline-block"

	Controls the overall layout of the items in the display. Allowed values are inline-block, flex, grid, pip, page and line.
`transition`	string When set to none, it disables transition or animation. Default is to use a 0.3 second transition, when this attribute is missing or not set.
`ratio`	string, default is "16:9" Controls the estimated aspect ratio of child elements, to guess the initial layout. It is not used when display is inline-block.
`disallow`	string, default is "" Comma separated list of features that are not allowed. The features include dblclick, dragmove, resize and scroll.
`min-count`	number, default is 9 Controls the minimum number of boxes shown, when display is page, and does not have any float item.
`restore-display`	bool, default is false Controls whether to restore the CSS display property of the included element after they are shown. Default is to reset the display property.
`float`	object (read-only) Indicates the current child element with float property, or null if none.

The following table shows all the methods of the component.

Function	Signature and description
`appendChild`	box.appendChild(el) Append a child element to this container, with animation.
`insertBefore`	box.insertBefore(el, anchor) Insert a child element to this container, with animation.

`removeChild`	box.removeChild(el) Remove a child element from this container, with or without animation.
`scrollTo`	box.scrollTo(el) Programmatically scroll to a child element to show it, even if scroll is disallowed. This is applicable only when display is page or line.
`applyPosition`	box.applyPosition() Force update the layout, with or without a delay.
`reorder`	box.reorder() Force a reordering of the children. This is required if the children are not added or removed, but just their order is changed.

The following table shows all the events dispatched by the component instance.

Event	Example and description
`change`	{type: "change", visible: [...], hidden: [...]} Dispatched when a child element is shown or hidden, and display is one of page or line, that allows showing or hiding some elements. The event includes two optional arrays, for list of elements that are made visible or hidden.
`float`	{type: "float", element: null} Dispatched when a float child is added or removed, or the float attribute on a child is changed. The element property indicates the new float child element or null if none. This event assumes that at most one float child can exist. This assumption may change in the future with support for multiple float children.

19. How to work with a media server?

The underlying WebRTC technology used in the `video-io` component is inherently peer-to-peer for media path. However, many real-world call and conferencing applications rely on media servers for various functions including recording, interactive voice prompts, audio mixing, or video switching or routing. Here, we will describe how to connect `video-io` with popular media servers.

19.1 MCU vs. SFU

There are two types of media server - mixing vs. switching. A mixing server typically combines the media stream from the participants, and sends back one stream to each participant. An audio bridge is an example that mixes audio, such that each participant receives one stream containing audio from all the other participants, excluding self audio. A switching server receives a media stream from each participant, and routes it to all the other participants. A video MCU (multipoint control unit) is an example of a mixing server, and an SFU (selective forwarding unit) is an example of a switching server.

Unlike a peer-to-peer full mesh topology, with N-1 outbound and N-1 inbound media streams at each participant, the switching mode reduces the number of outbound streams from each participant to just one. The inbound streams count remain the same. Additional video techniques such as SVC (scalable video coding) or Simulcast can further reduce the bandwidth of inbound streams at the participants. This makes switching or SFU servers very popular in emerging WebRTC based video conferencing systems. A real service often employs a combination of mixing and switching services for various types of optimizations.

Here we describe how to use the popular Janus SFU and FreeSwitch MCU as media servers with the `video-io` component. In particular, the new named stream components of `janus-stream` and `verto-stream` facilitate implementing the named stream abstraction that is used by `video-io` in various apps, while preserving the publish-subscribe model of the named stream abstraction.

19.2 Using Janus for notification and media service

The `janus-stream` component allows using the `video-io` instances with the Janus media server (https://github.com/meetecho/janus-gateway). The server is used for both notification and media path. This is an example of client-server conference where media path is from a publisher client to the Janus server, and from the Janus server to each of the subscriber client. This is unlike the peer-to-peer media path from publisher client to every subscriber client enabled by the previous `rtclite-stream`, `named-stream` and `firebase-stream` components. The `janus-stream` component presents a wrapper around the Janus APIs to provide named stream abstraction. Janus already includes the publish-subscribe abstraction as part of its `videoroom` plugin, which allows a participant to publish one feed and subscribe to that feed from all the other participants. The Janus APIs allow the subscriber to subscribe to a feed after it has started publishing. The `janus-stream` component works around this limitation to allow the publisher and subscriber clients to come and go in any order. This is done by using two plugin attachments in subscriber client, one for publisher type but without actually publishing, so that it can receive events, and another for subscriber type.

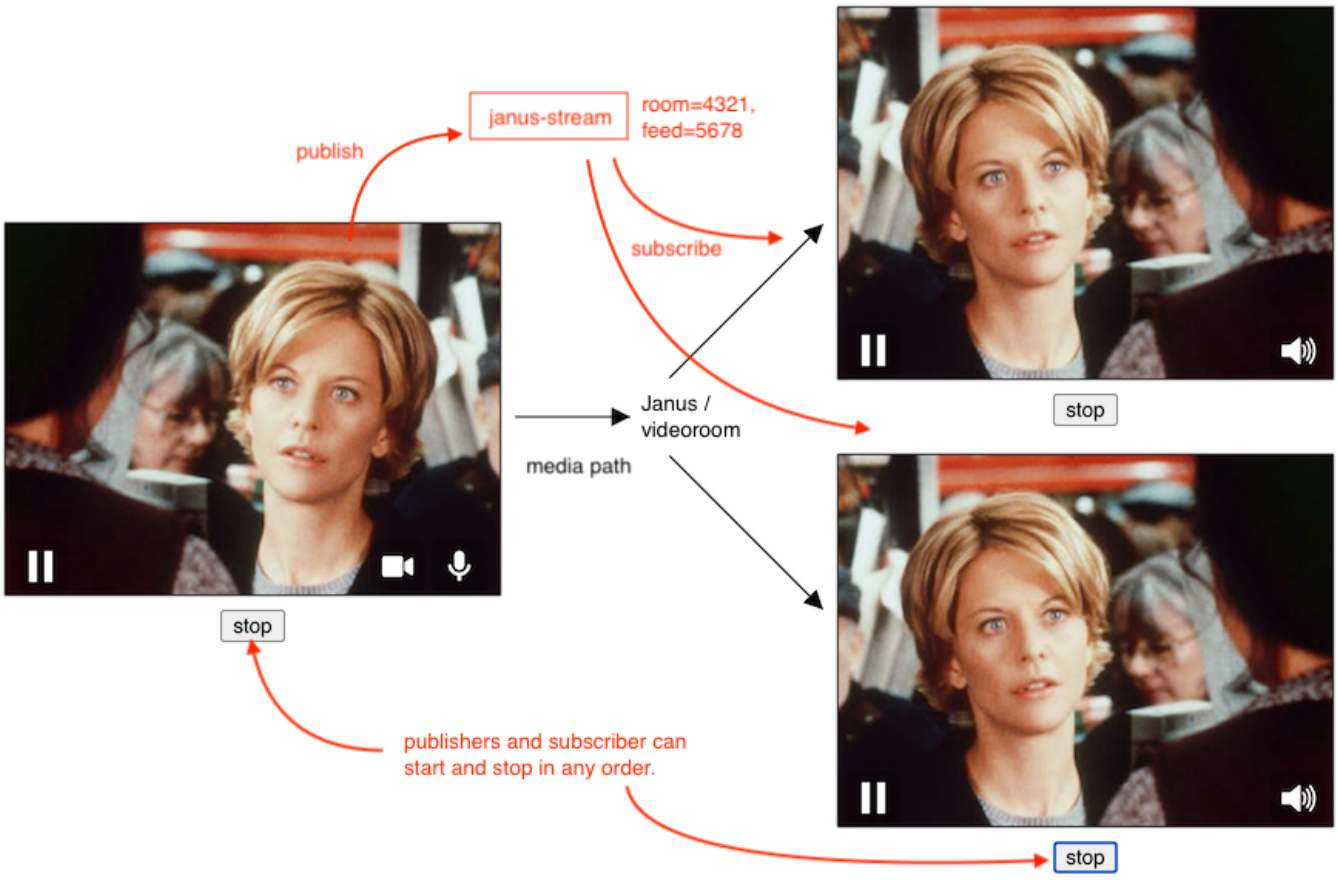
The example code is almost identical to the named stream examples shown previously, except that some external dependencies are included too. The component's `src` attribute may be configured to point to the Janus server instance, using either websocket or http-polling. The additional `room` and `feed` parameters configure the named stream. Behind the scenes, it uses that room and feed ID for the media publisher. If the room does not exist, then it is created dynamically. Note that the room and feed ID are numeric in earlier versions of Janus APIs.

```
<!-- in <head> -->
<script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs
/webrtc-adapter/9.0.3/adapter.min.js"></script>
<script type="text/javascript" src="https://janus-legacy.conf.meetecho.com
/janus.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/janus-
stream.js"></script>
...
<!-- in <body> -->
<janus-stream id="stream" src="https://janus.conf.meetecho.com/janus?room=1234&
feed=5678"></janus-stream>
<video-io id="video" controls autoenable="true" keeptracks="true" for="stream"
... ></video-io>
```

Note the `keeptracks` attribute in the example above. This allows a published component to keep the tracks active, and use the enabled flag to mute or unmute the audio or video track, when the control buttons are pressed or the `camera` or `microphone` property is changed. This is a workaround for the legacy `janus.js` implementation which does not correctly add or remove the tracks, when re-using an external stream. When the issue is fixed in that code, you may remove the `keeptracks` attribute. A downside of using this attribute is that the capture devices are occupied even if muted from the component.

Alternatively, you can use our modified `janus.js` file. The following sample is same as above, except that it loads our `janus.js` file, and does not use the `keeptracks` attribute.

```
<!-- in <head> -->
<script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs
/webrtc-adapter/9.0.3/adapter.min.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com
/v1/janus.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/janus-
stream.js"></script>
...
<!-- in <body> -->
<janus-stream id="stream" src="https://janus.conf.meetecho.com/janus?room=1234&
feed=9012"></janus-stream>
<video-io id="video" controls autoenable="true" for="stream" ... ></video-io>
```



In your real application, you may want to install your own Janus server, and connect using websocket

URL.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the server URL with room and feed parameters, e.g., "https://janus.conf.meetecho.com/janus?room=1234&feed=5678"

19.3 Using FreeSwitch as media server

The `verto-stream` component alows using the `video-io` instances with the FreeSwitch media server (https://signalwire.com/freeswitch) via it's Verto (https://developer.signalwire.com/freeswitch/FreeSWITCH-Explained/Modules/mod_verto_3964934/) endpoint. Unlike the previous Janus based component, this does not really need a notification service. The publisher publishes one stream to a conference room, and the subscribers subscribe to that stream from the conference room. Both publisher and subscribe connect to the server as active participants, sending the offer, and receiving the answer for media sessions. In a way, the MCU functions are minimized, since each named stream is mapped to a unique conference room, and using only one active stream in a conference room.

There are some important differences between the `verto-stream` component and the other similar components described previously. First, the stream instance can only be attached to one `video-io` instance at any time. Second, audio and video tracks are always included, although may be disabled if needed. Third, the underlying peer connection must include older "plan-b" semantics for SDP and "max-compat" mode of bundle policy.

```
<!-- in <head> -->
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/verto-stream.js"></script>
...
<!-- in <body> -->
<verto-stream id="stream" src="wss://my.freeswitch.org?params=..."></verto-stream>
<video-io id="video" controls autoenable="true" keeptracks="true" for="stream">
</video-io>
```

The `video-io` instance is configured to use plan-b and max-compat as follows. It also uses a default STUN server. This must be done before setting the publish or subscribe property.

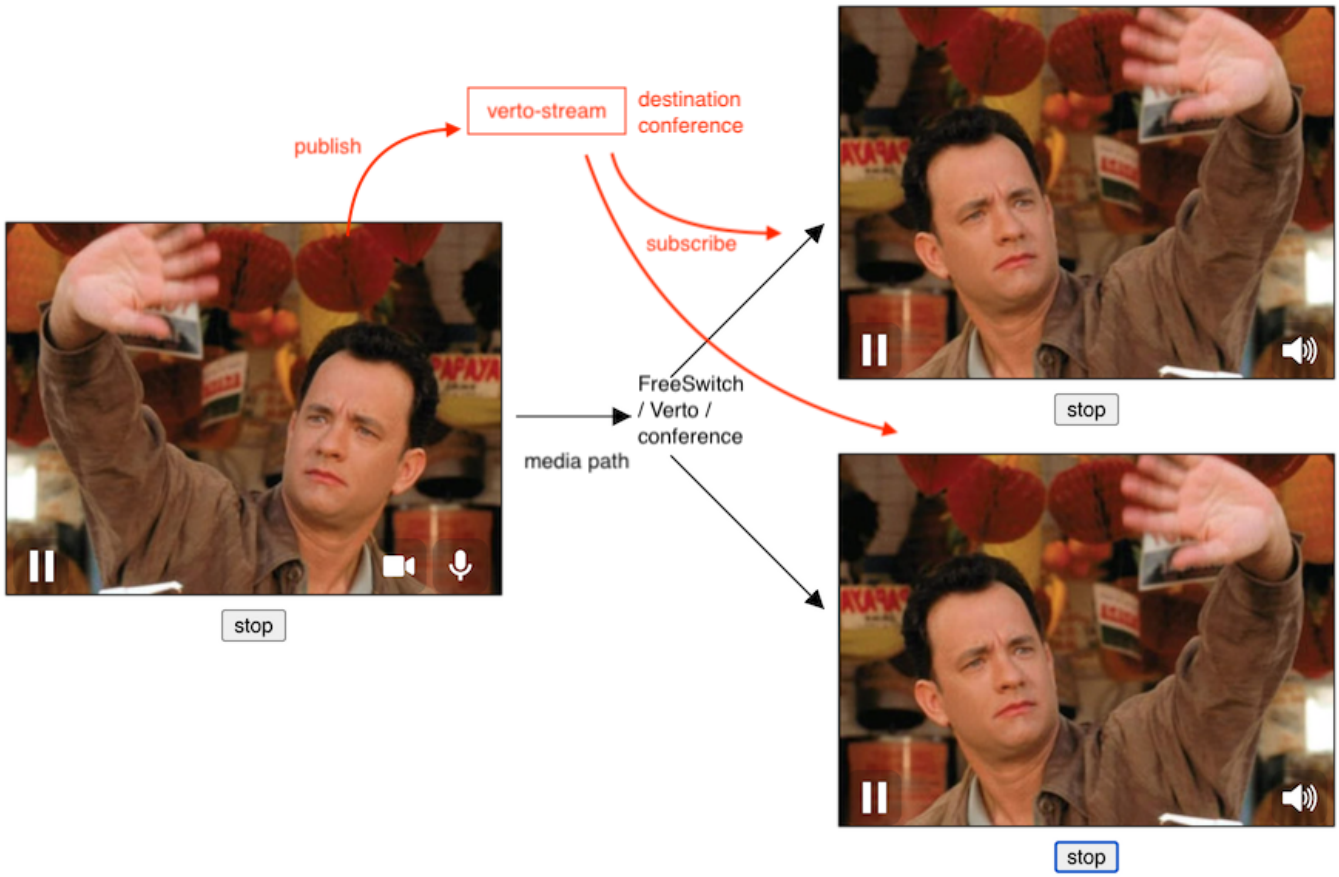
```
let video = document.querySelector("video-io");
video.configuration = {
    iceServers: [{urls: "stun:stun.l.google.com:19302"}],
    sdpSemantics: "plan-b",
    bundlePolicy: "max-compat"
};
```

The media server path specified in the `src` attribute is connected to via the Verto protocol over JSON RPC. The parameters supplied to that URL is used as parameters for various API requests such as `login`, `invite` or `bye`. And example is shown below:

```
let stream = document.querySelector("verto-stream");
let server = "..."; // host name or IP address of the media server
let sessid = "..."; // randomly unique session id
let dialogParams = {destination_number: "...", callID: "..."};
let params = {
    login: {sessid: sessid},
    relogin: {sessid: sessid, login: "...", passwd: "...", loginParams: {},
userVariables: {}},
    invite: {sessid: sessid, dialogParams: dialogParams},
    bye: {sessid: sessid, dialogParams: dialogParams},
}
let src = "wss://" + server + "?params=" +
encodeURIComponent(JSON.stringify(params));
stream.setAttribute("src", src);
```

The example above shows that the `login` request will use a `sessid` parameter, and `relogin` request after an authentication failure will use additional credentials such as `login` and `passwd`. The `verto.invite` request will use the same `sessid`, and a new `dialogParams` value containing the destination number and call identifier. All these parameters are specific to your setup of the FreeSwitch, and will change depending on what is needed by your setup. The example above assumes that the destination number is used to connect the call to the right conference room. In that case, the publisher and subscriber instances should both use the same destination number. However, sessid and call identifier should be randomly unique for each session and call attempt. Thus, when a new call is attempted, e.g., by resetting publish and setting it again, you should change the `callID` parameter.

Try the example below, assuming the server is properly configured.



The above example relies on a tightly controlled flow of publisher and subscriber. The component implementation itself is very primitive, and not ready for anything beyond a proof-of-concept or demonstration application. The main reason is that the Verto client library is too involved with tight coupling of notification and media features. So I decided to not use that, and directly implement the low level communication over web socket, for the minimum set of features needed for this project.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required

Set the server URL with additional configuration parameter, e.g., "wss://myserver.com?params=..."

`state` string

Indicates the internal connection state of the verto client, e.g., idle, inviting, invited, terminating, login, connected, ready, active, etc.

20. How to work with hosted conference services?

Here we describe how to connect with popular hosted conference services such as Agora, Jitsi, LiveKit, VideoSDK.live and others. Unlike the previously discussed Janus and Freeswitch media servers, these hosted services are one level up, i.e., they present a higher level API for implementing video call, conference or other application. Although most of these have a conference room abstraction, the specifics of the API are different. The basic idea is similar to the media server's named stream implementation, i.e., use a conference room as the stream name, and have only one publisher per room.

Building an application using video-io's generic application interface, and using a service specific named stream connecting to one of these services, allows you to decouple the application logic from the service specific access control or differences in the APIs of these services. However, since the peer connection is often handled by the service specific named stream implementation, some properties and attributes of video-io that are dependent on the connection, are not available with these named stream implementations.

20.1 Using Jitsi-as-a-Service

Jitsi is an open source video conferencing server, which also has a hosted jitsi-as-a-service offering. Our jitsi-stream web component takes a room identifier representing the stream name, an application identifier and an authentication token, to connect to this service.

```
let stream = document.querySelector("jitsi-stream");
let src = "roomid=...&appid=...&token=...";
stream.setAttribute("src", src);
```

To try the example below, first signup for an account on JaaS (https://jaas.8x8.vc), get the appid and 2-hr token, and plug that in, before trying the example below. Similar configuration should be possible for the installed Jitsi media server.

The following table describes all the attributes and properties of the component. Additional methods

are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the appid, roomid, and token. These are required to connect to the service. Example: "?roomid=...&appid=...&token=...". The individual values can also be set directly as a property on this object, e.g., stream.token = "...", instead of using the src attribute.
`debug_level`	number, property, optional, default 2 Set the log level from 0 to 5, for none, error, warn, info, debug and trace.

20.2 Using Agora service

Agora is another developer friendly video conferencing service. Our agora-stream component takes a channel name representing a named stream, and an application identifier and authentication token.

```
let stream = document.querySelector("agora-stream");
let src = "?channel=...&appid=...&token=...";
stream.setAttribute("src", src);
```

To try the example below, first signup for an account on Agora (https://agora.io), create a project, get the appId, generate a temporary token for channel test1, and plug those in, before trying the example below.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required

	Set the appid, channel, token and/or (optional) codec. The first three are required to connect to the service, and the fourth defaults to vp8. Example: "?channel=...&appid=...&token=...". The individual values can also be set directly as a property on this object, e.g., stream.token = "...", instead of using the src attribute.
`debug_level`	number, property, optional, default 2 Set the log level from 0 to 5, for none, error, warn, info, debug and trace.

20.3 Using LiveKit service

LiveKit is another open source developer platform for video conferencing. Our livekit-stream component takes a room name representing a named stream, and a sandbox test server to connect to. Connecting to non-sandbox, or production server, is similar, and can be accomplished by modifying the component implementation.

```
let stream = document.querySelector("livekit-stream");
let src = "?room=...&sandbox=...";
stream.setAttribute("src", src);
```

To try the example below, first signup for an account on LiveKit (https://livekit.io), create a project, use a sandbox token server, and plug those in, before trying the example below.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the room, and sandbox. These are required to connect to the service. Example: "?room=...&sandbox=...". The individual values can also be set

	directly as a property on this object, e.g., stream.sandbox = "...", instead of using the src attribute.
`debug_level`	number, property, optional, default 3 Set the log level from 0 to 5, for none, error, warn, info, debug and trace.

20.4 Using VideoSDK.live service

VideoSDK.live is also a developer platform and service for video conferencing. Our videosdklive-stream component takes a room name for a named stream, and an authentication token that includes other data for connection to that service.

```
let stream = document.querySelector("videosdklive-stream");
let src = "https://api.videosdk.live/v2/rooms?room=...&token=...";
stream.setAttribute("src", src);
```

To try the example below, first signup for an account on VideoSDK.live (https://videosdk.live), create a project or use auto generated, generate an API token, and plug that in, before trying the example below.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the server, room and token. These are required to connect to the service. Example: "https://api.videosdk.live/v2/rooms?room=...&token=...". The individual values other than server can also be set directly as a property on this object, e.g., stream.token = "...", instead of using the src attribute.
`debug_level`	number, property, optional, default 2

Set the log level from 0 to 5, for none, error, warn, info, debug and trace.

The examples shown above with four specific hosted services are for demonstration only, and we do not endorse, ensourage or discourage use of any specific service. The next section describes how to add a named stream connection to any third-party hosted service.

21. How to further customize a named stream?

Here, additional topics related to named streams are covered.

21.1 Using external-stream

The generic external-stream web component is useful in connecting to any external media server or conference service. It takes a URL of an external web app, loads it in an internal sandboxed iframe or an external popup window, and delegates the named stream interface function to that web app. Since Chrome does not support transfer of a `MediaStream` object between window contexts, it uses a peer connection between the main web application and the external web app, to exchange the media streams - the published media stream from the video-io is sent from the main app to the external web app in the iframe or window, and the subscribed media stream is sent from the external web app to the main app. This approach allows us to keep any service-specific named stream implementations outside our code, and potentially hosted by the same vendor that provides the service.

```
<external-stream ... src="https://..."></external-stream>
```

The following sample app delegates the named stream implementation to http://localhost:8004 /external-stream.html which takes name parameter for the stream name, and in turn implements a simple local named stream implementation for this demonstrations. First run a web server to make the included external-stream.html web app available at this URL before trying the example below.

```
$ python -m SimpleHTTPServer 8004
```

Then try the following example with external app loaded in a sandboxed iframe.

To load the external web app in a popup window, use the type of window in the attribute.

```
<external-stream ... type="window" src="https://..."></external-stream>
```

Try this example where the external app is loaded in a popup window.

The following table describes all the attributes and properties of the component. Additional methods are in the named-stream base class.

Name	Type and description
`src`	string, property and attribute, required Set the URL of the external web app that implements the named stream abstraction, e.g., "http://localhost:8004/external-stream.html".
`type`	string, attribute, optional, default is iframe Control whether to use iframe (default) or window to load the external web app.

21.2 Using split-stream

The named stream abstraction allows at most one publisher and zero or more subscribers attached to a single stream. It also requires a video-io component instance to be attached to only one named stream. Note that the video-io component has a reference to a named stream via the `for` or `srcObject` property, and the named stream's publish and subscribe methods get the video-io's reference as a parameter.

In a real video conference app, in one endpoint, usually only one video-io instance is attached to a named stream, because other video-io instances that need to be attached to the same named stream usually run on other endpoints. A subscriber video-io attached to one named stream is fine, but a publisher video-io attached to only one named stream can be limiting for some application use cases, where a single video-io may need to be published to multiple streams. One option is to use the `input` property of video-io to do a fork. Another option is to use a stream-stream component.

A split-stream acts as a container with two or more other named stream components. It allows the split-stream to use the published media stream in both the included named streams. The publisher video-io attached to the parent split-stream component, whereas the subscriber video-io attaches to

the individual child named stream.

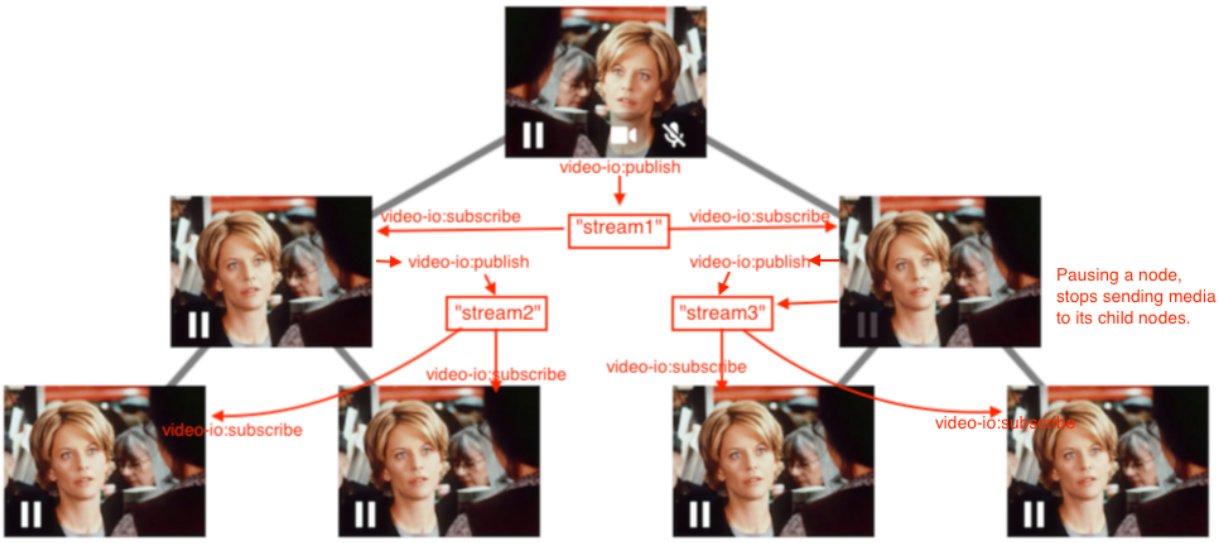
```
<split-stream id="stream1">
  <rtclite-stream id="stream2" ...></rtclite-stream>
  <firebase-stream id="stream3" ...></firebase-stream>
</split-stream>
```

Try this example which uses the basic named-stream components inside the split-stream.

22. How to do peer-to-peer broadcast without media server?

The techniques described in How to connect publisher and subscriber? and How to clone and modify the video stream? can be used to create a broadcast tree of the `video-io` instances running on various nodes. The publisher is the root node with only one `video-io` instance for publishing, and one `named-stream` (or any of its subclass) instance. The other viewers include two `video-io` instances, and two `named-stream` instances. One set is to subscribe to the parent node's stream in the broadcast tree. The other set is to publish to the child nodes in the tree. The publish instance uses the `input` property assigned to the subscribe instance, so that the received media stream is republished to a new named stream from that node.

The example below shows a 7-node broadcast tree, where each node republishes to two other child nodes. You can pause an root or intermediate node's video to see the effect on the subtree it publishes to.



Depending on the upstream bandwidth of the intermediate nodes, each node can determine how many child nodes it will serve. Depending on the latency among the nodes, an intermediate node can pick the right parent node. Such algorithms are outside the scope of this document, but have been well

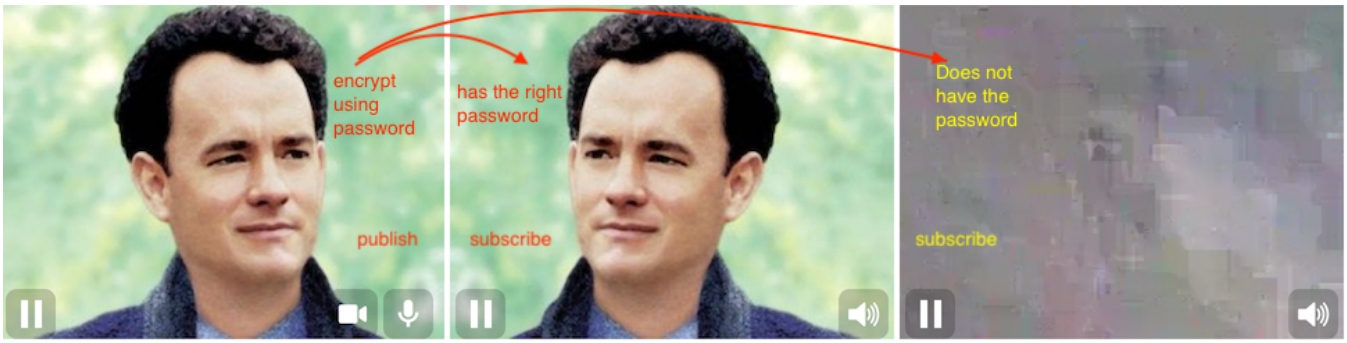
researched as part of the multicast and application level multicast related prior studies.

Furthermore, the techniques described in How to do end-to-end encryption? can be used to prevent intermediate nodes from decrypting the media unless they have the right key. This makes such intermediate nodes as part of the peer-to-peer infrastructure or super-nodes, that serve other nodes, without any self benefit in that particular session.

23. How to do end-to-end encryption using insertable streams?

Use the `secret` attribute or property to enable end-to-end encryption using insertable streams, in publish or subscribe `video-io` instance. Internally, the implementation uses a worker thread to perform the actual encryption or decryption.

```
<named-stream id="stream"></named-stream>
<video-io id="video1" autoenable="true"></video-io>
<video-io id="video2"></video-io>
<video-io id="video3"></video-io>
<script type="text/javascript">
    ...
    video1.srcObject = video2.srcObject = video3.srcObject = stream;
    video1.secret = video2.secret = "password123";
    video1.publish = video2.subscribe = video3.subscribe = true;
</script>
```



The example shows three `video-io` components, one publisher and two subscribers. One of the subscriber uses the right shared secret as the publisher, and can decode the audio and video stream. The other subscriber does not use the secret and cannot decode the audio and video stream. It is recommended to mute the sound on that instance, to avoid garbled audio playback from that instance.

The above sample does not use a middlebox or a selective forwarding unit. Hence, it does not really need end-to-end encryption, since WebRTC is already encrypted end-to-end for media path. However, the same code fragment will work with middlebox too that break the end-to-end media path

of WebRTC. In that case the encryption used here will prevent the middlebox from accessing the unencrypted media.

24. How to clone and modify the video stream

Previously, we have shown examples of capturing video from webcam, screen or app. Here, we will show how to modify a video stream in real-time, e.g., to put caption or mix or perform some image processing on each frame. This is doable both in publish and subscribe mode. In subscribe mode, it is also possible to re-publish the clone of the received video with or without modification.

First, there is a `input` property of the `video-io` component that can be assigned to either a `video` or `canvas` element, or a `MediaStream` instance. Alternatively, it can be assigned to another `video-io` instance, or to a `video-mix` instance. We will discuss `video-mix` later in this section. For now, the following example shows a `video` element that plays some stored MP4 file, and is piped to a publishing `video-io` instance, which is then transported to a subscribed `video-io` instance. Setting the `input` property of the middle `video-io` element makes it use the supplied `video` element as the media source on publish, instead of capturing from camera and microphone.

```
<named-stream id="stream"></named-stream>
<video id="video1" autoplay controls></video>
<video-io id="video2" autoenable="true" controls></video-io>
<video-io id="video3" controls></video-io>
<script type="text/javascript">
    const video1 = ..., video2 = ..., video3 = ..., stream = ...;
    video2.input = video1;
    video2.srcObject = video3.srcObject = stream;
    video1.src = "...somefile.mp4";
    video2.publish = video3.subscribe = true;
</script>
```

As mentioned earlier, it is recommended to set `autoenable` in a publisher instance, so that pausing the video also disables the published tracks. Note that the camera and microphone controls are not shown when the input source is used, e.g., in `video2` above.

24.1 video-mix

Second, there is a new `video-mix` custom element or component. It can modify and mix the audio/video stream from one or more sources. The following example shows how to add caption on a video. Internally, the component has a `canvas` element which is used to periodically render and manipulate the video stream.

```
<named-stream id="stream"></named-stream>
<video-io id="video1" microphone="false" controls></video-io>
<video-io id="video2" autoenable="true" controls></video-io>
<video-io id="video3" controls></video-io>
<video-mix id="mixer">
    <script for="video1" type="text/plain">
        canvas.width = video.videoWidth;
        canvas.height = video.videoHeight;
        let ctx = canvas.getContext("2d");
        ctx.drawImage(video, 0, 0);       // first draw the video frame
        ...                               // set text style
        let text = new Date().toLocaleString();
        ctx.fillText(text, 320, 10, 640); // then draw the text.
    </script>
</video-mix>
<script type="text/javascript">
    ...                                   // define video1, video2, etc
    video2.input = mixer;
    mixer.input = [video1];
    video2.srcObject = video3.srcObject = stream;
    video1.publish = video2.publish = video3.subscribe = true;
</script>
```

Note that the second `video-io` instance uses the `video-mix` instance as input instead of camera and microphone. The `video-mix` instance itself is defined to manipulate the canvas based on the video frame and current date string. The second `video-io` instance is published, and is subscribed by the third `video-io` instance to show publisher-subscriber media flow of the modified video stream.

The `video-mix` element can take multiple video input, and can compose the video layout based on the application logic supplied in the element's `script` child elements. The `for` attribute of the `script` element indicates the element that is fed to this script code. Note that such script tag must have the `type` attribute of `"text/plain"`. The script gets several local variables for use such as `canvas`, `video` and `script`, for those related DOM elements.

Instead of using the `script` child elements in the `video-mix` component instance, you can use an event handler to manipulate the canvas as follows. The `"frame"` event type is dispatched with an event object that includes the `canvas` and `videos` attributes. The `videos` value is an array with `video` elements corresponding to the `input` attribute of the `video-mix` instance. In this example, it is set to one item array of `video1`.

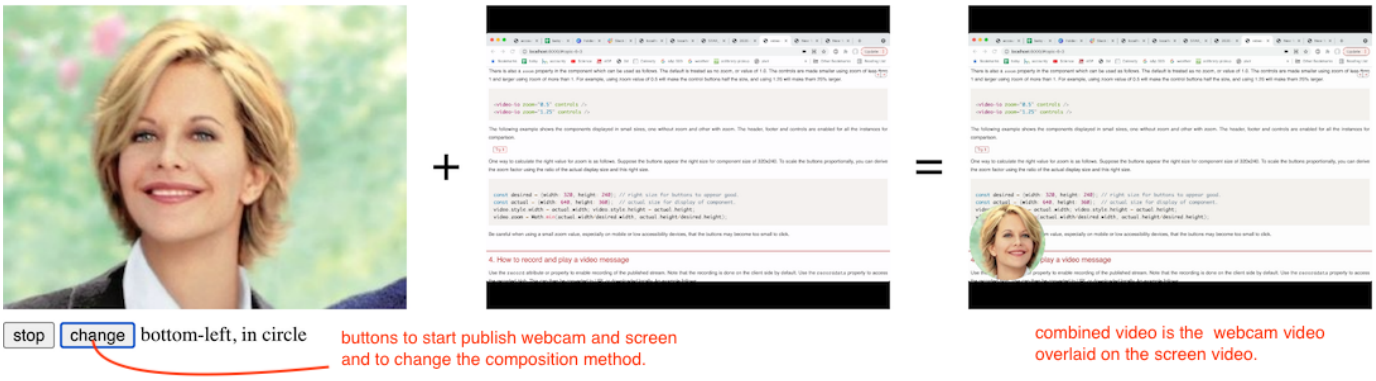
```
<video-mix id="mixer"></video-mix>
<script type="text/javascript">
    ...
    mixer.addEventListener("frame", e => {
        e.canvas.width = 640; e.canvas.height = 480;
        const ctx = e.canvas.getContext("2d");
        if (e.videos[0]) {
            ctx.drawImage(e.videos[0], 0, 0);
        }
        ...
        ctx.fillText(text, 320, 10, 640);
    });
    ...
    video2.input = mixer;
    mixer.input = [video1];
    video1.publish = video2.publish = true;
</script>
```

You may use both the `"frame"` event listener as well as the `script` child elements in the `video-mix` component. The event listener is processed before the script tags.

Consider another example as shown below, where `video1` and `video2` capture from the webcam and

screen, respectively, and feed their video to `video3`. Here `video3` combines the two streams, e.g., in picture-in-picture mode, to generate a new stream. Then `video3` may be published to a named stream, which other players can view as one stream.

```
<video-io id="video1" controls></video-io>
<video-io id="video2" controls screen="true" microphone="false"
desiredframerate="3"></video-io>
<video-io id="video3" autoenable="true" controls></video-io>
<video-mix id="mixer">
    <script for="video2" type="text/plain">
        canvas.width = 640; // stretch to fixed size background.
        canvas.height = 480;
        canvas.getContext("2d").drawImage(video, 0, 0, 640, 480);
    </script>
    <script for="video1" type="text/plain">
        // position foreground on top-right as picture-in-picture 60x60 size
        canvas.getContext("2d").drawImage(video, 120, 40, 400, 400, 570, 10, 60,
60);
    </script>
</video-mix>
<script type="text/javascript">
    ...
    mixer.audio = [video1];         // use audio from video1
    mixer.input = [video1, video2]; // layout has two videos
    video3.input = mixer;           // feed mixer to video3
    video1.publish = video2.publish = video3.publish = true;
</script>
```



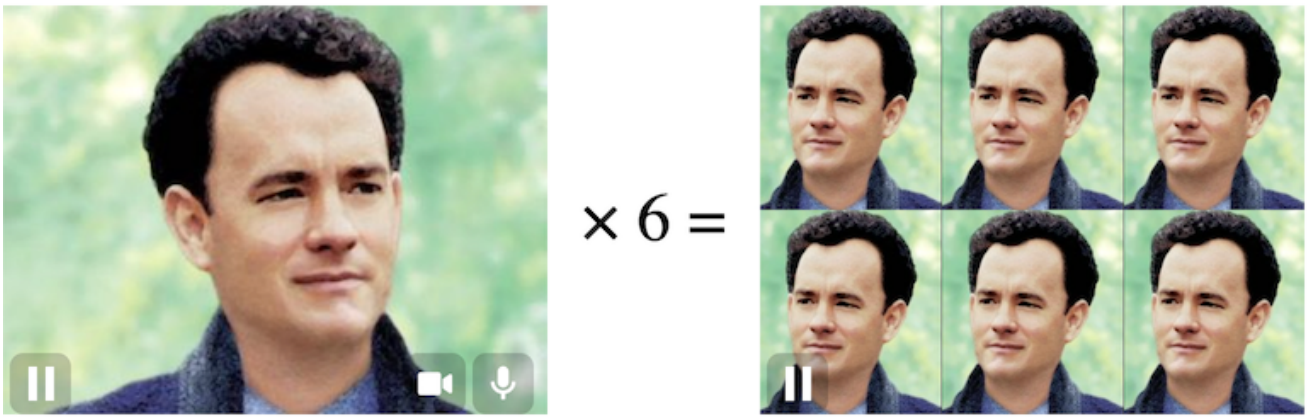
The `video-mix` custom element allows setting the video layout using canvas operations, and can do advanced layout such as with drop shadow and clip-in-circle. You can try the sample code by clicking on the "change" button in the previous example.

The following example shows how to change brightness, contrast, color, and other image properties in live video, which can then be published in a call. It also uses the `--preview-transfrom` CSS style to mirror the second video similar to the first camera published video.

```
<video-mix id="mixer">
    <script for="..." type="text/plain">
        canvas.width = video.videoWidth; canvas.height = video.videoHeight;
        const ctx = canvas.getContext("2d");
        ctx.filter = "brightness(130%) contrast(80%)";
        ctx.drawImage(video, 0, 0);
    </script>
</video-mix>
```

Here is another example that shows a multi-party conference layout. The video elements are laid out in 3x2 tile. You may alternatively add the `script` element dynamically in JavaScript. Please inspect the example code to learn how to do that.

```
<video-mix id="mixer">
    <script for="video1" type="text/plain">
        canvas.width = 640;
        canvas.height = 480;
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 0, 213, 240);
    </script>
    <script for="video2" type="text/plain">
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 214, 0, 213,
240);
    </script>
    <script for="video3" type="text/plain">
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 428, 0, 213,
240);
    </script>
    <script for="video4" type="text/plain">
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 0, 240, 213,
240);
    </script>
    <script for="video5" type="text/plain">
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 214, 240, 213,
240);
    </script>
    <script for="video6" type="text/plain">
        canvas.getContext("2d").drawImage(video, 107, 0, 426, 480, 428, 240, 213,
240);
    </script>
</video-mix>
```



Although the previous example demonstrates the same video copied to multiple slots, they can be different video elements, e.g., subscribed to different participant's published named streams in a conference call.

Note, however, that you do not generally need to use the `video-mix` component in a conference or video call application. Separate `video-io` elements subscribed to different participants' published named streams can be displayed separately in the app, instead of having to create a mixed video stream. However, for certain use cases, such as recording or republished mixed or modified stream, the application could use the `video-mix` component.

25. How to do image processing on video?

Previously, in How to clone and modify the video stream?, it was shown how to get access to and modify the raw image data, such as to put caption or multi-party layout. The same concept can be used to apply image processing algorithms in real-time to the frames of the video stream, and to publish the modified video stream.

25.1 Background detection, blur and removal

The following example uses MediaPipe to segment a person in an image. It generates four new video streams: for the segment, with blur background, with removed background, and with virtual background. For optimization, a single mixer is used to generate the segment mask video, and to write to other `canvas` elements. These other elements are used as `input` for the other `video-io` instances.

The following example uses Tensorflow to segment a person in an image using the bodypix model. It is similar to the previous except that it is slower, so framerate is reduced to 5fps. It generates three

new video streams: for the segment, with blur background, and with removed background. For optimization, a single mixer is used to generate the segment mask video, and to write to other `canvas` elements. These other elements are used as `input` for the other `video-io` instances.

In practice, you should move the Tensorflow related code to a separate worker thread to speed up processing, without blocking the user interface thread. Moreover, invoking the algorithm on every frame is not required either.

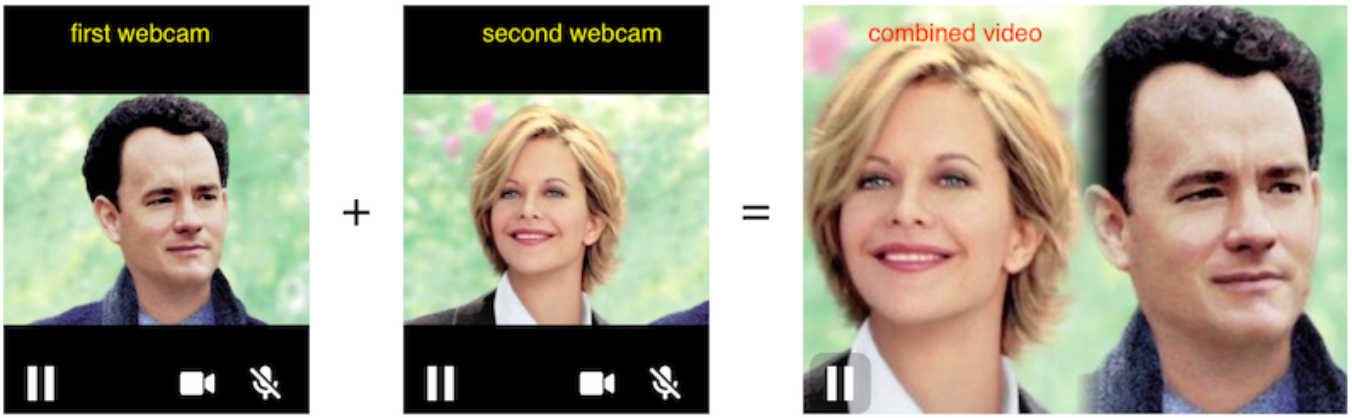
25.2 Face, eye and mouth tracking

The following example uses trackingjs (https://trackingjs.com/) library for detecting face, and draws a rectangle on top of the video identifying the detected face if any.

In practice, this can be used for zooming in to the detected face, or to blur out everything not a face, or to augment with external drawings such as hat or sunglasses on top of the video.

25.3 Merge multiple webcams

The following example shows how to mix images from multiple cameras to generate a single combined video stream that can be published. This example will work only if you have more than one cameras, and it will use the first two cameras found in the `devices` property. The example code uses intermediate canvas and image processing to combine the two images with alpha-gradient in the middle.



In practice, using multiple cameras can lead to many innovative use cases in video conferencing. The image processing shown in the above example is just one use case.

25.4 Change video speed

The following example shows how to alter the video speed in the modified video stream. The basic idea is to change the perceived frame rate to slow motion or fast forward, by saving images in the frame event or playing saved ones faster. The example alters between slow motion and fast forward mode.

Note that the audio is not altered. In practice this feature can be used for instant replay, e.g., to play last 10 seconds in slow motion, and to speed up after that to catchup. This is similar to instant replay in TV.

25.5 Capture slowly

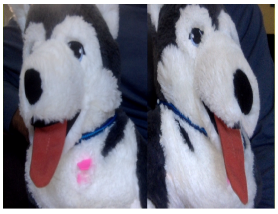
The following example shows capturing an image from the webcam slowly from left to right, so that the view can change during the capture, and create dramatic effects. It is modified from my earlier toy project capture-slowly (https://github.com/theintencity/samples). The basic idea is to use a backup canvas to capture one vertical line of pixels at a time. Additionally, the preview of the capture shows the part that are already captured as static image portion on the left of the yellow line, and the part that is still pending as video portion on the right of the yellow line, as the yellow line moves from left to right during capture.

Click on the start button to start the slow capture. Once completed, the download button is active, and

the right side preview shows the captured image. Click on the clear button to stop the capture or the pause button to temporarily pause the moving yellow line of active capture. The following examples illustrate the dramatic effects using slow capture.



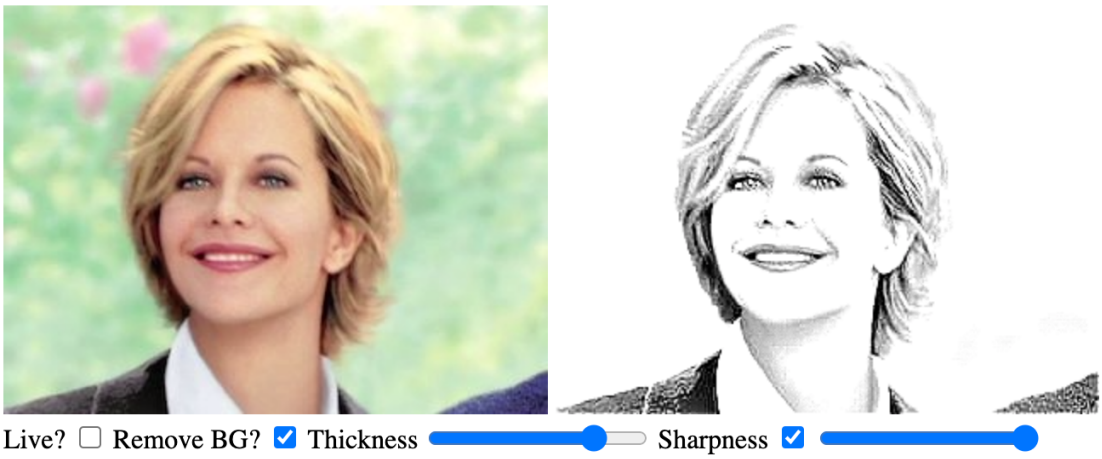





The last two images are captured with a single stuffie, using the pause button, to generate two pictures during slow capture. The first four effects are done by slowly moving the stuffie along or away from the moving yellow line, to stretch or compress the picture horizontally.

25.6 Sketch art

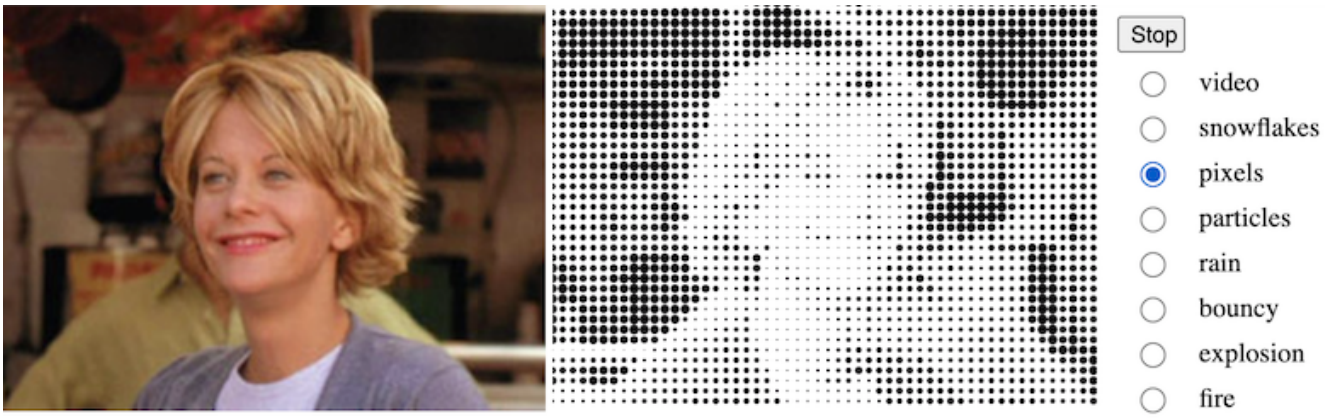
Here is an example that demonstrates how to convert live webcam feed to sketch art using the technique that uses grayscale, invert and blur filters followed by color-dodge to mix. Additionally, image sharpen is performed at the end.



A few controls allow removing background before conversion, changing the blur size, or sharpness scale.

25.7 Use p5.js for drawing

The p5.js (https://p5js.org/) project provides a JavaScript library for creative coding and drawing for artists and designers. The following example shows how to use this third-party library to add special effects like snowflakes, rain, fire, particles or pixels. The project includes hundreds of effects and drawing examples, and a handful of them are included in this example below.



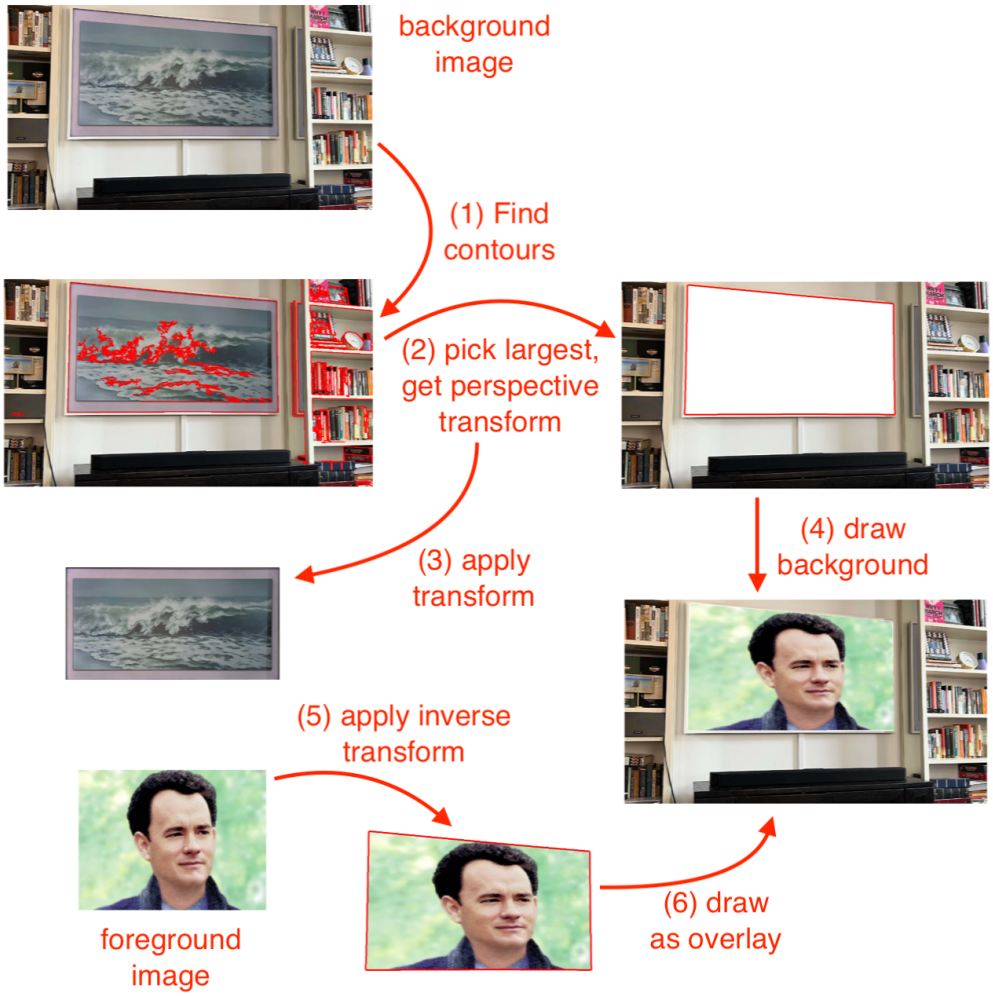
The included effects are further illustrated below: snowflakes, pixels, particles, rain, bouncy, explosion and fire.

This example does not use `video-mix` because p5.js already provides similar functions using its canvas for drawing. The example uses two `video-io` instances - the first one's `video` element is wrapped in `p5.MediaElement`, so that it can be used there, and the second one's `input` is assigned to p5's `canvas` element. After that all the drawings are done in p5, but without the global context.

25.8 Perspective projection

Here is an example that uses the popular opencv.js (https://github.com/TechStark/opencv-js) project to generate a new video stream with the webcam video projected onto a rectangle detected in a background image.

Clicking the first background image allows you to change the background in the generated and project third video. The application logic is explained in the following diagram.



Rectangle detection in the current implementation is not very accurate. This application is also meant only for demonstration purpose, and is not robust. The following example takes two input images and generates two output images using the above application logic.

Some use cases for detecting rectangles and perspective projections are as follows:

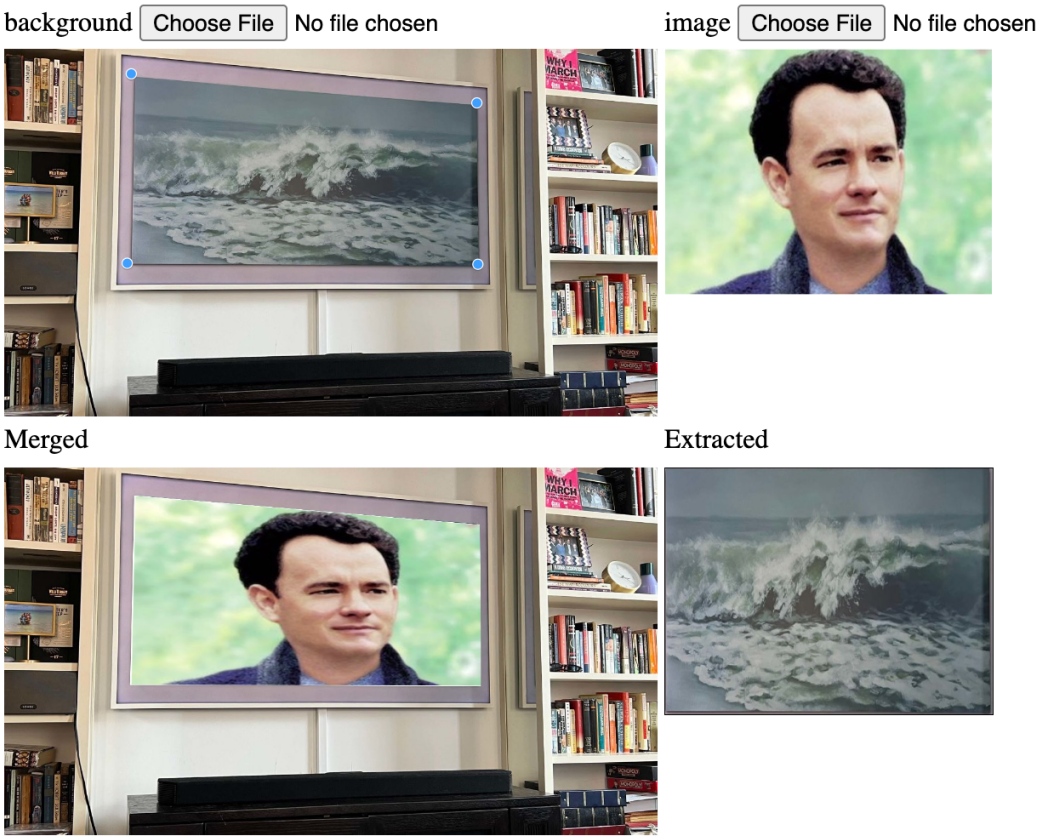
- Online virtual event environment where live slide share or webcam video can be projected to wall frames, TV or other objects in the simulated set up.
- Pointing a webcam to a real white board in a conference room, and be able to extract only the white board portion for streaming, recording or content analysis.

- Automatically detecting white board, paper, or billboard in a webcam video in the background, and replacing it with other content, to hide sensitive context and/or to replace with advertisement or promotional content.

The second and third use cases are not yet feasible in real-time, due to the large processing requirement of shape detection in the current code. They can however be done in a semi-real-time manner, where detection happens only periodically, say, once in 5 or 10 seconds. Furthermore, user assisted rectangle detection can be used instead of automatic, by allowing the user to click-select the four corners of the rectangle in the video.

25.9 Use glfx.js for effects

The alternative glfx.js (https://github.com/evanw/glfx.js) project provides a more efficient WebGL based perspective transformation. The higher level API of this project is also easier to use then the previous one.



The above example is similar to the one previously shown, except that it uses this new library, and it allows user assisted rectangle detection. It allows drag-move of the four corners of the rectangle in the source image.

In addition to perspective transform, the glfx.js project implements several image effects in JavaScript using WebGL. Here is an example that demonstrates various image processing effects on webcam video using the glfx.js project.

The included effects are further illustrated below: brightnessContrast, hueSaturation, vibrance, denoise, unsharpMask, noise, sepia, vignette, zoomBlur, triangleBlur, tiltShift, lensBlur, swirl, bulgePinch, perspective, ink, edgeWork, hexagonalPixelate, dotScreen, and colorHalftone.

25.10 Pixel match for security camera

The lightweight pixelmatch.js (https://github.com/mapbox/pixelmatch) library compares two images to detect differences in pixels. This is useful in a variety of scenarios, including optimization for security camera. The following example shows the difference detected using pixel match due a slight movement of the object in view.

Try the following as an example security camera application. Once started, move away from the camera for few minutes. Then appear again briefly for 10-30 seconds, and move away again. Come back and see the recordings captured, both snapshots and video, for the duration when there was some activity in the webcam video.

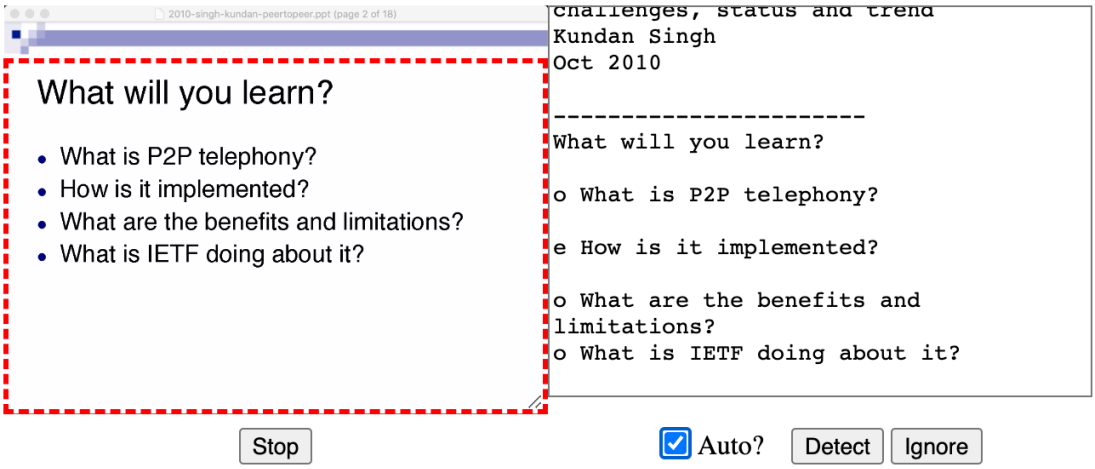
It uses `recordmax` property of the `video-io` component, to keep recording of the last ten seconds of the webcam video. It periodically captures snapshots every five seconds. It then uses pixelmatch.js to detect any differences in the snapshot from the previous snapshot. If a difference is detected, in more than 0.1% of pixels, indicating some activity in the webcam video, then it updates the `recordmax` property to record longer video, and continues to save the snapshots. After no activity is detected, it

saves the recorded video as well as stops saving the snapshots, and reverts the `recordmax` property back to last ten seconds.

The net effect is that it captures and records video and images of any activity detected, including few seconds before the activity started, and few seconds after it stopped. Not saving the images or video when there is no activity helps in storage management as well as review of the security camera footage. The sensitity of activity detection can be easily adjusted based on the threshold for pixel match.

25.11 Use tesseract for OCR

Tesseract.js (https://github.com/naptha/tesseract.js) is a JavaScript library for optical character recognition. It takes an image and extracts words in almost any language. The following example uses it to extract notes out of shared screen or app video.



First, click to start the screen or app capture in the `video-io` instance on the left. You can resize the red selector, to limit how much of the video image to use for text detection. Typically, you would ignore the window header or footer.

Click on the detect button to detect text and populate it in the `textarea` on the right. You can also check the auto checkbox. If checked, it automatically triggers detection when the video image

changes by more than 4% in pixel comparison. This is useful for slide share scenario, where it automatically captures the text notes when the slide changes. Clicking on the ignore button deletes the last detection from the text.

26. How to do signal processing on audio?

The Web Audio API is very powerful in applying simple processing such as gain, delay, low pass filter as well as for complex signal processing such as for sound analyzer, colvolver, wave shaper. The `audio-context` component wraps these features provided by the built-in `AudioContext` and related interfaces in the browser.

Similar to the `video-mix` component, it plugs into the `video-io` instances, and can intercept and modify the audio stream. Similar to the `delayed-video` component, you can include and attach an `audio-context` instance to a `video-io` instance using one of these attributes or properties: `for`, `input` or `srcObject`. Internally, both `for` and `input` are used to extract a `srcObject` and applied. Only one of `for`, `input`, or `srcObject` must be specified. These attributes and properties are summarized below.

Property	Description
`for`	attribute, optional Set to the id of the source video-io element. The video-io element must be present in DOM at the time this attribute is set.
`input`	property, optional Set to the video-io element DOM object.
`srcObject`	property, optional Set to the MediaStream instance. See localStream or videoStream of video-io.
`remote`	boolean, attribute and property, optional, default is false If attribute is present or if the property is set to true, then this instance is attached to a subscriber (or received or remote) MediaStream instance. Default is to assume a publish (or sent or local) MediaStream instance.

The `audio-context` component is implemented to work with both the publish and subscribe `video-io` instances. However, internally, the implementation differs due to some unresolved issues in the browser at this time. Thus, you must explicitly specify if the component is being applied to publish or

subscribe mode.

The following example shows how to use the component. It uses the `for` attribute to attach the component to the source.

```
<video-io id="video" publish="true"></video-io>
<audio-context for="video">
    <delay value="4"></delay>
    <gain value="0.8"></gain>
</audio-context>
```

The example shows two audio processing nodes applied to the published audio track — the delay and gain nodes — in that order. The delay node causes a delay in the audio path by the supplied number of seconds, and the gain causes the volume change on a scale of 0 to 1. Developers familiar with the Web Audio API or `AudioContext` can see how these map to the built-in APIs.

Here is another example that does the same things, but uses the `input` property of the component.

```
<video-io ... ></video-io>
<audio-context ...>...</audio-context>
<script type="text/javascript">
    const video = document.querySelector("video-io");
    const context = document.querySelector("audio-context");
    context.input = video;
</script>
```

The following example shows how to use the `srcObject` property directly if you do not use or want to use the `video-io` component, as long as you have a `MediaStream` object.

```
const stream = await navigator.mediaDevices.getUserMedia({audio: true});
context.srcObject = stream;
```

The following example shows the gain node applied to the subscribed track. Note the `remote`

attribute on the component instance.

```
<video-io id="receive" subscribe="true"></video-io>
<audio-context for="receive" remote="true">
    <gain value="0.5"></gain>
</audio-context>
```

The component implementation is actually pretty generic, and can include any type of audio processing node supported by `AudioContext`. The popular `DelayNode`, `GainNode` and `BiquadFilterNode` constructs are explicitly allowed via their named elements, `delay`, `gain` and `biquad-filter`, respectively. However, these or any other node instance can be included using the generic `script` element described below. Moreover, these explicitly allowed elements may also be included using the `input` element with the specified name.

Consider the following example, with four audio nodes in the component.

```
<audio-context ...>
    <delay value="2"></delay>
    <biquad-filter value="lowshelf" frequency="1000" gain="10"></biquad-filter>
    <input type="range" name="gain" min="0" max="1" step="0.02" value="0.8"
        onchange="event.currentTarget.setAttribute('value',
event.currentTarget.value);"/>
    <script type="text/plain">
        let node = context.createGain();
        node.gain.value = 1;
        return node;
    </script>
</audio-context>
```

The `gain`, `delay` and `biquad-filter` elements use the `value` attribute to set their primary values, which are the gain value between 0 and 1, delay value in seconds, and the filter type. The `delay` element also allows a `max` attribute for the maximum delay in seconds, and unlike the `DelayNode` API, the attribute defaults to 60 seconds. The `biquad-filter` element allows several other attributes

including `frequency`, `detune`, `Q` and `gain`, similar to the `BiquadFilter` API.

Using a headset is recommended for trying out the following example to avoid audio loop. It uses the above example snippet, at the publisher side, to play sound on the subscriber side. The camera is turned off for this audio-only example.

The example above shows four audio nodes: `delay` for 2 seconds, `biquad-filter` as bass booster, `input` for gain control via user input, and `script` for gain control via script. The last one particularly allows generic creation and application on any audio node.

The `input` element contained in the component is displayed as a regular HTML element, with the difference that its `name` attribute defines the audio node type and its `value` attribute defines the primary value of that node. To allow user control of the value, the change must be propagated to the attribute, as shown in the example with the `onchange` event handler. The primary value of the gain and the delay nodes is trivial, and that of the biquad-filter node is the filter `type` such as `lowshelf` or `lowpass`. For more information please refer to those built-in APIs.

The `script` element must have the `type` attribute set to `text/plain`. The body of the element must be written in JavaScript assuming that it will be called from a function, similar to the `video-mix` element's `script` child. Here, the function body must return an instance of the newly created audio node object. The above example shows a bypass audio node with gain of 1 for demonstration. In practice, this can be any other audio node such as a convolver or wave shaper, whose attributes may be controlled independently in the app. The function body gets a local parameter named `context` representing the underlying `AudioContext` instance.

Since enabling `AudioContext` requires user interaction in modern browsers, the above example includes another button to start, which when clicked triggers the user interaction necessary to enable the internal `audio-context` implementation.

The next example uses the `audio-context` component attached to a publishing `video-io` component, and uses `AnalyserNode` to draw the audio waveform and frequency.

Stop

Later in this document, we will also cover How to enable spatial or 3D audio?.

27. How to convert between speech and text?

Converting between speech and text is often needed for accessibility, captioning or just for saving bandwidth. Modern browsers natively support speech recognition and speech synthesis. However, there are certain restrictions, such as speech recognition can only be applied to local microphone captured sound. This makes certain features such as closed caption on received stream not trivial. In this section, we will describe how to achieve various such use cases in an application.

27.1 The speech-text component

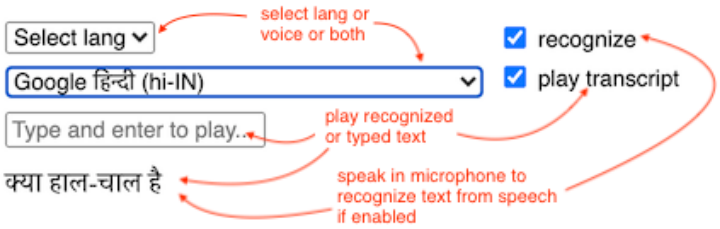
The `speech-text` component allows speech recognition and speech synthesis using builtin JavaScript APIs as follows. To enable continuous speech recognition, set the `recognize` attribute on the instance.

```
<speech-text id="speech" recognize></speech-text>
```

This will cause the `recognize` event dispatched often from the component instance whenever a final or interim transcript is recognized from the user's microphone.

```
let speech = document.querySelector("#speech");
speech.addEventListener("recognize", event => {
    // either event.transcript (final) or event.interim (interim) string is
valid.
});
```

Try the following example to perform both speech recognition and speech synthesis on the recognized final transcript.



The above example allows you to experiment with the `lang` and `voice` properties, described below. It also allows you speak out some custom text, or selectively disable or enable recognition and synthesis.

Property	Description
`lang`	A valid language code such as en-US. If not supplied, then uses platform specific `navigator.language` or defaults to en-US. If explicitly set, then it is used for both speech recognition and synthesis. If voice property is set, then the lang is implicitly derived from the voice value, but can be overwritten by explicitly setting this property.
`voices`	(readonly) A list of items, each containing name, lang or local attribute. The name and lang are strings, and local is boolean indicating local or server driven synthesis. The name of an item may be used as a value of the `voice` property.
`voice`	A valid voice name to be used for speech synthesis. It must be the name attribute of an item of the `voices` list.
`exclusive`	(boolean) If set, then speech recognition is paused when speech synthesis is in progress, to avoid feedback from spoken sound of speaker back to speech recognition from microphone. This is recommended when not using the headset and when both recognition and synthesis are active.

These properties are also reflected as attributes. Thus, the following two are equivalent.

```
speech.setAttribute("lang", "hi-IN"); // attribute
speech.lang = "hi-IN";                // property
```

Usually only one of `lang` or `voice` needs to be set, and the other is automatically derived.

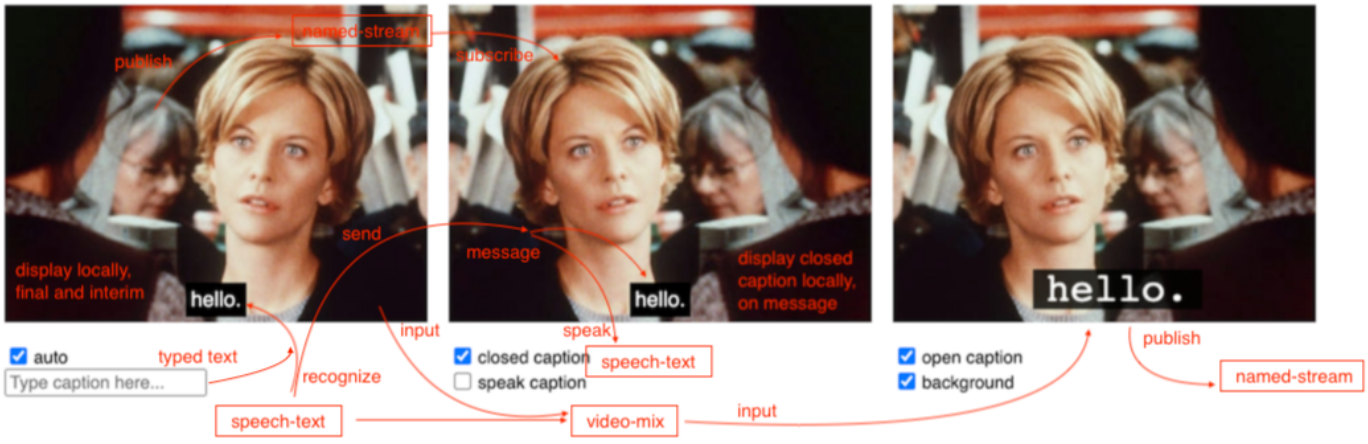
Function	Description
`speak`	speech.speak("Hello there, how are you?"); Convert the supplied text to speech and play out the voice.
`cancel`	speech.cancel(); Cancel any ongoing text to speech and stop voice play out.
`text`	var text = await speech.text("yes | no | maybe"); Recognize speech to text using the supplied optional grammar. It returns a promise that resolves to the recognized text. The supplied grammar string should either be in `#JSGF` format, or contain list of text phrases such as `red | green | blue | black`.

More examples of this component are described next.

27.2 Closed caption

Closed caption can be implemented using the `speech-text` component. The data channel described earlier can be used to send the recognized text from publisher to subscriber and displayed as closed caption on subscriber as well.

Try the following example to see the closed and open captions in action.



The example above allows you to experiment with various options such as to enable or disable automatic speech recognition for caption, to speak out closed caption, or to hide background in open caption.

The example above uses a `speech-text` to detect text from speech, and when detected, uses the `send` function on the publisher `video-io` to send the caption text.

```
speech.addEventListener("recognize", event => {
    if (event.transcript && !event.interim)
        video1.send(JSON.stringify({type: "caption", caption:
event.transcript}));
});
```

In this example, for closed caption, the publisher side displays both the final and interim transcript, whereas the send is done to the subscriber only for the final transcript, which only displays that.

27.3 Open caption

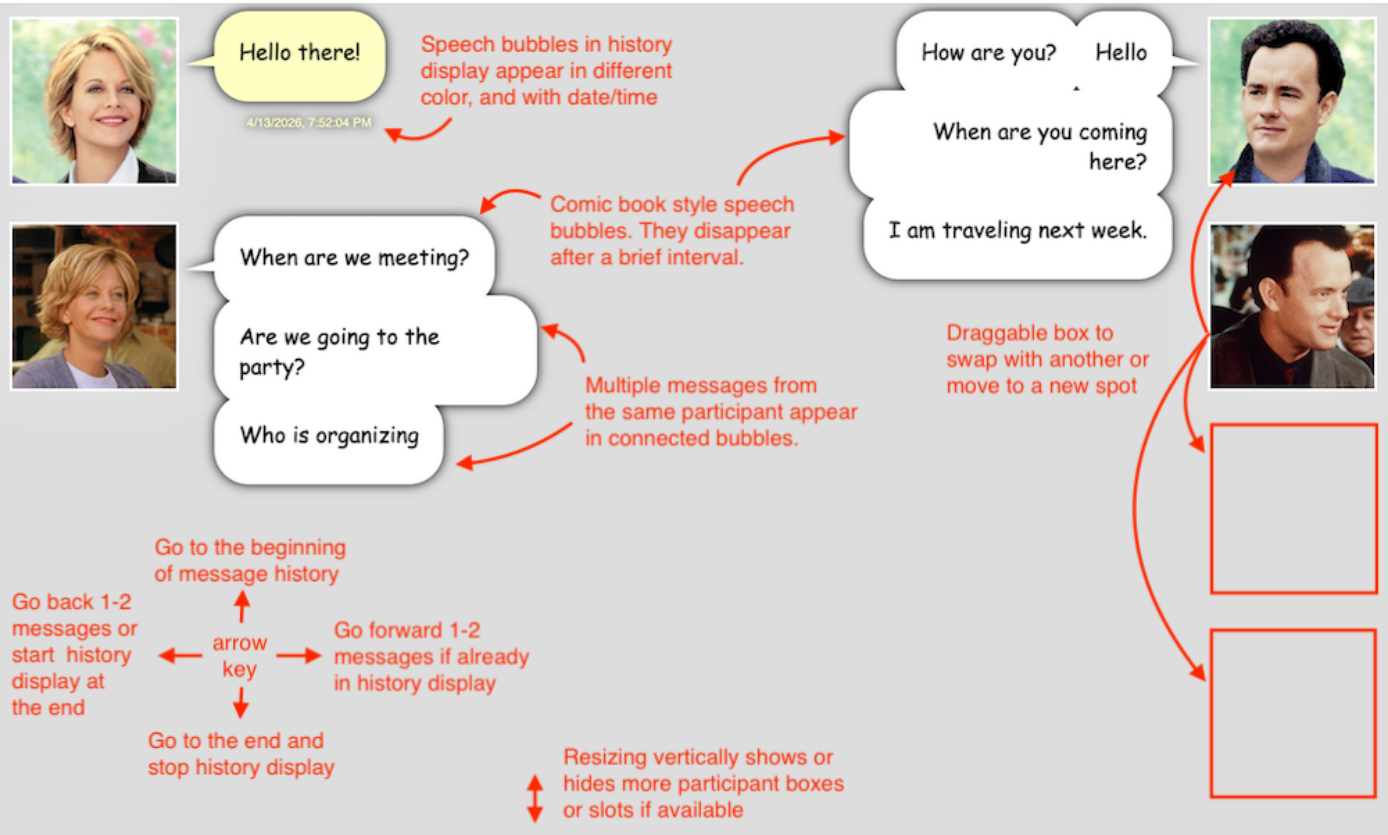
Open caption differs from closed caption in that the caption text is part of the video stream in open caption, whereas the user can control when and how to display the caption text in closed caption. These differ from subtitles, which often refers to caption text with translated language, e.g., sound is in one language and caption text is in another.

Open caption is implemented using the `video-mix` component in the above example. In particular, it draws the text on the canvas of the component, which is then used as input source of another publisher. The canvas context's `measureText` function is used to detect long line captions, and split them across multiple lines. In the above example, the open caption is set for both final and interim transcript of speech recognition. The checkbox allows enabling or disabling the closed caption on the publisher side. However, that is not possible on the subscriber side, since caption text will already be part of the received video stream, instead of out-of-band, via data channel.

27.4 Speech bubble

Chat or comic book style speech bubbles can easily be implemented and attached to the speech recognition flow. The `speech-bubble` container component implements a multi-party conference interface where each participant appears in a tiny box, and speech bubbles are used to show the spoken text by the participants. If text chat is enabled, then it can reuse the speech bubbles too.

Try the following example with a pre-configured conversation flow to get started to see that in action.



In the above example, you can move the participant boxes to a different position on left or right side. Click-and-hold on the box to enable move. When you click on a participant box, it allows you to type a message sent from that participant in the layout. Spoken voice is also captured and recognized using the `speech-text` component, and sent as message from a random participant. This is for demonstration purpose only. Resizing the display verically shows or hides participant boxes or slots at the bottom if available or applicable.

Furthermore, the message history is stored, and can be retrieved, using the arrow keys. The up arrow goes all the way to the beginning of the conversation. The left and right arrows go one message at a time backwards or forwards. And the down arrow stops the history display, and goes to the end of the conversation so far, for next live message display. The message bubble from history display appears in a different color, and also shows the date/time of when the message was added to the component. You cannot click on the box to send a live message in the history display.

The container component is used similar to other containers such as `flex-box` as shown below. It is recommended to use `div` elements as children, and wrap other elements such as `img` or `video` or `video-io` inside `div` if needed.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/speech-bubble.js"></script>
...
<speech-bubble>
    <div>..first participant...</div>
    <div>..second participant...</div>
    <div>..third participant...</div>
</speech-bubble>
```

A couple of customization is allowed by the component, e.g., the `shape` attribute can take value of "rounded" or "circle", to show the participant boxes in that shape.

```
<speech-bubble shape="rounded">...</speech-bubble>
```

The `textsmall` property with default 0 can take a number, for length of the text, such that a smaller text is displayed in ellipse shaped bubble instead of rectangular. The `textclip` property with default 100 can take a number, for length of the text, such that a larger text is clipped and a ellipsis is shown.

```
const space = document.querySelector("speech-bubble");
space.textsmall = 50;
space.textclip = 200;
```

Finally, CSS style can directly be used on the container as well as the bubbles as follows.

```
speech-bubble {
    background: black;
}
speech-bubble::part(bubble) {
    border: solid 2px black;
}
```

The underlying code of the example application shows the usage of certain functions such as `says` and `input`. These are illustrated below.

```
const space = document.querySelector("speech-bubble");
const second = document.querySelector("speech-bubble > :nth-child(2)");
space.says(second, "How are you?"); // live message
```

```
const first = document.querySelector("speech-bubble > :nth-child(1)");
const ts = new Date("4/13/2026 6:30:05 PM").getTime();
space.says(first, "Hello there!", ts); // history message with timestamp
```

```
space.input(second, "Hello"); // unsent typed message in input box
```

As mentioned before, the `speech-text` component can be used to feed a text message from a participant displayed in the container.

```
<speech-text recognize></speech-text>
```

```
const speech = document.querySelector("speech-text");
speech.addEventListener("recognize", event => {
    if (event.interim) {
        space.input(first, event.interim); // unsent yet
    } else if (event.transcript) {
        space.input(first, ""); // remove input box
        space.says(first, event.transcript); // sent message
    }
});
```

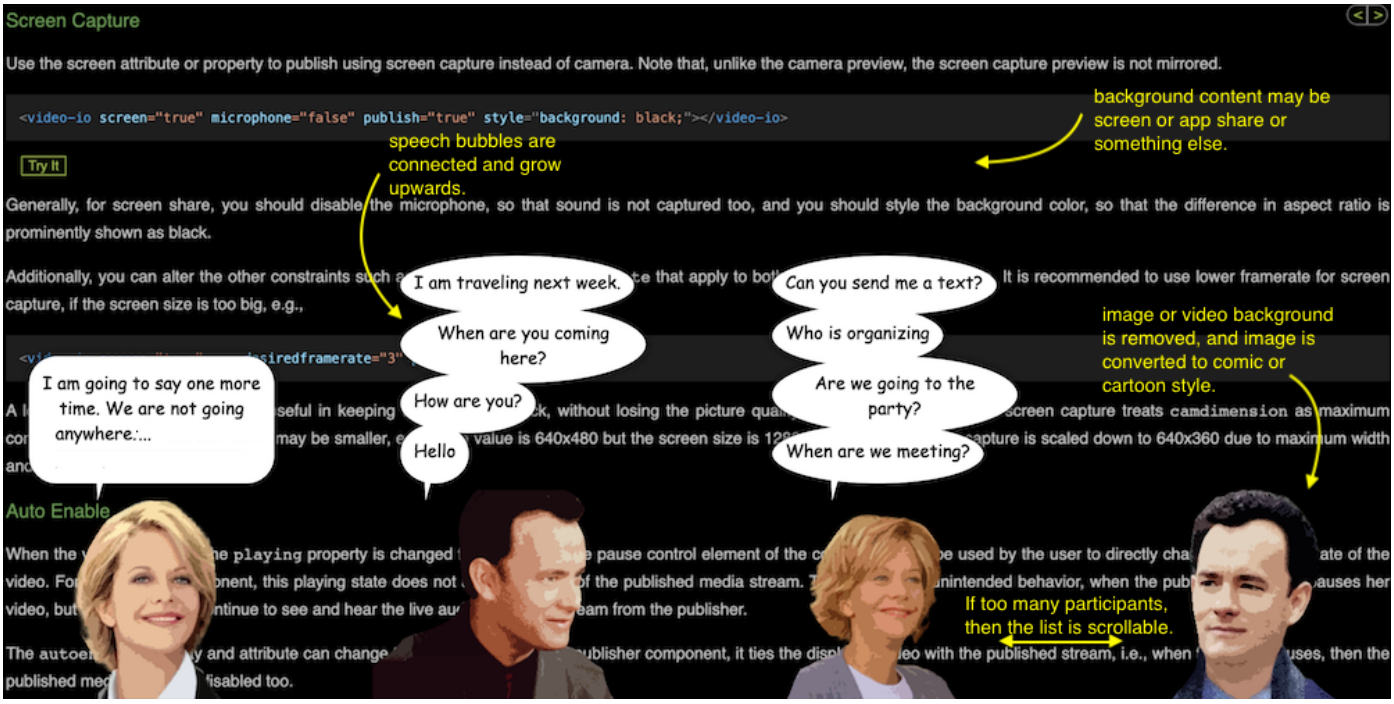
Note that the container component is just for display, and does not actually send the text message. You can use the other mechanisms such as data channel or shared data described earlier to send and receive text chat in an application.

The image processing techniques such as face tracking described earlier using the `video-mix` component can potentially be used to zoom to the participant face to be displayed in the box, captured from live camera, for a video conferencing experience.

27.5 Comic book

Another component `comic-space` is a container that implements comic book style speech bubbles where participants or characters are aligned at the bottom of the page, and some content such as shared screen video can be in the background. It also removes background from participant image using the body-pix segmentation model mentioned earlier, and converts the images to comic book style characters by re-adjusting the colors. In the future, this may be changed using AI to use, say, Gibli style pictures.

Try the following example with pre-configured conversation flow to get started to see that in action.



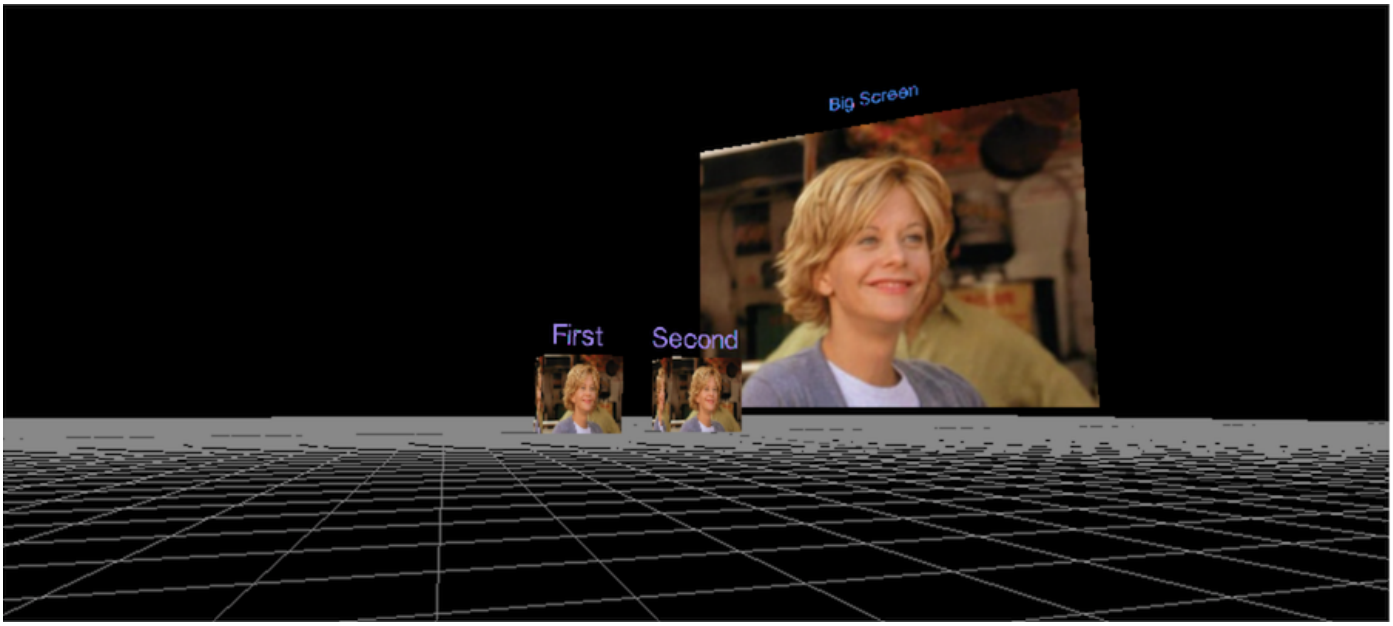
Many of the other functions in this component is similar to that in the `speech-bubble` component. The properties of `textsmall` and `textclip`, and the style for the bubble part are also applicable to this component. Some differences are as follows. The participants are represented using background removed image or video instead of in a circle. The speech bubbles grow upwards instead of downwards. The participant images are not draggable. And if there are too many participants that can fit horizontally, then the list of participants becomes scrollable. The background removal and comicification is done in the app itself instead of the component, and the component just displays the supplied images representing the participants as an overlay.

28. How to display in 3D?

We provide two web components for displaying multiple `video-io` or other components in a 3-dimensional (3D) space. These are primitive implementations, and may require further work in a real 3D video conferencing application. The components are generic and can be used for display of other web elements besides the `video-io` components.

28.1 Virtual space using three.js

The following example shows a sample 3D space using the popular three.js (https://threejs.org) Javascript library. It uses `video-io` elements, but can be changed to `video` or custom `img` elements, as we will see later.



Note that the example uses threejs' `OrbitControls` to navigate the camera around the scene. You can,

- move while [holding mouse left / single finger on trackpad] to rotate camera around target point
- move [mouse wheel / two fingers on trackpad] to move closer/farther to the target point
- hold [cmd / windows key] + [mouse left / single finger on trackpad] to move camera to another target point

The `threejs-space` web component is a wrapper around the three.js library to facilitate the above behavior. Besides the default navigation shown above, the component also allows clicking on the displayed items, and when clicked, attempts to put that item as target focus of the camera.

By default a grid is displayed, along with some ambient lighting. Those can be altered by changing the component implementation.

To use the component in your implementation, first include the `three.js` and `OrbitControls.js` from that project, and then our `threejs-space.js`, as follows.

```
<script type="text/javascript" src="https://rawcdn.githack.com/mrdoob/three.js
/r132/build/three.min.js"></script>
<script type="text/javascript" src="https://rawcdn.githack.com/mrdoob/three.js
/r132/examples/js/controls/OrbitControls.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/threejs-
space.js"></script>
```

After that, use the `threejs-space` element as the container for other elements of type `video-io`, `video` or `img`. An example is shown below. The path to the font file should be correct, e.g., https://rawcdn.githack.com/mrdoob/three.js/r132/examples/fonts/helvetiker_regular.typeface.json

```
<threejs-space font="https://... typeface.json"
    camera3d="x:-100,y:10,z:300" target3d="x:0,y:50,z:0" >
    <video-io id="video1" for="stream" subscribe="true"
        displayname="Big Screen"
        position3d="shape:rectangle,w:240,h:180,x:150,y:100,z:-100,ry:-45deg"
></video-io>
    <video-io id="video2" for="stream" autoenable="true" microphone="false"
publish="true"
        displayname="First"
        position3d="shape:cube,side:30,x:-50,y:15,z:0" ></video-io>
    <video-io id="video3" for="stream" subscribe="true"
        displayname="Second"
        position3d="shape:cube,side:30,x:0,y:15,z:0" ></video-io>
</threejs-space>
```

Many of the attribute values shown above are optional, and the implementation picks the right defaults as needed. The attributes are in a set of name-value pairs, and set as comma separated name:value format as shown above. The name-value pairs can also be represented using JSON object, and set using property via script as shown below. When setting via script, numeric values vs. string are used as applicable.

```
document.querySelector("threejs-space").target3d = {x: 100, y: 50, z: 0};
document.querySelector("#video1").position3d = {x: 300, y: 200, shape:
"rectangle"};
```

Setting an attribute/property applies the change, instead of full override of the name-value pairs. For example, if the initial attribute value for `camera3d` included x, y, z; but the property JSON object included only y, then other x and z will remain unchanged.

The attributes/properties are described below. For the container element:

- **font** - the path of the font file compatible with three.js. An example font file is included in our demonstrations. This is needed only when the `displayname` attribute of any of the container item

is set. The font is needed for rendering the display name text. There is no default for `font`, and if not supplied, then display names are not shown.

- **camera3d** - this defines the properties of the camera, including its position. The property names are x, y, z for position, and `fov`, `aspect`, `near` and `far` for the underlying `PerspectiveCamera` instance of three.js. The default for `camera3d` is `{x:0,y:10,z:300, fov:45,aspect:...,near:1,far:10000}`, where the default for the `aspect` property is derived from the containers currently displayed aspect ratio.
- **target3d** - this defines the properties of the target which is in focus by the camera. The property names are x, y, z for position, and `min` and `max` for `minDistance` and `maxDistance`, respectively, of the underlying `OrbitControls` instance of three.js. The default for `target3d` is `{x:0,y:0,z:0, min:50,max:500}`.

For the container items, the allowed attributes are:

- **hidden** - if this attribute is present, then the item is not included in the display.
- **displayname** - if this attribute is present and has some text, that is displayed on top of the item in the space. The `font` attribute of the container must be valid too.
- **position3d** - this defines the shape, size, position and rotation of the item. The property names are x, y, z for position, rx, ry, rz for rotation, and `shape` for the display shape. Currently, shape can be one of "cube" or "rectangle" (default). For cube, additionally, the `side` property can specify the size of the side, default to 30. For rectangle, the w and h properties can specify the width and height, and default to 40 and 30, respectively.

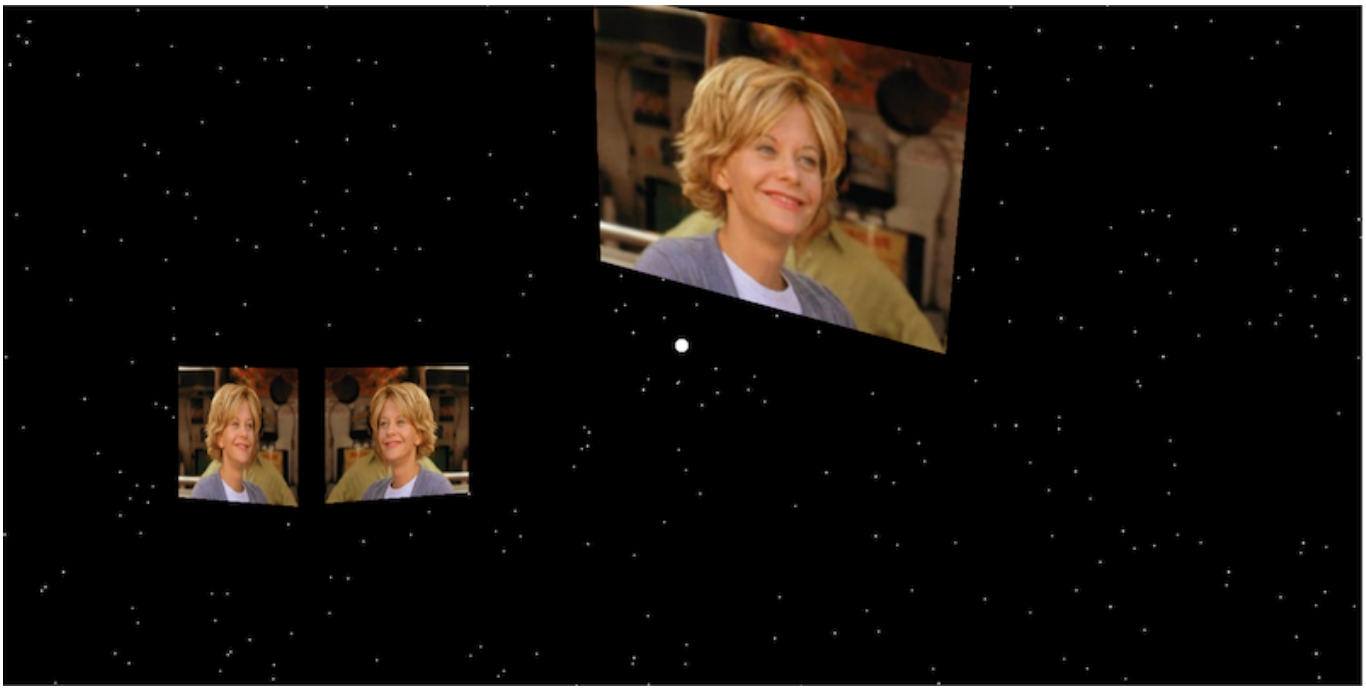
28.2 Virtual space using CSS transform

One issue with the previous three.js based approach is that it uses `canvas` internally, and WebGL for rendering everything on that canvas. This makes it hard to apply CSS or other DOM manipulation to the 3D objects directly. Thus, the rendered cube or rectangle or other shapes are rigid, and cannot be easily styled or changed by the application, unless the component creates an appropriate mapping from those styles to the rendered objects on the canvas.

Fortunately, 3D is natively supported in CSS, using perspective and transform attributes. Unlike a

true computer graphics or vision library like three.js, this approach lacks the implicit lighting and shadow support, making the visuals less appealing. However, it is easier to deal with and has better integration with existing web development tools and skills.

Here, we describe an alternate web component that facilitates rendering of `video-io` instances in a 3D space using CSS and DOM manipulation. Try the following example.



It shows multiple elements included in a 3D space. Double-clicking on an element makes it focussed in the view by moving the camera infront of that element. A small anchor point appears at the center to allow resetting the camera to the original position. Several white dots on black background appear mimicing stars in the space. The above example uses the `virtual-space` web component described next.

The `virtual-space` web component can be included and used in your application as follows.

```
<script src="https://rtcbricks.kundansingh.com/v1/virtual-space.js"></script>
<virtual-space stars bgstars>
    <img src="..."
        style="width: 1000px; height: 700px;"
        position3d="x:200,y:-400,z:0,rx:-30,ry:-30" />
    ...
</virtual-space>
```

The component supports these attributes:

- **stars** - if present then small white dots appear in the 3D space mimicking stars. When the camera position changes, these stars appear to move too.
- **bgstars** - if present then small white dots appear in the background 2D space as if they are very far away. When the camera position changes, these background stars do not move.

The container items can be any valid HTML element including `img`, `video`, `video-io` or even `span` or `div`. The size of the item can be specified using standard CSS or other means. The parent container component interprets these attributes on the item:

- **hidden** - if present, then the item is not shown in the 3D space.
- **selected** - if present, then the camera is moved to bring this item in front.
- **position3d** - specifies the position and rotation of the item in the 3D space.

The `position3d` attribute directly maps to the CSS transform attribute for positioning the element. It just provides a convenient way to easily change the position of the item. The item is comma separated list of `name:value`, where the property name is one of x, y, z for position in `px` unit, rx, ry, rz for rotation in degrees, and s for scaling if needed.

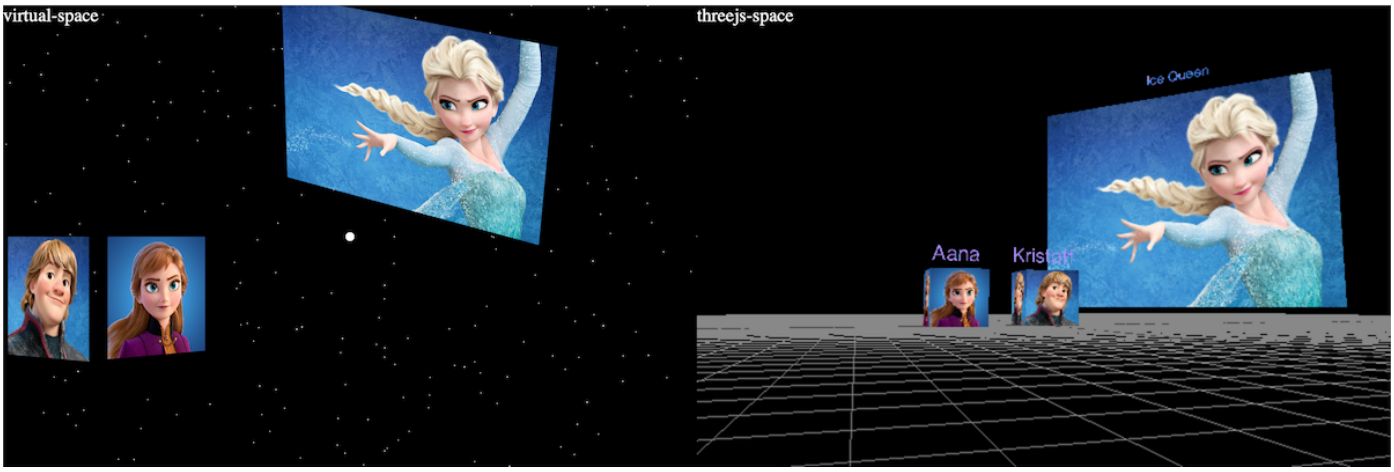
To bring the camera to the front of the item on some event, just set the selected property, as shown below.

```
<img ... ondblclick="event.currentTarget.setAttribute('selected', '');" />
```

```
document.querySelector("img").ondblclick = event => {
    event.currentTarget.setAttribute('selected', '');
}
```

A number of controlling behavior of the component is currently fixed in the implementation, and may be exposed as configurable properties or attributes in the future.

Try the following example to compare the two components, `virtual-space` on left, and `threejs-space` on right.



Rendering video elements for multi-party conferencing using the three.js or CSS based components described previously is not trivial. In particular, it requires you to visualize the 3D layout, and setup the positions and rotations of the video elements, and camera angles and target focus precisely for a good visual effect.

Here we show how to define a generic behavior for N-elements, such as in a carousel. This can be used to display the multi-party video elements in a circle, and can scale to different number of participants. The element selection can be done using events such as click or talker indictaion, to rotate the carousel, and bring the selected element to the front of the camera. The example below shows five boxes in a eight-slot carousel display. Double clicking on a box brings it to front.

The code snippet which calculates the `position3d` attribute of the boxes is shown below.

```
let count = 5, minimum = 8;   // actual and slots count
let w = 320, h = 180, m = 10; // box size and margin
const radius = Math.round(((w + 2*m)/2)/Math.tan(Math.PI/Math.max(minimum,
count)));

for (let i=0; i<count; ++i) {
    // to keep first item in center.
    const j = count >= minimum || i < count / 2 ? i : (minimum - count + i);
    const theta = Math.round((j / Math.max(minimum, count)) * 360);
    const p = {ry: theta, z: radius}; // transform
    ...
    const div = document.createElement("div");
    div.style.width = w + 'px'; div.style.height = h + 'px';
    div.setAttribute("position3d", `ry:${p.ry},z:${p.z}`);
    document.querySelector("virtual-space").appendChild(div);
    ...
}
```

To visualize the carousel, you need to visualize the transform for each box. First, we calculate the angle of the box. Then rotate the box with that angle on Y-axis, and move the box away from center on Z-axis. How much to move away depends on the radius of the carousel, which depends on the number of slots and width of each slot. Note that the order of transform is crucial here to see the desired effect, because the rotation also causes the axes to rotate for future moves and rotations.

The `virtual-space` component also dispatches three events — `added`, `removed` and `transform` — when a container item is added or removed or its position is altered by applying the CSS 3D transform. The `transform` event is also dispatched when the viewer or camera position is altered in the component, e.g., via navigation described earlier. The `element` property in the event object contains the DOM element such as the container item to which the event applies.

For the `transform` event, the `subtype` and `transform` properties are also present. The `subtype` is either `observer` or `object`, to indicate that the element is the viewer or camera or the container item. The `transform` property is just the string containing the applied CSS transform, which can also be obtained via the CSS transform style attribute. These events are used by spatial audio as discussed

later, and can be used by your application for other purposes.

29. How to enable spatial or 3D audio?

Previously we showed how to use the Web Audio API with `video-io` using the `audio-context` component. Here, we further expand the use of Web Audio API for spatial or 3D audio. Unlike attaching to the `video-io` instance, the spatial audio contructs attach to the container instances such as `flex-box` or `virtual-space`. The basic idea is to make the sound from a container item appear to come from a position and in a direction, and have the listener present in the space to listen to the sounds from different container items differently.

We have implemented two such spatial audio components — `spatial-audio` and `audio-space` — that attach to `flex-box` and `virtual-space`, respectively, to cater to 2D and 3D positions of the container items, respectively. However, these new components are generic and can potentially be attached to other similarly behaving containers of video elements. In particular, `spatial-audio` can potentially be used with the `comic-space` component too.

29.1 spatial-audio

This component caters to the spatial sound requirements of 2D layouts such as `flex-box`. The sound source model does not use a panner cone, but assumes equal sound in all direction, attenuated by distance. The 2D position of the container item inside the container component determines the position of the sound source from that container item. The listener is assumed to be at the center of the rectangular box that covers all the container items. In particular, it is not at the center of the container, but at the center of the imaginary rectangle that covers all the container items, especially when there are empty spaces in the container. At this time, the component does not work with the scrollable view of the `flex-box`, e.g., when the `display` is set to `page`.

To use the component, just create it and assign its `for` attribute or `input` property. The `for` attribute contains the `id` of the associated 2D container such as `flex-box` as shown below.

```
<flex-box id="flexbox" ...>
    <video .../> <video .../> <video .../>
</flex-box>
<spatial-audio for="flexbox"></spatial-audio>
```

The container item must be present in the DOM, when the `for` attribute is assigned. Alternatively, the `input` attribute can be set to the container instance as shown below.

```
<flex-box> ... </flex-box>
<spatial-audio></spatial-audio>
<script type="text/javascript">
let flexbox = document.querySelector("flex-box"),
    spatial = document.querySelector("spatial-audio");
spatial.input = flexbox;
</script>
```

The `flex-box` container items must include `width` and `height` for their layout, and may be of a sound producing elements such as `video` or `video-io`, or some non-sound producing element. Internally, the `spatial-audio` component ignores the non-sound producing elements in the container.

Once attached, the component listens for any `change` event dispatched from the container, and readjusts the spatial sound positions of various sound sources on such events, and on the initial attachment. The `flex-box` container dispatches such an event anytime there is any change in the position or any container item or any change in the size of the container itself.

Try the following example with a headset to see the spatial audio combined with `flex-box`.

The example above has three container items, all `video` elements, playing the same video. As you mute and unmute some or all of the elements, you can hear the sound coming from different directions.

The spatial sound position of the elements are assumed to be all the way from left to all the way to

right, and all the way from top to all the way bottom. Thus, if there are only one row of elements, as in the above example, they will all be centered vertically, and the three elements are aligned at -0.5, 0 and +0.5 positions, in a -0.5 to 0.5 space horizontally. If there are five such items, then they will likely get positioned at -0.5, -0.25, 0, +0.25 and +0.5. Other layout positions are similarly calculated by mapping the center of the element to a 2D space such that the elements cover the whole space both vertically and horizontally. Thus, this is just one way of mapping the 2D positions to 2D sound positions.

29.2 audio-space

For a real 3D positional audio, the actual position of the container item is assigned to the sound source associated with that item. This only makes good sense when the layout is also in 3D, such as with `virtual-space` or `threejs-space`. The `audio-space` component does this and is described here.

Using the component is similar to the previous, using either the `for` attribute or the `input` property. The following example shows the `for` attribute.

```
<virtual-space id="space" ...>
    ...
</virtual-space>
<audio-space for="space"></audio-space>
```

Try the following example with a headset to see the spatial audio combined with `virtual-space`. Click on a video to toggle play and pause. Then use the 3D navigation described earlier to rotate or move the listener in the space. As mentioned earlier, double clicking on the video brings the listener to focus.

Try the following example as another layout of the same set of video elements.

Unlike the previous component which keeps the listener position and orientation fixed, but changes the sound source positions, this one can modify both the listener position and orientation as you

navigate in the 3D space, and the source position and orientation. By default, the sound is assumed to be front facing from the sound source, and the listener position and orientation is same as interpreted in the 3D view of the container.

When attached, the `audio-space` component instance listens for the three events from the container instance — `added`, `removed` and `transform` — and alters the position and orientation of the source of the container item and/or the listener.

Unlike the previous 2D spatial audio component, this one uses a panner cone for the sound source. The default values for the `PannerNode` is shown below. As mentioned before, the position and orientation of the sound source is same as their position and front-facing vector in the 3D layout of `virtual-space`.

```
{
    coneInnerAngle: 30, coneOuterAngle: 90, coneOuterGain: 0.1,
    panningModel: "equalpower", distanceModel: "linear",
    maxDistance: 10000, refDistance: 1, rollOffFactor: 1, ...
}
```

The default values for the specific sound source can be altered by using the `audio3d` attribute on the container item as shown below. The first `video` element alters the panner attribute, but the second one uses the default.

```
<virtual-space id="space" ...>
    <video ... audio3d="i:90,o:180,g:0,m:40000"></video>
    <video ... ></video>
</virtual-space>
```

The value of `audio3d` attribute is a comma separate name:value pair, where name is a short hand for the panner properties as shown below.

```
{
    i: "coneInnerAngle", o: "coneOuterAngle", g: "coneOuterGain",
    p: "panningModel", d: "distanceModel", m: "maxDistance",
    r: "refDistance", f: "rollOffFactor",
}
```

Thus the example above changes for the first video: `coneInnerAngle` from default 30 to new 90, `coneOuterAngle` from default 90 to new 180, `coneOuterGain` from default 0.1 to new 0 (no sound if outside the outer angle), `maxDistance` from default 10000 to new 40000 (in pixels). The net effect of these is that the first video can be listened much farther, and at a larger angle, but cannot be listened if not in front facing.

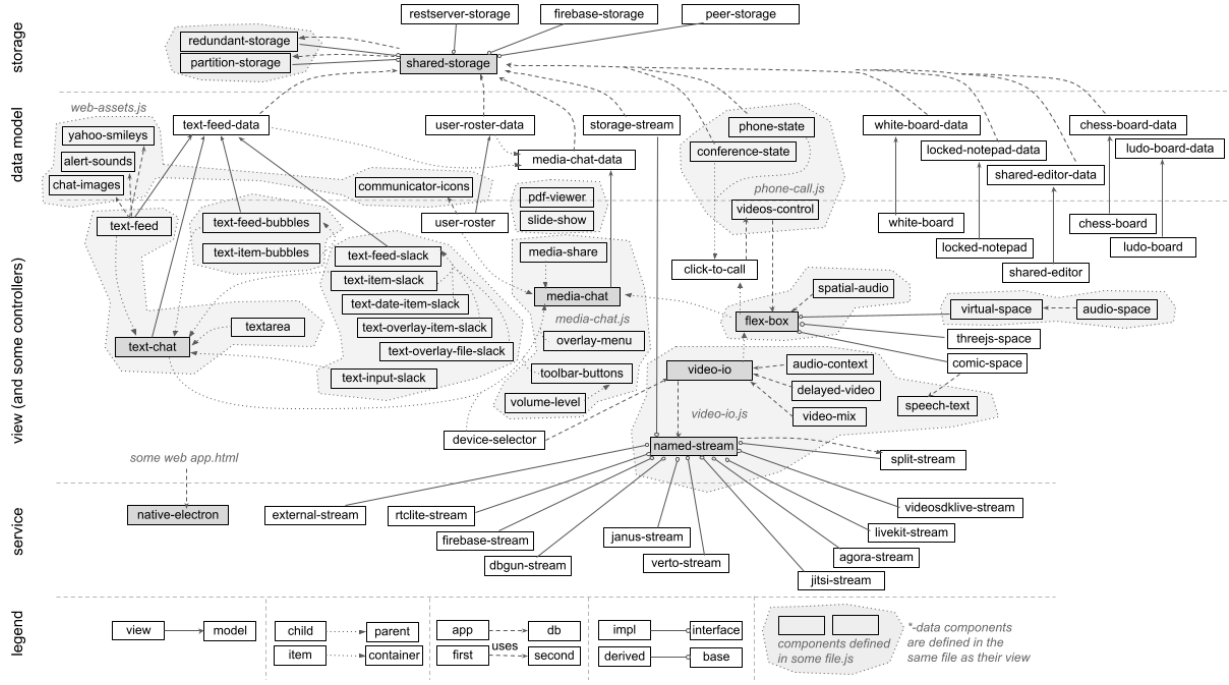
Both, 3D layout and 3D sound, are very complex topics, and these components attempt to provide a bridge to use them with other useful components of `video-io` or `flex-box` we created. However, the new components `virtual-space`, `spatial-audio` and `audio-space` are not comprehensive to cover all types of application scenarios. Some generic hooks are available nevertheless, to allow using some complex scenarios. If the existing implementation is not enough, you can always create a derived component that extends our initial implementation.

30. How to create components using shared storage?

We have created several web components to support multimedia collaboration use cases such as text chat, user roster, white board, notepad, and multimedia conference. These components use the shared storage abstraction described in How to use shared data? The basic idea is to provide the data model for the component via a `shared-storage` instance, at a specific data path, e.g., "path/to/my/contacts". The separate instances of the web components running on separate machines can then interact with the data in real-time and provide the needed functionality to the user.

For each of the collaboration use case component, we also created a data model component that attaches to a `shared-storage`. This allows separating the view and functionality of the collaboration use case, from its data, and more importantly, allows replacing with a different data model that does not use our shared storage based architecture.

The following diagram shows how various web components including the collaboration components are related, use the shared storage, and interact with other components.



Besides the `list` and `object` data abstractions discussed earlier, there are several other supporting

implementations in `shared-storage.js` as shown below. These are used in implementing the various collaboration use cases described in subsequent sections using the model-view design pattern. In particular, the main collaboration use case is implemented in the view component such as `text-feed` or `shared-editor`, and `shared-storage` based data model is implemented in a separate component such as `text-feed-data` or `shared-editor-data`. The programming interface of the data model component is designed to be generic enough, such that it can be replaced with another component implementation using the same interface, but a different backend service, instead of the storage based one, such as my `restserver` project.

Class	Description
`ProxyDataElement`	Base-class for view component. The constructor allows creating shadow DOM and properties based on the supplied metadata object and HTML+CSS text. The `data` and `for-data` properties are included in the base class implementation, and allow setting the data model object by reference or by DOM id, respectively. A sub-class instance can set the `data_handler` property in the constructor to receive and process events from the attached data model. Additonally, a `ready` read-only property is available to indicate when the data model is set and is ready to be used. If additional properties are specified using the metadata in the constructor, those are created, and convenient methods are used to read or write them. For example, if property `name` is defined, then `_on_name(...)` is invoked for that property access.
`ProxyStorageElement`	Base-class for storage based data model component. The constructor allows creating optional shadow DOM and properties based on the supplied metadata object and HTML+CSS text. The sub-class can use convenient methods such as `wraplist` and `wrapobject` to create wrapper list and object even before the storage is ready or connected. The `storage` and `for-storage` properties are included in the base class implementation, and allow

setting the storage object by reference or by DOM id, respectively. Additonally, a `ready` read-only property is available to indicate when the data model is set and is ready to be used. If additional properties are specified using the metadata in the constructor, those are created, and convenient methods are used to read or write them. For example, if property `name` is defined, then `_on_name(...)` is invoked for that property access.

The `metadata` object used in the sub-class constructor provides a high level programmatic description of the component. This is used for automatic document generation as well as for creating property accessors in the constructor. An example is shown below.

```
const metadata = {
    name: "my-view",
    description: "An example view to show in different ways.",
    properties: Object.assign({
        display: {
            type: "string", default: "inline", ...
            desc: "Controls the overall display.",
        },
        ...
    }, ProxyDataElement.metadata.properties),
    methods: {
        adjust: {
            desc: "Adjust the display now or on delay",
            example: 'view.adjust(200)',
            args: [{
                name: "delay", type: "number",
                desc: "Delay in milliseconds.",
            },{
                name: "callback", type: "function", required: false,
                desc: "Optional callback when completed.",
            }],
        },
        ...
    },
    events: {
        move: {
            desc: "Dispatched when view is moving.",
            example: '{type: "move", data: ...}',
            related: "method:adjust",
            attrs: {
                data: {
                    desc: "Additional data about the move",
                    type: "object",
                },
                ...
            },
        },
        ...
```

```
    },
    styles: {
        "--bgcolor": {
            desc: "Background color",
            default: "lightgreen",
        },
        "--color": {
            desc: "Text color",
        },
        ...
    },
}
```

There are several attributes such as `default`, `desc`, `related` in various objects that define the behavior of the property, method, event or style. For example, the property object can additionally include `instanceof:[...]`, `readOnly:true`, or `automatic:false` properties to further refine the property behavior.

An example code structure for a fake view component is shown below.

```
const metadata1 = {...};
const template1 = document.createElement("template");
template1.innerHTML = `... CSS + HTML ...`;
class MyViewElement extends ProxyDataElement {
    static get metadata() { return metadata1; }
    static get observedAttributes() {
        return ProxyBaseElement.attributes(metadata1);
    }
    constructor() {
        super(metadata1, template1);
        ...
        this.data_handler = {
            set: (old, value) => { ... },
            ready: e => { ... },
            moving: ({value}) => { ... },
        };
    },
    _on_display(old, value) {
        ...
    }
    adjust(delay, callback) {
        ...
    }
    ...
}
customElements.define("my-view", MyViewElement);
```

An example code structure for a fake data model component is shown below.

```
const metadata2 = {...};
class MyDataElement extends ProxyStorageElement {
    static get metadata() { return metadata2; }
    static get observedAttributes() {
        return ProxyBaseElement.attributes(metadata2);
    }
    constructor() {
        super(metadata1);
        ...
        this._list = this.wraplist('{path}/moves');
        this._object = this.wrapobject('{path}/info');
        this._list.onchange = ({type, value, id}) => {...};
        this._object.onnotify => ({data}) => {...};
        ...
    },
    _connectedCallback() {...}
    _disconnectedCallback() {...}

    _on_moving(old, value) {
        ...
    }
    ...
}
customElements.define("my-data", MyDataElement);
```

The `wraplist` and `wrapobject` methods in the data model instance return a wrapper to the list and object reference. They behave similar to the those as described in How to use shared data?. A wrapper, allows those references to be updated automatically when the parameterized `path` property is set, e.g., when `path` is set to "data/123" then '{path}/info' becomes "data/123/info", and an actual list or object is created for that. The `onchange` and `onnotify` methods on those wrappers can be assigned to handle change or notify events on the underlying data path's list or object. The event is same as described earlier. Those wrappers also have methods such as `add`, `set`, `setattrs`, `remove`, `removeall`, `getall` and `notify`.

31. How to do text chat?

To enable text chat among collaborating users, there are two web components: `text-feed` and `text-chat`, and one data model web component: `text-feed-data`. The `text-feed` component displays real-time text feed of a shared list of messages. The `text-chat` component then uses this, along with a text input area, typing indication and drag-and-drop file sharing features, to provide a full text chat support among collaborating users.

31.1 text-feed

The following example shows how to include the `text-feed` component.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/text-chat.js"></script>
...
<text-feed></text-feed>
```

This component also supports popular text chat features such as smileys or emoticons, and alert sound on new messages. To show smileys or to play sound on new messages, you can set the smileys or sounds property to the corresponding data objects that supply those assets. Alternatively, the `for-smileys` or `for-sounds` attribute can be used to identify the data object elements as follows. These included web assets have example components for sounds and smileys from popular third-party services.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/web-assets.js"></script>
...
<alert-sounds id="sounds" />
<yahoo-smileys id="smileys" />
<text-feed for-smileys="smileys" for-sounds="sounds"></text-feed>
```

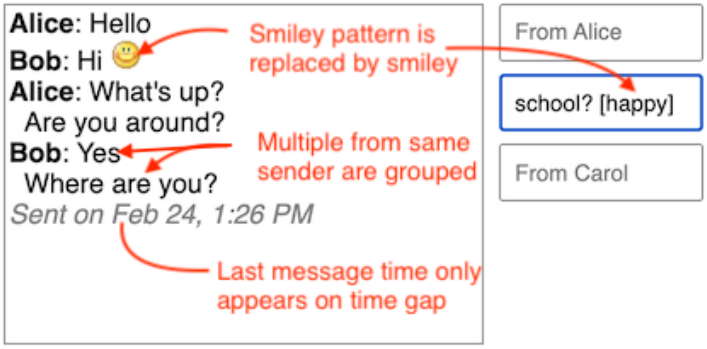
To add a new message to the feed, use the `add` method. The message data should include the optional

sender name and message text. It may include other information as described later.

```
const feed = document.querySelector("text-feed");
let msg_id = "M1234"; // some unique identifier
feed.add(msg_id, {from: "Alice", text: "Hello there!"});
```

A missing sender name indicates a system generated message, and is displayed differently. Successive messages from the same sender are grouped together. Usually the message date is not displayed unless there is a time gap since the last message.

Try the following example to see the component in action, as messages are typed on behalf of different users. Wait a minute after a message to see the last message's date/time too.



Without attaching to a storage, the component just acts as a user interface for displaying text feed. The following code fragment attaches a `shared-storage` instance to a `text-feed-data`, which in turn attaches to the `text-feed` instance, so that it can read messages from the storage. The required `path` property determines the storage path of the list of messages to show in real-time. Internally, the data model component reads and subscribes to changes in the list of messages on that storage path.

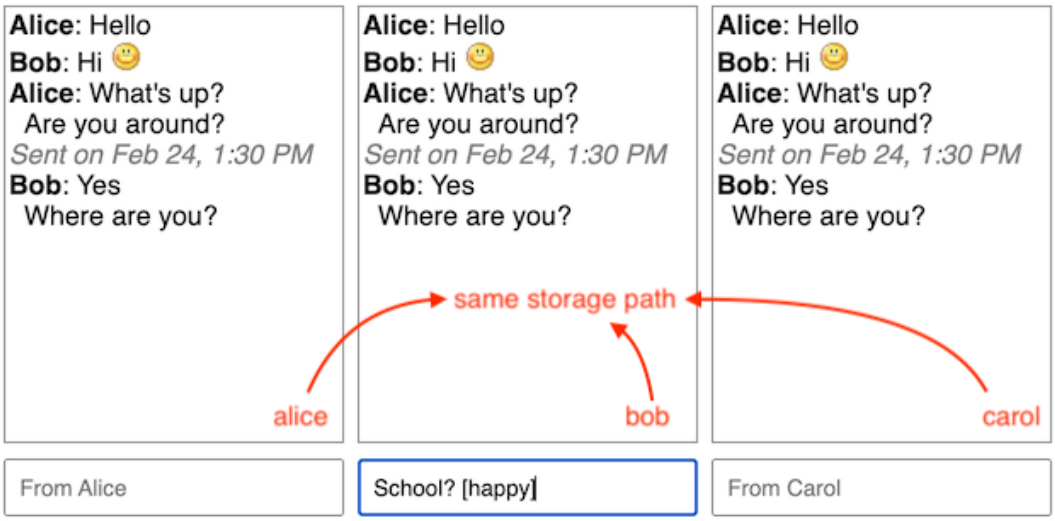
```
<shared-storage id="storage" ...></shared-storage>
<text-feed-data id="data" for-storage="storage" path="sessions/chat123"></text-
feed-data>
<text-feed for-data="data" ...></text-feed>
```

By changing the storage instance using its `src` property, the application can use different backend databases such as `RestserverStorage` or `FirebaseStorage`. By replacing the data model of `text-feed-data` with a different component, the application can use a different messaging service instead of the shared storage component.

An example message object is shown below. All fields are optional, except for text. The disposition of "message" is assumed if missing, if `from` or `fromid` is present, otherwise "info" is assumed. The created attribute stores a numeric timestamp or a string representing date/time of when the message was generated. Interpretation of these attributes remains with the application. The `text-feed` component uses the disposition to display the messages differently.

```
{
    from: "sender name", fromid: "sender id", created: ...timestamp...,
    text: "message content", type: "text/plain", disposition: "message"
}
```

Try the following example with three `text-feed` instances for three example users, that can add messages to the attached `shared-storage`, where all the instances use the same `path` property.



The `text-feed` component also implements several other common features found in popular instant

messagsers such as to convert typed URL text to clickable links, play sound alert on received messages, or convert typed patterns to corresponding smileys.

The following table describes all the properties of the `text-feed` component.

Name	Type and description
`autotime`	bool, default is true Whether to put automatic date/time in the display. This is done after one minute of no activity since the last message received, but not from history.
`allowhtml`	bool, default is true Controls whether to allow displaying rich text using HTML. When set to false, future add with formatted object containing type other than 'text/plain' results in an error. Note that linkify and smileys still work even if this property is false. See method `add`
`linkify`	bool, default is true Whether to replace URLs with clickable links in the text. It uses a primitive match for http: and https: URLs.
`allowedit`	bool, default is false Controls whether message editing is allowed. If not set, then a replacement message appears as a new message at the end of the feed, but the original one is struck out.
`sounds`	element If set, then use its data to determine the alert sounds to play on new messages. This does not apply to messages loaded from history. The element must have a data property, which must be an object, e.g. if set to {data: {message: "URL of sound file"}}. The URL may be http/https or data URL.
`for-sounds`	string

	Use this to set the id of the external sounds DOM element. See `sounds`
`smileys`	element If set, then use its data to replace smileys in text feed. The element must have a data property, which must be an object, e.g., {data: {":)": "", 'sad': ""}}. The text replacement is done only when the smiley text is present within square brackets such as [sad].
`for-smileys`	string Use this to set the id of the external smileys DOM element. See `smileys`
`items`	object (read-only) Contains the current list of text feed items. The application should not modify the content of this property.
`data`	object underlying data model component instance.
`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `text-feed` component.

Function	Signature and description
`add`	feed.add("M123", {text: "Hello", from: "Alice"}) Add a new message to the feed display. This is called implicitly when a text message is sent or received on the shared storage path. It can be called explicitly,

	to just update the user interface, independent of the shared storage. See event `add`
`update`	feed.update("M123", {text: "Hello there!", from: "Alice"}) Update an existing message in the feed display if allowedit is true. This is called implicitly when a text message edit event is received on the shared storage path. It can be called explicitly, to just update the user interface, independent of the shared storage. See event `update`
`update_id`	feed.update_id(context, id) Update the message id of a previous message added to the feed, based on the id retrieved from the data model. When ignoreself is true, the message is added to the feed display before it is actually sent on the data model, and hence, a fake message id is created. Later when the real id is obtained from the data model, the feed is updated to replace the previous fake id of that message with the real id. See `ignoreself`
`remove`	feed.remove("M123") Remove a message either by id or object. It updates the user interface, and removes the message from internal list locally, but does not update the storage. See event `remove`
`clear`	feed.clear() Clear the feed by removing all items in the display. See event `clear`
`reset`	feed.reset() Clear the feed by removing all items in the display, as well as in the storage. It also sends a notification to other connected instances to clear their display as well. See method `clear`
`fetch`	feed.fetch(1000, 4000)

Fetch the next set of feed messages if pagination is enabled. On completion, it updates the display with the new feed messages.

The following table shows all the events dispatched by the `text-feed` component.

Event	Example and description
`add`	{type: "add", id: ..., item: ..., display: ..., offline: ...} Dispatched when a message is added to the feed display. See method `add`
`update`	{type: "add", id: ..., item: ..., offline: ...} Dispatched when a message is replaced in the feed display. See method `update`
`remove`	{type: "remove", id: ..., item: ..., display: ...} Dispatched when a message is removed from the feed display. See method `remove`
`clear`	{type: "clear"} Dispatched when the feed display is cleared. See method `clear`
`openurl`	{type: "openurl", href: "...", download: "...", target: "_blank", type: "image/jpeg"} Dispatched when a link in the text message is clicked. If the listener resets the href property to empty then the original click event is cancelled.

The user interface of the `text-feed` component can be customized using the following styles.

Style	Description and default
`--font-weight-sender`	Default `bold` font-weight of the sender name
`--font-weight-info`	Default `normal`

	font-weight of the info message
`--font-style-info`	Default `italic` font-style of the info message
`--font-weight-warn`	Default `bold` font-weight of the warn message
`--font-style-warn`	Default `normal` font-style of the warn message
`--color-info`	Default `grey` color of the info message
`--color-warn`	Default `red` color of the warn message

The following table describes all the properties of the `text-feed-data` component.

Name	Type and description
`limit`	number, default is 1000 Controls the maximum number of feed items to fetch on initial load.
`offset`	number, default is 0 Controls the offset of feed items to fetch on initial load.
`reverse`	bool, default is false Control the order of display compared to the order of feed items in storage. If true, the order is reversed, i.e., if the feed in the storage has chronological order, then the display will be reverse chronological.
`displayname`	string, default is "Anonymous" Controls the display name of the self instance. See property `self`
`allowedit`	bool, default is false

Controls whether replacing an existing feed item is allowed. If not, then edit method is ignored. If this is false, then receive update in storage also triggers the add event instead of the update event.
See method `edit`, event `update`

`is_ready` bool (read-only), default is false
Indicates the ready state of the storage, when path and self are set, and it is ready.

`self` string, default is ""
Controls the identifier of the self instance. This must be unique among all the instances connected to the same storage path.

`path` string, default is ""
storage path of the list data representing the text chat feed, e.g., "sessions/call123". Each item in the storage must be JSON object of the form {from: "sender name", fromid: "sender id", created: ...timestamp..., text: "message content", type: "text/plain", disposition: "message"} where most fields are optional, except for text. Disposition of "message" is assumed if missing but from or fromid is present. Otherwise, "info" is assumed. The created value may be a numeric timestamp or a string representing date/time.Additionally, notification with data { type: "typing", value: true} is used to indicate user typing.

`persistent` bool, default is false
Controls the persistence of storage data. By default the data is transient but tied to the parent resource, i.e., data is deleted when no more listeners exist on the list resource. If true, then the data is marked as persistent.

`storage` object
underlying shared-storage instance.
See `path`

`for-storage` string, default is ""

	Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `text-feed-data` component.

Function	Signature and description
`send`	data.send({...}) Sends a message, and invokes success or error callback on completion, if needed
`send_typing`	data.send_typing(true) Send typing indication from self, if the storage is ready and path and self are set.
`edit`	data.edit({...}, "...") Edits an existing message. If allowedit is not true, then this is ignored. See property `allowedit`
`reset`	data.reset() If the storage is ready, send a clear notification to all connectived instances, and remove all the messages from the storage.
`fetch`	data.fetch() Get the next set of messages from the storage.

The following table shows all the events dispatched by the `text-feed-data` component.

Event	Example and description
`ready`	{type: "ready", value: true}

Dispatched when the storage becomes ready or not-ready. A ready state also requires path and self to be set.

`add` {type: "add", id: "...", value: {...}, offline: false, mine: false}
Dispatched when an item is added to storage. The event also includes information such as whether the message was sent by self, or whether it was from history.

`update` {type: "update", id: "...", value: {...}, offline: false, mine: false}
Dispatched when an item is replaced in storage, and allowedit is true. The event is similar to add.

`remove` {type: "remove", id: "..."}
Dispatched when an item is removed from storage.

`typing` {type: "typing", from: "...", fromid: "...", value: true, mine: false}
Dispatched when a typing notification is received. The sender name and id are available in the event object.

`clear` {type: "clear"}
Dispatched when a clear notification is received on storage, to clear the local display.

31.2 text-chat

The `text-chat` component uses the `text-feed` component and a text input area to implement multiparty text chat. It can use `text-feed-data` as the data model to send messages or typing indication. It also supports file sharing using convenient drag-and-drop to the input area. The following example shows a component instance with the supplied user information, unique identifier and screen name.

```
<text-feed-data id="data" self="alice" displayname="Alice" for-storage="..."
path="..." />
<text-chat for-data="data" />
```

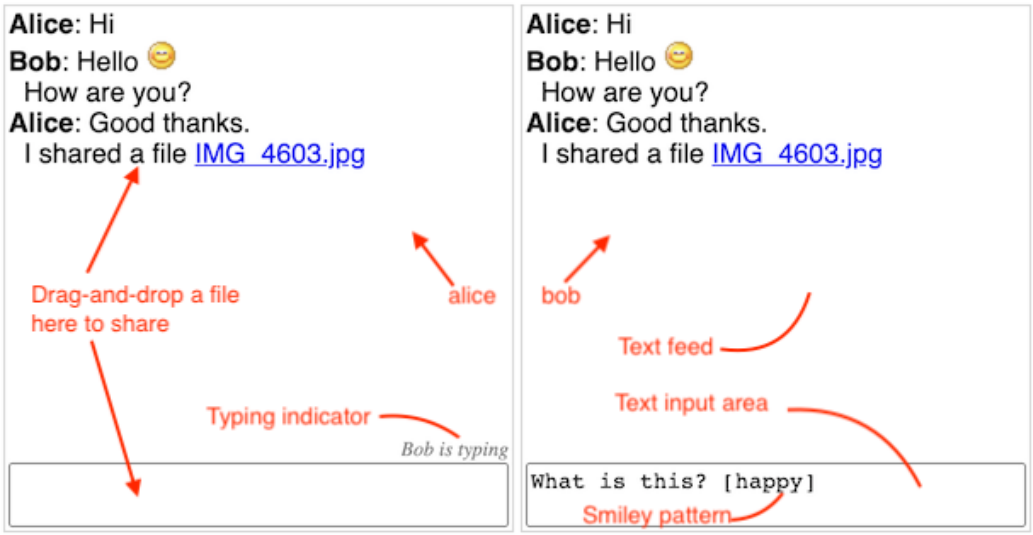
The following example shows a component instance with an explicitly supplied and nested `text-feed` component instance. This allows customizing the nested component such as for styles, smileys or sounds. The data model is set on the container `text-chat` instance, which is automatically passed to the nested instance.

```
<text-chat for-data="data">
    <text-feed for-smileys="..." for-sounds="..."></text-feed>
</text-chat>
```

The following example shows a nested `textarea` component that serves as the input area. This allows customizing the nested component such as for the placeholder text, font or color.

```
<text-chat for-data="data">
    <text-feed for-smileys="..." for-sounds="..."></text-feed>
    <textarea slot="textarea"></textarea>
</text-chat>
```

Try the following example with two `text-chat` instances for two example users. Also try the file sharing using drag-and-drop. Besides showing the text messages, it also shows typing indication.



And here is the same example, but using a peer-to-peer storage.

And the same example, but using Cloud Firestore storage. Make sure to set the right Firebase configuration in localStorage for this to work.

The following table describes all the properties of the `text-chat` component.

Name	Type and description
`feed`	object (read-only) A reference to the underlying text-feed or similar element.
`input`	bool, default is true Controls whether the input text area appears or not. In some cases such as when using inline speech bubble or external rich text editor for input, this should be set to false. In that case, it still allows sending messages via the send method, but not in the user interface of this component. Note that the default typing indicator is also part of the input text area.
`typing`	bool (read-only), default is false Indicates whether the self user is currently typing in the chat input area or not? See event `typing`
`showtyping`	bool, default is true Controls whether to show received typing indication. When set to false, it removes the typing indicator if any, and stops showing future received typing notification. When set to true, it starts showing future received typing notification, but does not show an indicator for past received notification. See `typing`
`filtertyping`	string Controls the text regular expression to match to trigger typing indication on or off for local chat input area. Default is to trigger typing on any text. If this property is set to, say "^[^@/]", then it will not trigger typing if the first

character is @ or /.
See `typing`

`allowhtml` bool, default is true
Controls whether to allow sending and displaying rich text using HTML. When set to false, future send with formatted object containing type other than 'text/plain' results in an error, and adding a received or sent rich text to the display is not allowed. Setting this property also sets the allowhtml property of the nested text-feed component.
See method `send`

`allowedit` bool, default is false
Controls whether the messages sent can be edited later. The maxhistory property must also be set to a positive number to allow editing in the user interface.
See `maxhistory`

`maxhistory` number, default is 0
Controls the maximum history of sent messages to keep, to allow up and down arrows to scroll through sent messages. If allowedit is false, then re-sending an edited message after up and down arrow, just sends a new message, instead of editing the previous one.

`minsize` string
Sets the minimum size of the component. Example: "200x300". If the actual size is smaller than this, then it applies zoom to shrink it proportionally. This is useful to display the component where size could become too small for it to be displayed correctly.

`droppable` bool, default is true
Controls whether file sharing is allowed via drag-and-drop of files anywhere on this component.

`data` object

	underlying data model component instance.
`for-data`	string, default is `""` Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `text-chat` component.

Function	Signature and description
`send`	chat.send("Hello there!") Send some text message to others using the data model. It can accept a text string or a formatted object with attributes of disposition, type, text, and others. The formatted object allows sending rich text such as HTML, by setting the type as 'text/html'. Note that disposition, from, and fromid are implicitly set before sending the message, and ignored from the supplied object, if set. See `allowhtml`
`sendfile`	chat.sendfile(..., (result) => {...}) Send a file to others using the data model, as a clickable link to download the content. Display error on failure. Optional callback is triggered with result of success or failure.
`sendedit`	chat.sendedit({...}, "...") Send an edit to a previous message using the data model. See method `send`
`setinput`	chat.setinput("Typing...") Set the text in the input area with the supplied text. This just updates the user interface, without actually sending the message.

The following table shows all the events dispatched by the `text-chat` component.

Event	Example and description
`typing`	{type: "typing", value: true} Dispatched to indicate whether the local user's typing status has changed See property `typing`
`sending`	{type: "sending", method: "send", data: {...}} Dispatched to indicate that some data will be sent. The application can modify the data such as to add icon or color. If the application set the disposition property in data to "ignore", then the component ignores the data and does not send it any more. The method is one of the methods used for sending. See method `send`, method `sendfile`, method `sendedit`

The user interface of the `text-chat` component can be customized using the following styles.

Style	Description and default
`--color-typing`	Default `grey` color of the typing indicator
`--font-style-typing`	Default `italic` font-style of the typing indicator
`--font-input`	font of the input textarea

31.3 text-feed-bubbles

The `text-feed-bubbles` component is similar to `text-feed`, except that it shows the chat messages as speech bubbles, instead of a simple continuous text area, similar to other popular text chat applications. Additionally, it includes child elements of `text-item-bubbles` component, one per message. This allows better styling or replacing the individual message display, if needed.

The following example shows how to include the `text-feed-bubbles` and `text-item-bubbles` components. It has a dependency on `text-chat` component.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/text-chat.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/text-chat-bubbles.js"></script>
...
<text-feed-bubbles ...>
    <text-item-bubbles ...>...</text-item-bubbles>
    <text-item-bubbles ...>...</text-item-bubbles>
    ...
</text-feed-bubbles>
```

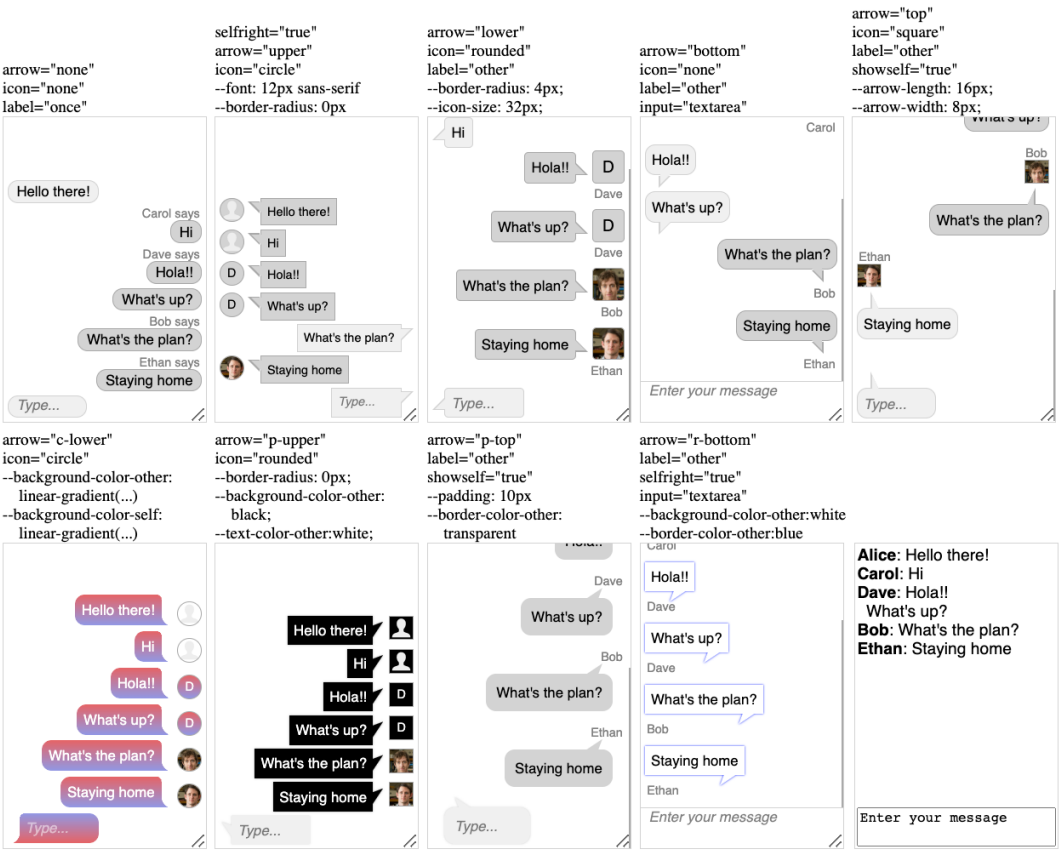
When this component is included in a `text-chat` instance or attached to a storage path, it add the child `text-item-bubbles` elements automatically based on the messages received or sent on the storage path. An example embedding is shown below, where you do not need to explicitly include the `text-item-bubbles` elements

```
<text-chat for-data="data">
    <text-feed-bubbles input="true" showtyping="true"></text-feed-bubbles>
</text-chat>
```

Note the `input` and `showtyping` attributes above. The component also includes text input area and typing indicator, separate and independent from the parent `text-chat` component. Thus, to use those features, the input is disabled in the parent, which implicitly disables typing indicator in the parent, and both input and typing indicators are enabled in the child component.

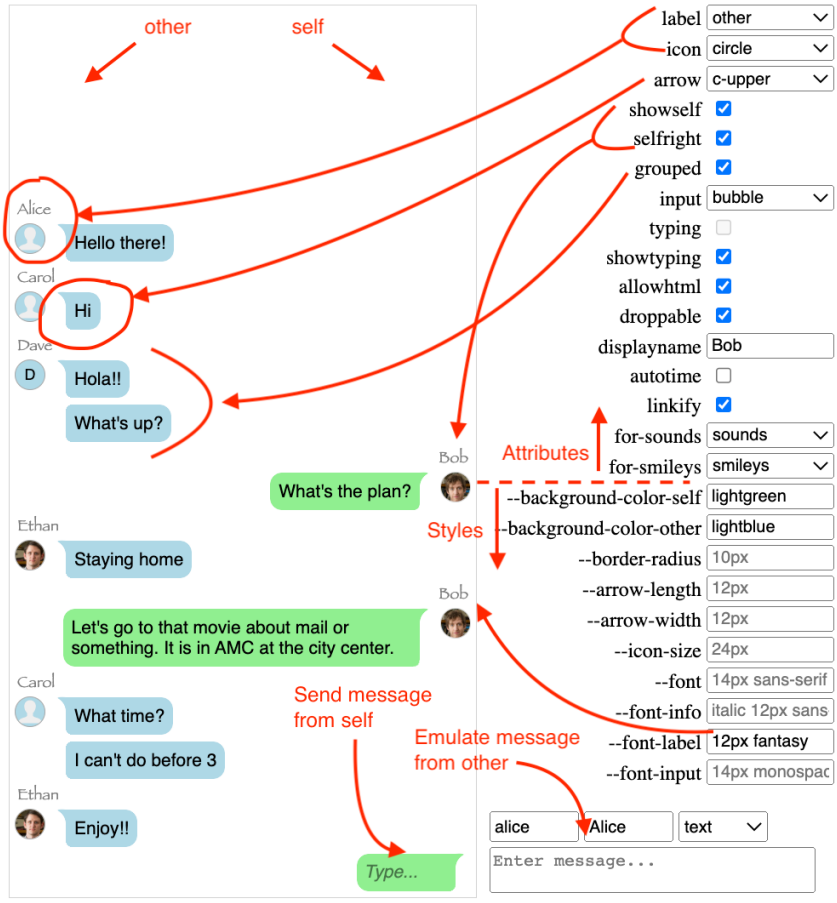
Try the following example with two text chat instances, each including a `text-feed-bubbles` instances, and one `text-chat` instance with a default `text-feed` implicitly included, representing three separate users. All instances are connected to the same storage path, and can interoperate with each other. Note the difference in how the typing indication is shown.

This component can be customized in a variety of ways. Unlike the previous simple example, you can set the bubble arrow, color, font, sender icon, sender label and many other attributes. Try the following example with ten text chat instances, representing ten separate users in the chat, nine of which use customized `text-feed-bubbles` instances, and the last one does not. The various attributes and styles configured on each instance are also shown for reference. The example has code to inject pre-defined messages from different instances. You can also interact with any of the connected component to see how the chat messages and typing indications are shown.



Try the following example to experiment with various attributes and styles on this component. On the left is the component instance of the following form. On the right, it has controls to change the properties and styles of the component instance. If you change a property or style in a text box, press the enter key to apply the changes. It also allows adding a message to the component, by emulating a message sent by another user, using the text input area on the bottom right.

```
<text-feed-data id="data" self="bob" displayname="Bob" path="..."></text-feed-
data>
<text-chat for-data="data" ... input="false">
  <text-feed-bubbles input="true" showtyping="true" for-storage="..." for-
sounds="..." for-smileys="..."
    arrow="c-upper" icon="circle" label="other" selfright="true" showself="true"
grouped="true"
    style="--background-color-other:lightblue;--background-color-
self:lightgreen;...">
  </text-feed-bubbles>
</text-chat>
```



The component may be used for user interface without any attached data model such as `text-feed-`

`data` or `shared-storage`. The attached storage based data model is needed only for sending some message, or receiving shared message. The example above uses the component directly for many of the controls including sending and receiving of messages. Only file sharing needs the data model in the above example.

Similar to the `text-chat` and `text-feed` components, you can share files using drag-and-drop, send HTML content, send smileys, and convert typed URLs to clickable links, in the message display. Alternatively, you can use another rich text editor such as the `shared-editor` component, described later, to facilitate HTML editing for use with sending HTML content. In that case, you should disable the built-in input area using the `input` attribute. The `enter` event from the editor instance should be used to explicitly send a chat message, using the correct `type`. In particular, if the content is not HTML, it should use "text/plain", and if the content is HTML, it should use "text/html".

Example code snippet is shown below.

```
<text-chat ... input="false">
    <text-feed-bubbles ...></text-feed-bubbles>
</text-chat>
<shared-editor disabled="..." wraptext="true"></shared-editor>
```

```
const editor = document.querySelector("shared-editor");
const chat = document.querySelector("text-chat");
editor.addEventListener("enter", event => {
    let text = editor.content;
    setTimeout(() => { editor.content = ""; });
    let type = "text/html";
    const match = text.match(/^<p>([\s\S]*)<\/p>$/m);
    if (match)
        text = match[1];
    const type = (text.indexOf("<") < 0) ? undefined : "text/html";
    chat.send({type, text});
});
```

Instead of using an external `shared-editor`, you can embed it by including as a child of `text-chat`

in the `inputarea` slot as follows. Note that in this mode, it should not disable chat input, and it should use events on the editor to inform the parent `text-chat` about this new text input. Since the editor is included in the chat component as `inputarea`, the chat component can listen to the `textinput` and `typing` events from the embedded editor.

```
<text-chat ...>
    <text-feed-bubbles ...></text-feed-bubbles>
    <shared-editor slot="inputarea" disabled="..." wraptext="true"></shared-
editor>
</text-chat>
```

```
const editor = document.querySelector("shared-editor");
editor.addEventListener("enter", event => {
    let text = editor.content;
    setTimeout(() => { editor.content = ""; });
    let type = "text/html";
    const match = text.match(/^<p>([\s\S]*)<\/p>$/m);
    if (match)
        text = match[1];
    const type = (text.indexOf("<") < 0) ? undefined : "text/html";
    const ev = new Event("textinput");
    ev.data = {type, text};
    editor.dispatchEvent(ev);
});
```

Try the following example, with two instances of the `text-chat` component attached to two instances of `shared-editor`, and a third `text-chat` component with default input, representing three separate users in a chat conversation. The first instance uses an external `shared-editor` whereas the second one uses an embedded `shared-editor`.

The following table describes all the properties of the `text-feed-bubbles` component.

Name	Type and description
`input`	bool, default is false Controls whether the input text area appears in this component or not. By default, it shows a similar speech bubble as the message sent by the self user, but without icon or label. When set to false, the input area is not shown in this component.
`label`	string, default is "none" Controls whether the sender name is displayed near the sender's speech bubble. Allowed values are 'none', 'once', 'other'. If set to once, then other

user's label is displayed first time in consecutive messages from that user. If set to other, then other user's label is displayed every time.
See `showself`

`icon` string, default is "none"
Controls whether the sender icon or image is displayed near the sender's speech bubble. Allowed values are 'none', 'circle', 'rounded', or 'square'. If set to something other than none, then the message data should include the image URL of the sender. If set to rounded, then the --border-radius style is applied to icon in addition to the speech bubble.
See `arrow`

`arrow` string, default is "none"
Controls whether to include an arrow in the speech bubble, pointing to the sender. This should be used together with the sender icon property. Allowed values are 'none', 'bottom', 'top', 'lower', 'upper', 'p-bottom', 'p-top', 'p-lower', 'p-upper', 'c-lower', 'c-upper', 'i-lower', or 'i-upper'. When set to none, no arrow is included in the chat bubbles. When set to top or bottom, the arrow appears on top or bottom of the bubble, respectively. When set to lower or upper, the arrow appears either on the upper or lower part of the side of the bubble. The other elements such as icon and label are adjusted based on the arrow property. The values with p- prefix behave similarly, except that the implementation is different, and using clip-path to get more pointed (p-) arrows. This difference allows the use of gradient for background and drop-shadow for border. When set to r-bottom or r-top, it behaves similar to p- style, but reverses (r-) the position of the arrow so that left one is moved to right, and vice versa. When set to c-lower or c-upper, a curved arrow (c-) is shown using -webkit-mask on the lower or upper side of the bubble. Note that in this mode, the border is not shown, and it relies on the background color for highlighting the bubble. This mode may not work on non-webkit browsers. When set to i-lower or i-upper, it uses an external image for the border of the chat bubbles. It can be attached to the chat-images component,

using the for-images attribute or the images property. In this mode some background and border color styles are not used.

`typing` bool (read-only), default is false

Indicates whether the self user is currently typing in the inline chat input area of this component or not?

See event `typing`

`showtyping` bool, default is false

Controls whether to show received typing indication in this component. When set to false, it removes the typing indicator if any, and stops showing future received typing notification. When set to true, it starts showing future received typing notification, but does not show an indicator for past received notification.

`filtertyping` string

Controls the text regular expression to match to trigger typing indication on or off for local chat input area. Default is to trigger typing on any text. If this property is set to, say "^[^@/]", then it will not trigger typing if the first character is @ or /. This only applies if input is set.

See `typing`, `input`

`showself` bool, default is false

Controls whether to display the label and icon of the messages with sender as self.

`selfright` bool, default is false

Controls the position of messages with sender as self. Default is to put them on left. If this property is true, then they are put on the right.

`showempty` bool, default is true

Controls whether or not to display messages with empty text content. Items with empty content are marked with an attribute, empty.

`grouped` bool, default is false

Controls whether the successive messages from the same sender are grouped together.

`allowstyle` bool, default is false

Controls whether the CSS style received in an incoming message is applied to the corresponding text-item-bubbles element for that message.
See `inputstyle`, `colors`

`inputstyle` string

Controls the CSS style of text-item-bubbles element for the messages sent by this client or added with the mine parameter as true. The style is stored with the message and is available to other participants too. This property is applicable only when the input property is set.
See `allowstyle`, `input`, method `send`, `add`

`bgcolors` string

Controls the automatic assignment of theme colors to received messages based on the sender identifier. Value is a string with comma separated list of colors in CSS format, e.g., "lightgreen,lightblue,#ffa0a0" provides for three colors, that get assigned for first three different senders, and if there are more than three, then those get the default colors. If allowstyle is set, then any style received in the message gets priority over the colors picked from this list. Changing this property does not affect the messages that are already displayed.
See `allowstyle`

`images` element

If set, then use its data to display border image of chat bubbles when arrow is i-upper or i-lower. The element must have a data property, which must be an object, e.g., {data: {"bubble-left-bottom": "...", "bubble-right-bottom": "...", "bubble-left-top": "...", "bubble-right-top": "..."}, and the values should be image data such as using data or http(s) URL.

`for-images` string
Use this to set the id of the external images DOM element.
See `images`

`ignoreself` bool (read-only), default is true
Indicates whether the component ignores the text messages sent by self, and received from the data model. If true, then the parent text-chat component adds the text message in this feed display before sending the message to the data model. If false, then this component adds the message in its feed display after receiving from the data model.

`displayname` string, default is "Anonymous"
Controls the display name of the self instance. This is implicitly set by the parent text-chat element.
See property `self`

`self` string, default is ""
Controls the identifier of the self instance. This is implicitly set by the parent text-chat element.

`autotime` bool, default is true
Whether to put automatic date/time in the display. This is done after one minute of no activity since the last message received, but not from history.

`allowhtml` bool, default is true
Controls whether to allow displaying rich text using HTML. When set to false, future add with formatted object containing type other than 'text/plain' results in an error. Note that linkify and smileys still work even if this property is false.
See method `add`

`linkify` bool, default is true
Whether to replace URLs with clickable links in the text. It uses a primitive match for http: and https: URLs.

`allowedit` bool, default is false

Controls whether message editing is allowed. If not set, then a replacement message appears as a new message at the end of the feed, but the original one is struck out.

`sounds` element

If set, then use its data to determine the alert sounds to play on new messages. This does not apply to messages loaded from history. The element must have a data property, which must be an object, e.g. if set to {data: {message: "URL of sound file"}}. The URL may be http/https or data URL.

`for-sounds` string

Use this to set the id of the external sounds DOM element.

See `sounds`

`smileys` element

If set, then use its data to replace smileys in text feed. The element must have a data property, which must be an object, e.g., {data: {":)": "", 'sad': ""}}. The text replacement is done only when the smiley text is present within square brackets such as [sad].

`for-smileys` string

Use this to set the id of the external smileys DOM element.

See `smileys`

`items` object (read-only)

Contains the current list of text feed items. The application should not modify the content of this property.

`data` object

underlying data model component instance.

`for-data` string, default is ""

	Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `text-feed-bubbles` component.

Function	Signature and description
`setinput`	feed.setinput("Typing...") Set the text input area with the supplied text. This just updates the user interface, without actually sending the message.
`add`	feed.add("M123", {text: "Hello", from: "Alice"}) Add a new message to the feed display. This is called implicitly when a text message is sent or received on the shared storage path. It can be called explicitly, to just update the user interface, independent of the shared storage. See event `add`
`update`	feed.update("M123", {text: "Hello there!", from: "Alice"}) Update an existing message in the feed display if allowedit is true. This is called implicitly when a text message edit event is received on the shared storage path. It can be called explicitly, to just update the user interface, independent of the shared storage. See event `update`
`update_id`	feed.update_id(context, id) Update the message id of a previous message added to the feed, based on the id retrieved from the data model. When ignoreself is true, the message is added to the feed display before it is actually sent on the data model, and hence, a fake message id is created. Later when the real id is obtained from the data model, the feed is updated to replace the previous fake id of that message with the real id.

	See `ignoreself`
`remove`	feed.remove("M123") Remove a message either by id or object. It updates the user interface, and removes the message from internal list locally, but does not update the storage. See event `remove`
`clear`	feed.clear() Clear the feed by removing all items in the display. See event `clear`
`reset`	feed.reset() Clear the feed by removing all items in the display, as well as in the storage. It also sends a notification to other connected instances to clear their display as well. See method `clear`
`fetch`	feed.fetch(1000, 4000) Fetch the next set of feed messages if pagination is enabled. On completion, it updates the display with the new feed messages.

The following table shows all the events dispatched by the `text-feed-bubbles` component.

Event	Example and description
`typing`	{type: "typing", value: true} Dispatched to indicate whether the local user's typing status has changed. See property `typing`
`textinput`	{type: "textinput", text: "Hello, how are you?"} Dispatched when the user enters some text in the input area and presses the return key. This is applicable only when input is true to enable text input area within this component. See property `input`

`add`	{type: "add", id: ..., item: ..., display: ..., offline: ...} Dispatched when a message is added to the feed display. See method `add`
`update`	{type: "add", id: ..., item: ..., offline: ...} Dispatched when a message is replaced in the feed display. See method `update`
`remove`	{type: "remove", id: ..., item: ..., display: ...} Dispatched when a message is removed from the feed display. See method `remove`
`clear`	{type: "clear"} Dispatched when the feed display is cleared. See method `clear`
`openurl`	{type: "openurl", href: "...", download: "...", target: "_blank", type: "image/jpeg"} Dispatched when a link in the text message is clicked. If the listener resets the href property to empty then the original click event is cancelled.

The user interface of the `text-feed-bubbles` component can be customized using the following styles.

Style	Description and default
`--text-color-self`	Default `black` text color of speech bubbles by self including input area
`--text-color-other`	Default `black` text color of speech bubbles by others including typing indicator
`--text-color-info`	Default `grey`

	text color of various info text and message with disposition of info.
`--text-color-label`	Default `grey` text color of various group label and label info for speech bubble.
`--text-color-input`	Default `black` text color of the input area when the input property is set to textarea. This is separate from earlier style attribuute, because the earlier one applies to the input area in the chat bubble when the input property is set to bubble.
`--background-color-self`	Default `#f0f0f0` background-color of speech bubbles by self including input area
`--background-color-other`	Default `lightgrey` background-color of speech bubbles by others including typing indicator
`--border-color-self`	Default `lightgrey` border-color of speech bubbles by self including input area
`--border-color-other`	Default `darkgrey` border-color of speech bubbles by others including typing indicator
`--padding`	Default `4px` padding used for speech bubbles
`--border-radius`	Default `10px` border-radius of speech bubbles
`--arrow-length`	Default `12px`

	length of the arrow pointer of the speech bubble if any See property `arrow`
`--arrow-width`	Default `12px` width of the arrow pointer of the speech bubble if any See property `arrow`
`--icon-size`	Default `24px` width and height of sender icon in speech bubble See property `icon`
`--font`	Default `14px sans-serif` font of all the text including speech bubble, info text, sender label, and input area. Default is to use different font for speech bubble, info text, and input area. But if this is set, it applies that font for all three, unless info and input are altered too. See `--font-info`, `--font-input`
`--font-info`	Default `italic 12px sans-serif` font of the info text, if it needs to be different than the speech bubble text. If this is not set, it falls back to using --font for info text too if that is set
`--font-label`	Default `12px sans-serif` font of the sender label, if it needs to be different than the info text. If this is not set, it falls back to using --font-info, then to --font, if that is set.
`--font-input`	Default `14px monospace` font of the input area, if it needs to be different than the speech bubble text. If this is not set, it falls back to using --font for input area too if that is set.

Currently, the `text-feed-bubbles` implementation has some limitations such as lack of pagination or

scrolling, and inability to delete a message. These may be improved in the future.

31.4 text-item-bubbles

As mentioned before, a `text-item-bubbles` instance represents a single text message or speech bubble as a child element of the `text-feed-bubbles` instance. When `text-feed-bubbles` component is used and attached to a data model, then its `add` or `send` method create the `text-item-bubbles` component instances as needed. However, when creating custom feed, with custom items, you can create the `text-item-bubbles` manually, and add as child of `text-feed-bubbles`.

Try the following example to see the component display with various included `text-item-bubbles` instances customized using their various attributes. The component may include other HTML elements too, similar to the last `div` element shown below.

```
<text-feed-bubbles>
    <text-item-bubbles class="chat" mine="false" place="left"
        arrow="c-upper" icon="circle" hasicon="true" haslabel="true"
        from="Bob" fromid="bob">
        Hello, how are you?
    </text-item-bubbles>
    <text-item-bubbles ... mine="true" place="right"
        arrow="c-lower" icon="square" ... haslabel="false"
        style="--background-color-self: lightblue;">
        Where are you? Are you <b>around</b>?
    </text-item-bubbles>
    <text-item-bubbles class="info">
        This is a system message
    </text-item-bubbles>
    <text-item-bubbles ...
        arrow="p-upper" icon="none" hasicon="false" ...
        style="--background-color-other: lightgreen;">
        check this out.<br/>
        <img src="51-text-chat-face1.jpg" width="30">
    </text-item-bubbles>
    <div style="clear: both; text-align: right; margin: 10px;">
        This div is with embedded content <b>image</b><br/>
        <img src="51-text-chat-face1.jpg" style="zoom: 0.2;">
    </div>
</text-feed-bubbles>
```

The following table describes all the attributes of the `text-item-bubbles` component, with the exception of `data` and `input`, which are properties. Note that unlike other components, this one does not map the attributes to properties.

Name	Type and description
`class`	string Class name of the speech bubble. Allowed values are info or chat. Some attributes are required for chat, as mentioned below.
`place`	string

Controls the placement of speech bubble. Allowed values are left or right. This is required for class chat.

`arrow` string

Controls the type of arrow in speech bubble. See text-feed-bubbles for allowed values and description.

`mine` bool, default is false

Whether the sender is self or not? This is required for class chat.

`grouped` bool, default is false

Presence of this attribute indicates true, and absence false. Whether the message item is grouped with other messages from the same sender, so that the arrow, label and icon are hidden.

`typing` bool, default is false

Presence of this attribute indicates true, and absence false. Whether this speech bubble represents typing indication? Typing indicator has different style.

`icon` string

Controls the type of icon shown for this message. This is required for class chat. See text-feed-bubbles for allowed values and description.

`label` string

Controls the type of label shown for this message. This is required for class chat. See text-feed-bubbles for allowed values and description.

`hasicon` bool, default is false

Whether to show the icon for this message or not? This is required for class chat. The icon should not be shown in several cases such as when icon is none or this item is grouped or showself is false in parent and this is a message from self.

`haslabel` bool, default is false

Whether to show the label for this message or not? This is required for class chat. The label should not be shown in several cases such as when label is none or this item is grouped or showself is false in parent and this is a message from self.

`disposition` string
The message disposition of the message data. Allowed values are message or info.

`data` object
The data object associated with this text chat item. It can include properties such as disposition, from, fromid, created, type and text, some of which are optional. See the description of the path property of text-feed-data for chat message format.

`input` object
An instance of textarea or similar element, to represent the text input area. Setting this also turns the speech bubble into a text input area. Only one of data or input may be assigned at any time.

There are no methods, but setting the `data` or `input` property cause the desired effect of creating the internal elements in the display.

All the styles described in `text-feed-bubbles` also apply to `text-item-bubbles`, and may be set on that component, if needed.

31.5 Editable message

By default, once a message is sent, it cannot be changed. However, message editing feature can be enabled in various components using the `allowedit` property. Enabling it on `text-chat` allows use of up and down arrow to select a previous message from the history of messages sent from this instance, and be able to edit and re-send it. Enabling it on `text-feed` or `text-feed-bubbles` allows replacing an existing message with the edited one received from the data model. Enabling it on the `text-feed-`

`data` data model allows replacing the actual message in the storage, and triggering the right update event to inform the attached `text-feed` element to update its interface.

To enable the editable message feature, all the three components should have `allowedit` set, and additionally, the `text-chat` component should have the `maxhistory` set, as shown below.

```
<text-feed-data id="data" ... allowedit="true"></text-feed-data>
<text-chat for-data="data" allowedit="true" maxhistory="10">
    <text-feed ... allowedit="true"></text-feed>
</text-chat>
```

Try the following example emulating two users in a text chat using `text-feed`. After sending new messages, use the up arrow to select one of the previously sent message, edit it, and press enter to send an update.

The only difference is that the left one does not have `allowedit` for the `text-feed` component. Thus, when an update or edit is received, the left one strikes out the previous message, and adds the new one at the end, whereas the right one with `allowedit` for its `text-feed` replaces the previous message with the new one.

The `allowedit` property on the parent `text-chat` component enables viewing historical message in the input area, and when a message from history is edited, it enables storing the message edit event in the chat history. The `allowedit` property on the `text-feed` component enable replacing a message from history with the edit, and without that property, it appends at the end, while striking out the message from history. In addition to replacing a previous message with an edit, it also enables removing the previous message if the edit deletes the message text.

Now try again with the `text-feed-bubbles` component used by the first two users, and `text-feed` without `allowedit` by the third.

The above example is similar to the earlier one, except that `allowedit` is set on various components. Note that the `text-feed-bubbles` component hides an empty or deleted message only when

`showempty` is set to false, which is done for the second chat component in the example above, but not the first one.

Message editing is also allowed in the component described next.

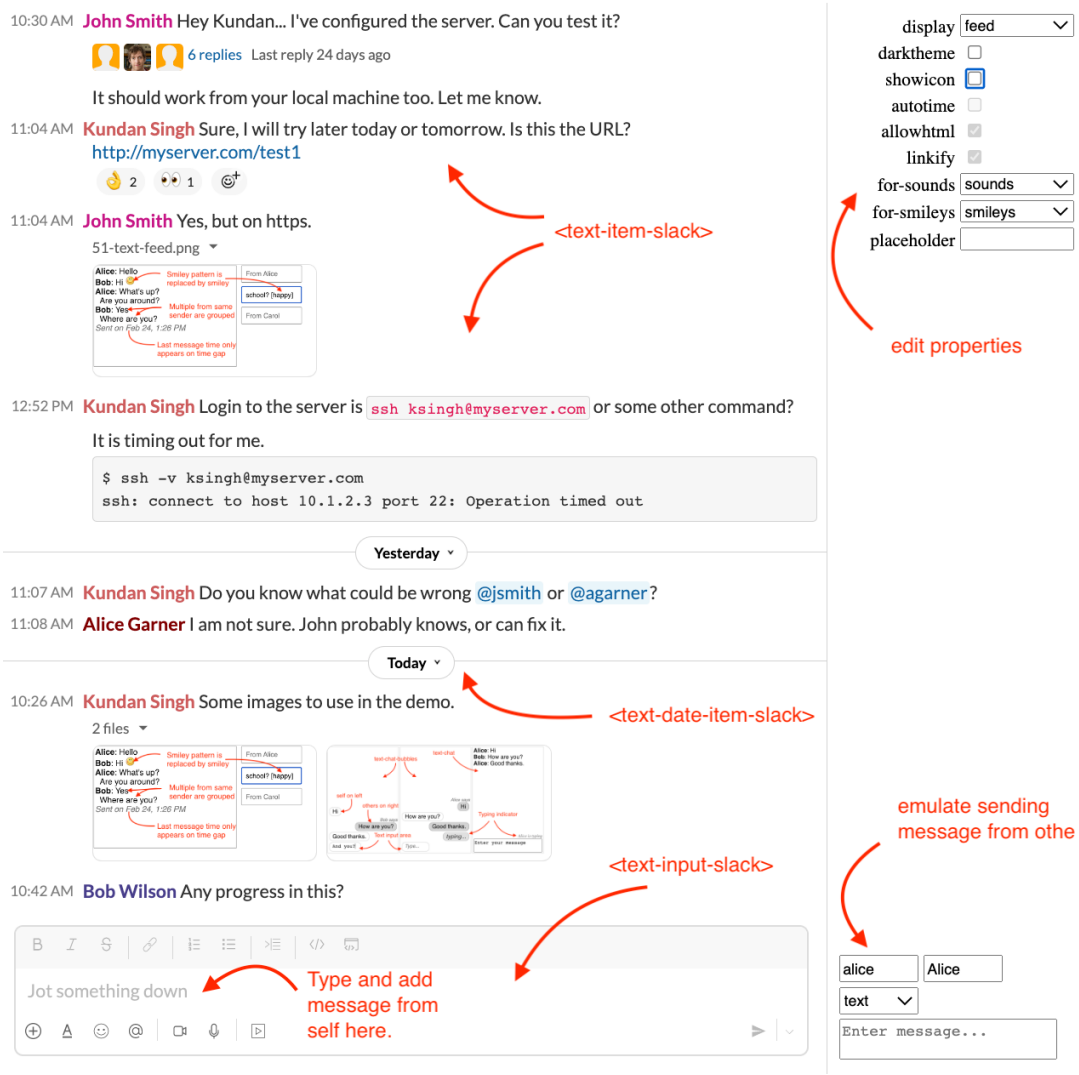
31.6 text-feed-slack

To demonstrates the use of web components in enterprise messaging related use cases, we also implemented these components: `text-feed-slack`, `text-item-slack`, `text-input-slack`, and related `text-date-item-slack`, `text-overlay-file-slack`, and `text-overlay-item-slack` components. The `text-feed-slack` component extends `text-feed` to implement the user interface inspired by and mimicking the popular Slack application. It embeds `text-item-slack` and `text-date-item-slack` elements to represents chat messages and date demarcation, respectively. Additionally, the user interface for overlay on chat message or attachment, are in `text-overlay-item-slack` and `text-overlay-file-slack`, respectively.

```
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/text-
chat.js"></script>
<script type="text/javascript" src="https://rtcbricks.kundansingh.com/v1/text-
chat-slack.js"></script>
...
<text-feed-slack ...>
    <text-date-item-slack ...>...</text-date-item-slack>
    <text-item-slack ...>...</text-item-slack>
    <text-item-slack ...>...</text-item-slack>
    ...
</text-feed-slack>
```

These components are highly experimental and primitive, and only the basic user interface and connection to storage is implemented for demonstration purpose. These components are not endorsed, supported or related to the official Slack product or its organization in any way. The goal is to merely show that real-world user interfaces and messaging applications can be built using the web components and supporting storage elements described in this project.

The following example shows how to try out these components, in an example message session.



The following table describes all the properties of the `text-feed-slack` component.

Name	Type and description
`display`	string, default is "feed" Controls how the feed is displayed. Allowed values are feed, thread, compact, direct, mentions.
`darktheme`	bool, default is false

If present then use dark theme in the colors.

`showicon` bool, default is false

If present then show sender icon on the left, instead of time, and move the time after the sender name.

`autotime` bool (read-only), default is false

Whether to put automatic date/time in the display. This is done after one minute of no activity since the last message received, but not from history.

`allowhtml` bool (read-only), default is true

Controls whether to allow sending and displaying rich text using HTML. When set to false, future send with formatted object containing type other than 'text/plain' results in an error, and adding a received or sent rich text to the display is not allowed. Setting this property also sets the allowhtml property of the nested text-feed component.

`linkify` bool (read-only), default is true

Whether to replace URLs with clickable links in the text. It uses a primitive match for http: and https: URLs.

`allowedit` bool, default is false

Controls whether message editing is allowed. If not set, then a replacement message appears as a new message at the end of the feed, but the original one is struck out.

`sounds` element

If set, then use its data to determine the alert sounds to play on new messages. This does not apply to messages loaded from history. The element must have a data property, which must be an object, e.g. if set to {data: {message: "URL of sound file"}}. The URL may be http/https or data URL.

`for-sounds` string

	Use this to set the id of the external sounds DOM element. See `sounds`
`smileys`	element If set, then use its data to replace smileys in text feed. The element must have a data property, which must be an object, e.g., {data: {":)": "", 'sad': ""}}. The text replacement is done only when the smiley text is present within square brackets such as [sad].
`for-smileys`	string Use this to set the id of the external smileys DOM element. See `smileys`
`items`	object (read-only) Contains the current list of text feed items. The application should not modify the content of this property.
`data`	object underlying data model component instance.
`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `text-feed-slack` component.

Function	Signature and description
`add`	feed.add("M123", {text: "Hello", from: "Alice"}) Add a new message to the feed display. This is called implicitly when a text message is sent or received on the shared storage path. It can be called explicitly,

	to just update the user interface, independent of the shared storage. See event `add`
`update`	feed.update("M123", {text: "Hello there!", from: "Alice"}) Update an existing message in the feed display if allowedit is true. This is called implicitly when a text message edit event is received on the shared storage path. It can be called explicitly, to just update the user interface, independent of the shared storage. See event `update`
`update_id`	feed.update_id(context, id) Update the message id of a previous message added to the feed, based on the id retrieved from the data model. When ignoreself is true, the message is added to the feed display before it is actually sent on the data model, and hence, a fake message id is created. Later when the real id is obtained from the data model, the feed is updated to replace the previous fake id of that message with the real id. See `ignoreself`
`remove`	feed.remove("M123") Remove a message either by id or object. It updates the user interface, and removes the message from internal list locally, but does not update the storage. See event `remove`
`clear`	feed.clear() Clear the feed by removing all items in the display. See event `clear`
`reset`	feed.reset() Clear the feed by removing all items in the display, as well as in the storage. It also sends a notification to other connected instances to clear their display as well. See method `clear`
`fetch`	feed.fetch(1000, 4000)

Fetch the next set of feed messages if pagination is enabled. On completion, it updates the display with the new feed messages.

The following table shows all the events dispatched by the `text-feed-slack` component.

Event	Example and description
`add`	{type: "add", id: ..., item: ..., display: ..., offline: ...} Dispatched when a message is added to the feed display. See method `add`
`update`	{type: "add", id: ..., item: ..., offline: ...} Dispatched when a message is replaced in the feed display. See method `update`
`remove`	{type: "remove", id: ..., item: ..., display: ...} Dispatched when a message is removed from the feed display. See method `remove`
`clear`	{type: "clear"} Dispatched when the feed display is cleared. See method `clear`
`openurl`	{type: "openurl", href: "...", download: "...", target: "_blank", type: "image/jpeg"} Dispatched when a link in the text message is clicked. If the listener resets the href property to empty then the original click event is cancelled.

The following table describes all the properties of the `text-item-slack` component.

Name	Type and description
`data`	object The data object associated with this text chat item. It can include properties such as disposition, from, fromid, created, type and text, some of which are optional. See the description of the path property of text-feed-data for chat message

format. Additional attributes such as reaction, replies, attach or icon should be removed the object before setting to this property.

`reaction` object

An object with key-value pairs, where key is the reaction code such as ok_hand or eyes, and value is an array of strings, each string representing the sender such as 'jsmith;John Smith', with id and name.

`replies` object

An objects with key-value pairs, with keys of thread, last and senders attributes. The thread attribute is the thread identifier. The last attribute is the timestamp in milliseconds for the last reply in the thread. The senders attribute is an array of objects, each with optional image and name properties. This is used to display the replies below the message item, with up to three sender icons.

`attach` object

An array of objects, each with type and src properties, representing the file attachment. Additionally, each object may include name and size properties for the file to attach. The src object should be a data URL. This is used to display the attachments below the message item. The attachments may be collapsed.

`icon` string

Constrols the optional icon URL. If not set, then default icon is shown when needed.

`grouped` bool, default is false

Presence of this attribute indicates true, and absence false. Whether the message item is grouped with other messages from the same sender, so that left icon or time is shown only only hover, and sender label is hidden.

`display` string

Controls how the feed is displayed. See display property in text-feed-slack for allowed values and description.

`darktheme` bool, default is false

If present then use dark theme in the colors.

`showicon` bool, default is false

Presence of this attribute indicates true, and absence false. Whether to show the icon for this message or not? If set then icon is shown on the left, and time is moved to after sender label. Otherwise, time stays on left, and icon is not shown.

The following table shows all the events dispatched by the `text-item-slack` component.

Event	Example and description
`itemclick`	{type:"itemclick",item:"user",data: {...}} Dispatched when user clicks on this item or some other item included in this item. The item property indicates the type, and data property has additional data.
`itementer`	{type:"itementer",item:"attach",data:...,innerTarget:...} Dispatched when mouse enters this component or some other item included in this component. The item property indicates the type, and optional data or innerTarget property has additional data.
`itemleave`	{type:"itemleave",item:"attach",data:...,innerTarget:...} Dispatched when mouse leaves this component or some other item included in this component. The item property indicates the type, and optional data or innerTarget property has additional data.

The following table describes all the properties of the `text-date-item-slack` component.

Name	Type and description
`data`	object A Date object representing the date to display.

The following table describes all the properties of the `text-input-slack` component.

Name	Type and description

`darktheme`	bool, default is false If present then use dark theme in the colors.
`placeholder`	string, default is "Jot something down" Placeholder for input area.
`allowedit`	bool, default is false Controls whether the messages sent can be edited later. If true, then pressing up arrow key when input area is empty moves the focus to the last feed item from this user, so that it can be edited and re-sent. The allowedit property on the container text-chat as well as the related text-feed-slack must also be set to true.
`typing`	bool (read-only), default is false Indicates whether the user is currently typing in the input area or not? See event `typing`
`smileys`	element If set, then use its data to replace smileys in text feed. The element must have a data property, which must be an object, e.g., {data: {":)": "", 'sad': ""}}. The text replacement is done only when the smiley text is present within square brackets such as [sad].
`for-smileys`	string Use this to set the id of the external smileys DOM element. See `smileys`

The following table shows all the methods of the `text-input-slack` component.

Function	Signature and description
`createlink`	Create a clickable link in the text input area, using the supplied URL as target href attribute, and current selected text as text if selected, or the same URL as text. This should be called by the application, when this component dispatches

	the createlink event.
`triggersend`	chat.triggersend() Emulate a click on the send button, assuming that the input area is set. See `setinput`
`setinput`	chat.setinput("Hello there") Set the text and attachments in the input area with the supplied data. This just updates the user interface, without actually sending the message. If previous text exists, those are overwritten. If previous attachment exists, those are overwritten only if new attachments are supplied in this function. To overwrite and remove, supply attach parameter as empty array []. See `triggersend`
`settyping`	chat.settyping({from: "...", fromid: "...", value: true}) Set the typing state for some sender.

The following table shows all the events dispatched by the `text-input-slack` component.

Event	Example and description
`typing`	{type: "typing", value: true} Dispatched to indicate whether the local user's typing status has changed See property `typing`
`textinput`	{type: "textinput", data: {text: "*Hello*, how are you?", type: "text/html"}} Dispatched when the user enters some text in the input area and presses the return key.
`textedit`	{type: "textedit", id: "...", data: {text: "*Hello*, how are you?", type: "text/html"}} Dispatched when the user edits an existing message and presses the return key.
`createlink`	{type: "createlink"}

Dispached when the user click to add a clickable link. Some text may or may not be selected. The application should prompt the user to enter or select a URL, and then call the createlink method with that URL to insert a clickable link.

32. How to display user roster?

Collaborative applications often need the ability to display a list of users along with their attributes or capabilities. For example, a contact list in a messenger application or an attendee list in a conference application show the list of users along with some audio or video indication.

The `user-roster` component shows a list of users and their attributes, based on the list data from a data model. An example is shown below.

```
<shared-storage id="storage" src="..."></shared-storage>
<user-roster-data id="data" for-storage="storage" self="alice"
path="sessions/contacts123"></user-roster-data>
<user-roster for-data="data"></user-roster>
```

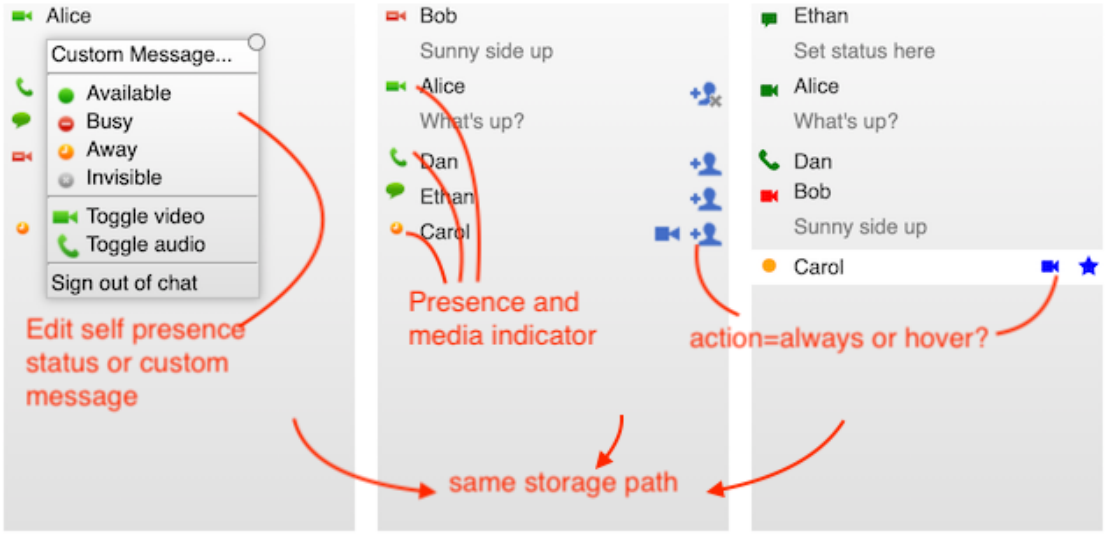
The default icons can be altered using a web assets component that supplies the relevant image data. This is similar to the sounds and smileys web assets components used in `text-feed`, and illustrated below.

```
<communicator-icons id="icons"></communicator-icons>
<user-roster for-icons="icons" ...></user-roster>
```

The user item in the list data is an object with these attributes: name, status, message, chatting, audio, video, contact. The first three are of type string, and others are boolean. Only the name attribute is required, and all others are optional. Additionally, these attributes may be present to indicate the current communication state: play_audio, play_video, publish_audio, publish_video. The index of the item in the list data is the identifier of the user item. Thus, the list could actually be treated as a map or hash table data.

Try the following example with three `user-roster` instances, each attached to a separate `user-roster-data` instance, but all the data model instances using the same user list in the same storage. The three roster and data model instances represent three separate logged in user via the `self` property. The first two use custom icons from web assets. The last two order the list by name. The

second instance is configured to always show the action buttons. These are similar to the attendee lists shown in a conference application, to three different users.



Try the following example to edit various properties of the `user-roster` component to see how it behaves. Setting the local presence status is only allowed for the self item, displayed as the first in the list. The action buttons, to initiate audio/video call or to star/unstar an item, may be displayed on mouse hover or always. The audio and video capabilities are reflected in the presence icon, but only when it is not offline. The external items from the `communicator-icons` web assets component appears different than the default.

The above example also shows how the component behaves when searching for an item, and how the component groups the users by their presence status.

32.1 user-roster

The following table describes all the properties of the `user-roster` component.

Name	Type and description
`order`	string, default is "name" *(not implemented)* Control the order of the user list. Allowed values are "name", "id", "time", "presence,name", "presence,time", "none".
`filter`	string, default is "" If set, then filter the roster display with only a subset of items, e.g., during search.
`action`	string, default is "hover" Controls how the action buttons are shown for roster items. Allowed values are "always" or "hover".
`contact`	bool, default is true

Controls whether the add and remove contact button is present?

`audio` bool, default is true

Controls whether the audio button is present? This can be used to initiate an audio call by the application or to indicate the audio capability of the item.

`video` bool, default is true

Controls whether the video button is present? This can be used to initiate an video call by the application or to indicate the video capability of the item.

`controls` bool, default is true

Controls whether to allow changing the self user's status.

`dense` bool, default is false

Controls whether to display the user roster in dense packing mode.

`icons` element

If set, then use its data to show various icons. The element must have a data property, which must be an object, e.g., {data: {online: "...", offline: "...", busy: "...", ...}. The value of these attributes must be HTML fragment such as img element or unicode character representing the image for the icon.

`for-icons` string

Use this to set the id of the external images DOM element.

See `icons`

`items` object (read-only)

Contains the current list of roster items. The application should not modify the content of this property.

`data` object

underlying data model component instance.

`for-data` string, default is ""

	Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `user-roster` component.

Function	Signature and description
`get_item`	roster.get_item("alice") To get the user item data object by its identifier
`add`	roster.add("alice", {...}) Add an user item data in the display See event `add`
`remove`	roster.remove("bob") Remove an user item data from the display See event `remove`
`update`	roster.update("alice", {status: "busy"}, "status") Update an user item data or property in the display See event `update`
`clear`	roster.clear() Clear the roster display, and remove all the user items See event `clear`
`move`	roster.move("alice", 3) Move an user item to a different index position See event `move`

The following table shows all the events dispatched by the `user-roster` component.

Event	Example and description
`openuser`	{type: "openuser", id: "alice"} Dispatched when a user item from the list is clicked
`addremove`	{type: "addremove", id: "bob"} Dispatched when the contact or star action button is clicked to add or remove the user as contact or favorite
`changevideo`	{type: "changevideo", id: "carol"} Dispatched when the video action button is clicked to start or stop video call
`changeaudio`	{type: "changeaudio", id: "dan"} Dispatched when the audio action button is clicked to start or stop audio call
`logout`	{type: "logout"} Dispatched when the signout menu item is clicked from the status change dropdown
`layout`	{type: "layout", height: 120} Dispatched when the height of the roster display is changed due to add/remove of an item or change in attribute value. The height attribute supplies the new height number in pixels.
`add`	{type: "add", id: ..., data: ..., index: ...} Dispatched when an user item is added to the display See method `add`
`remove`	{type: "remove", id: ..., data: ..., index: ...} Dispatched when an user item is removed from the display See method `remove`
`update`	{type: "update", id: ..., data: ..., existing: ..., property: ...} Dispatched when an user item's property or associated data is updated. The existing data and property name are optional. See method `update`

`move`	{type: "move", id: ..., old: ..., index: ...} Dispatched when an user item is moved in position in the display. Both old and new index position are in attributes. See method `move`
`clear`	{type: "clear"} Dispatched when the roster display is cleared See method `clear`

The user interface of the `user-roster` component can be customized using the following styles.

Style	Description and default
`--background-color-users`	Default `#e0e0e0` background-color of the users list display

The following table describes all the properties of the `user-roster-data` component.

Name	Type and description
`items`	object (read-only) Refers to the internal roster object with key as id, and value as user data. Application must not modify the content directly.
`self`	string, default is "" Controls the identifier of the self instance. This must be unique among all the instances of the roster to the same storage path.
`path`	string, default is "" storage path of the list data to show in the roster, e.g., "sessions/call123/attendees". Each item in the storage must be JSON object of the form {name: ..., status: ..., message: ..., chatting: ..., speaking: ..., audio: ..., video: ..., contact: ..., } where only the name is required.
`storage`	object

	underlying shared-storage instance. See `path`
`for-storage`	string, default is "" Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `user-roster-data` component.

Function	Signature and description
`set_status`	data.set_status("status", "offline") Set a status name-value for the self user. The name can be one of status, audio, video, message. If name is status, value may be any availability status including available, busy, idle, or offline. If name is audio or video, value is a boolean indicating whether audio or video is on or off. If name is message, value is some user generated message string.

The following table shows all the events dispatched by the `user-roster-data` component.

Event	Example and description
`reset`	Dispatched when the storage is ready.
`self`	{type: "self", old: "...", value: "..."} Dispatched when self property is set. The event includes old and new value.
`add`	{type: "add", id: "...", value: {...}} Dispatched when an item is added to the storage.
`update`	{type: "update", id: "...", value: {...}}

Dispatched when an item is updated in the storage.

`remove` {type: "remove", id: "..."}

Dispatched when an item is removed from the storage.

33. How to do multimedia chat?

The `media-chat` component enables a full fledged multimedia chat, and includes other components to perform text chat, display attendee list, and optional video-io elements. Separate instances of the component can connect to the same storage path to participate in a multimedia chat. An example is shown below that includes `text-chat`, `user-roster` and `flex-box` to handle text chat, attendee list and videos display, respectively. Additionally `toolbar-buttons` is used to display the toolbar. Except for the toolbar or overlay menu, the order of the included components is important, and is preserved in the display.

The `media-chat` instance uses a `media-chat-data` instance as the data model, which in turn includes `text-feed-data` and `user-roster-data` as data models for the included `text-chat` and `user-roster`, respectively.

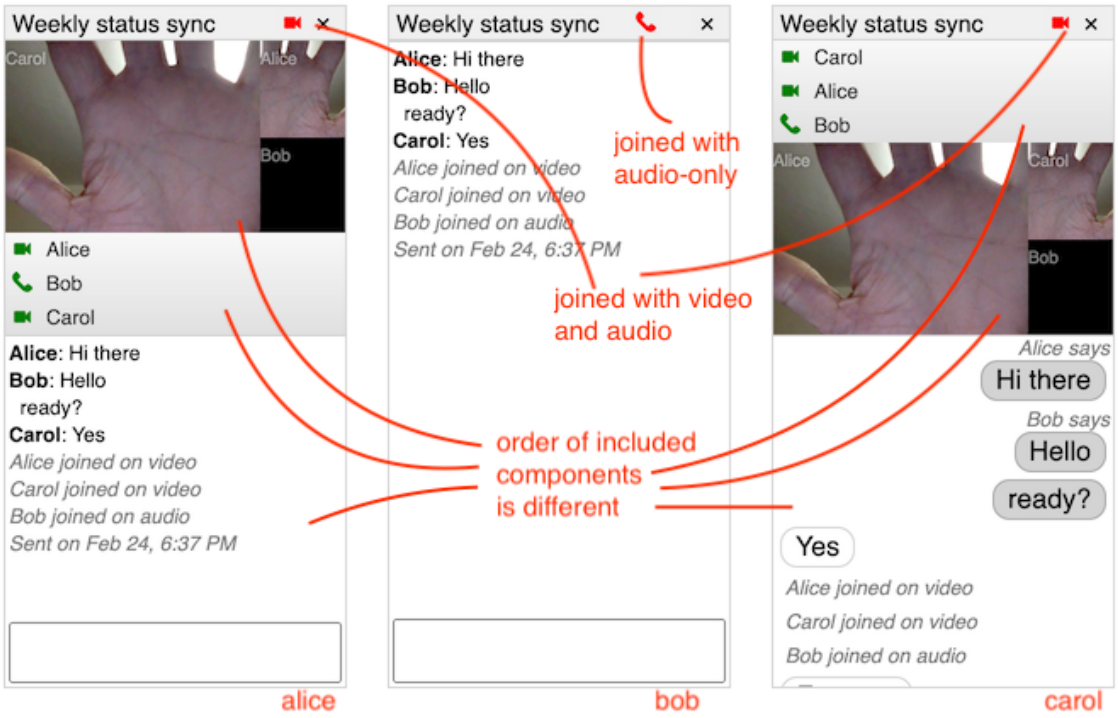
```
<media-chat-data id="data" self="alice" displayname="Alice"></media-chat-data>
<media-chat for-data="data" ...>
    <toolbar-buttons slot="buttons">
        <span>Weekly status sync</span>
        <button name="audio" toggle></button>
        <button name="video" toggle></button>
        <button name="clear"></button>
    </toolbar-buttons>
    <flex-box slot="videos"></flex-box>
    <user-roster slot="roster"></user-roster>
    <text-chat slot="chat">
        <text-feed></text-feed>
    </text-chat>
</media-chat>
```

The data model is passed to the included component when needed. Thus, the top level data model component creates the included data model components for feed and roster, using the same storage, and after modifying the path as needed. For example, if the top level component's path is "sessions/conf123" then the path for roster's data model becomes "sessions/conf123/users", for chat's data model becomes "sessions/conf123/messages", and the path to store the audio/video attendees

becomes "sessions/conf123/calls".

Try the following example with three `media-chat` instances, each attached to the same storage path, but representing separate logged in user via the `self` property. The attributes used in the three instances are indicated below. Note the use of different `videos-ratio` in the second, the use of `text-feed-bubbles` in the third, and the use of `overlay-menu` in the third.

```
<media-chat-data id="data1" for-storage="..." path="..."
    self="alice" displayname="Alice"></media-chat-data>
<media-chat for-data="data1">
  <toolbar-buttons slot="buttons">...</toolbar-buttons>
  <flex-box slot="videos"></flex-box>
  <user-roster slot="roster"></user-roster>
  <text-chat slot="chat">
    <text-feed for-smileys="..." for-sounds="..."></text-feed>
  </text-chat>
</media-chat>
<media-chat-data id="data2" for-storage="..." path="..."
    self="bob" displayname="Bob"></media-chat-data>
<media-chat for-data="data2" videos-ratio="1.333">
  <toolbar-buttons slot="buttons">...</toolbar-buttons>
  <flex-box slot="videos"></flex-box>
  <text-chat slot="chat" showtyping="true">
    <text-feed for-smileys="..." for-sounds="..."></text-feed>
  </text-chat>
</media-chat>
<media-chat-data id="data3" for-storage="..." path="..."
    self="carol" displayname="Carol"></media-chat-data>
<media-chat for-data="data3">
  <toolbar-buttons slot="buttons">...</toolbar-buttons>
  <overlay-menu slot="menu">...</overlay-menu>
  <user-roster slot="roster"></user-roster>
  <flex-box slot="videos"></flex-box>
  <text-chat slot="chat" input="false">
    <text-feed-bubbles input="true" showtyping="true"></text-feed-bubbles>
  </text-chat>
</media-chat>
```



And here is the same example, but with four users and using a peer-to-peer storage.

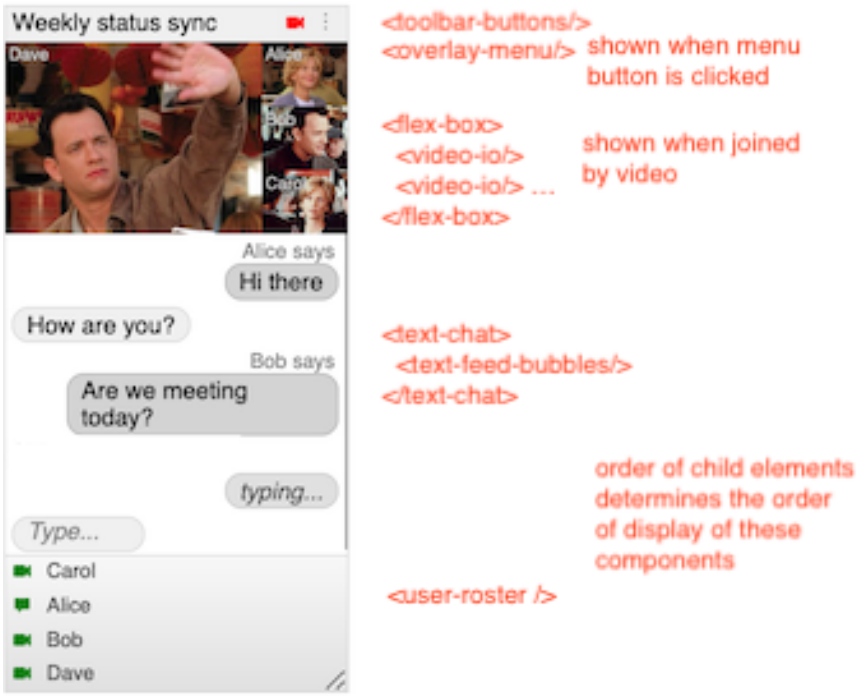
And here is the same example, but using Cloud Firestore storage. Make sure to set the right Firebase configuration in localStorage for this to work.

The examples above show the default messenger style display.

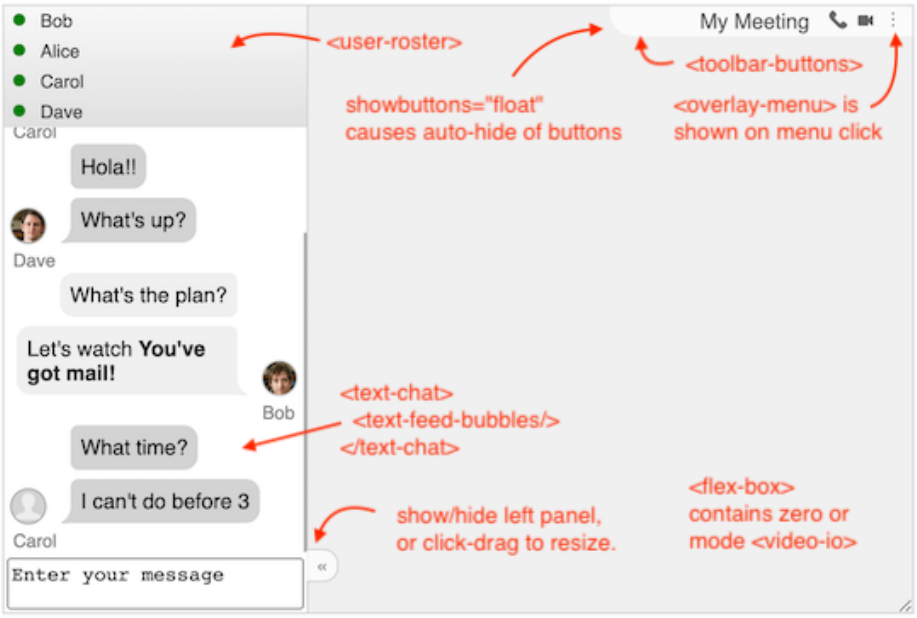
33.1 Messenger vs. Hangout

The user interface is highly customizable to cater to different scenarios. The `display` property controls the overall layout. It can be set to messenger, hangout, filmstrip or videocity.

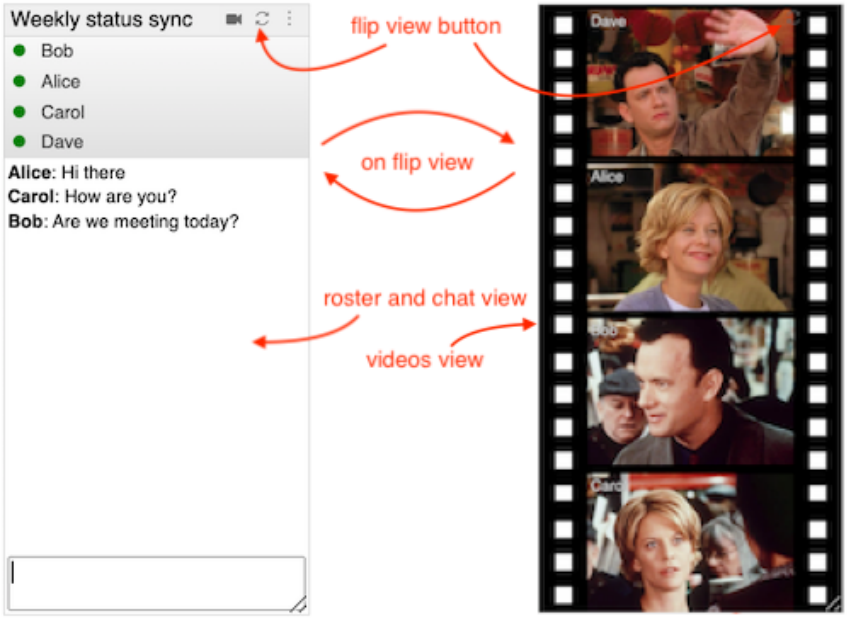
The messenger display is similar to chat-first apps such as once popular Yahoo messenger, with focus on text chat, and inline videos box when needed. The order of included components determines the display order in which the user-roster, text-chat and flex-box (videos box) are displayed.



The hangout display is similar to video-first apps such as Google hangout, with focus on videos, and the ability to show chat and roster on the side. The order of included user-roster and text-chat determines their display order. Also, whether the flex-box is included before or after those components, determines whether the videos appear on the left or right of those components.



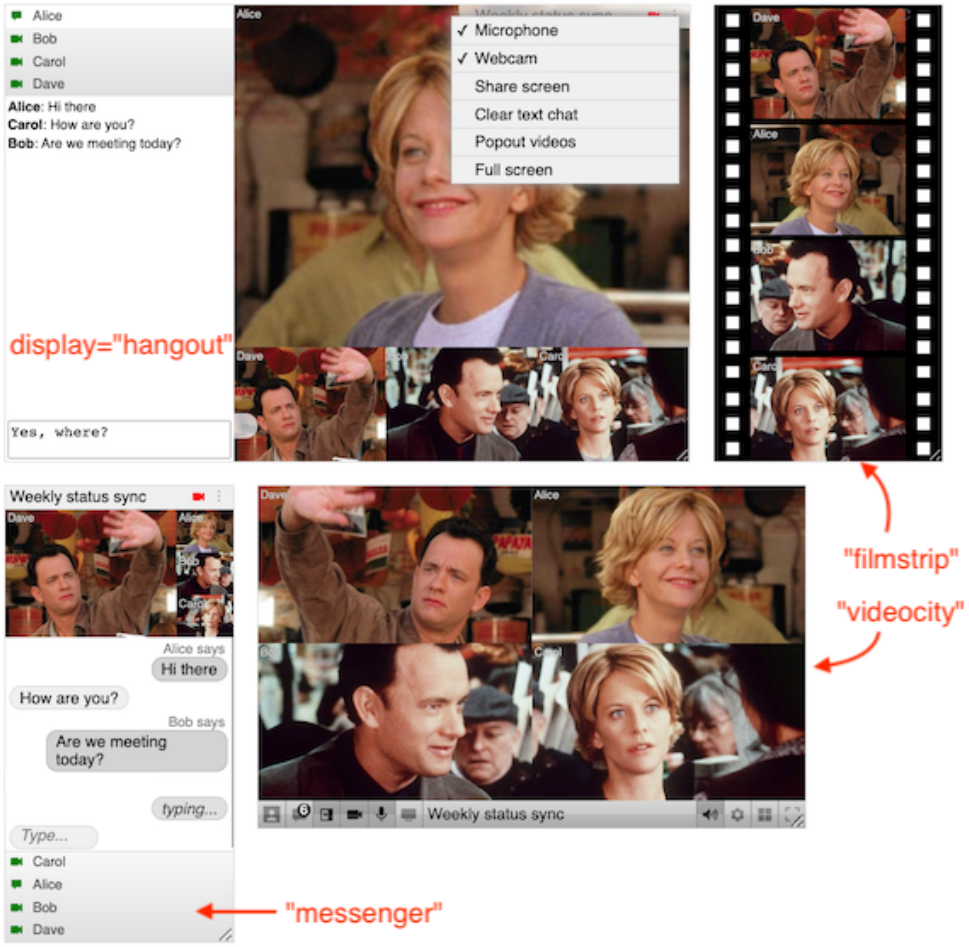
The filmstrip display is intended for a narrow aspect ratio near the side of display area. Without any audio or video call, it appears similar to the messenger display, with the order of text-chat and user-roster preserved based on the included components' order. However, videos are displayed in a separate view. The flip view buttons allows flipping between the chat and roster view on one side and the list of videos laid out in filmstrip on the other.



The videocity display is inspired from my earlier Flash-based project (https://github.com/theintencity/videocity) of the same name. It displays a video player style interface, where all the elements such as text-chat, user-roster, individual video or screen share, or other items, are included in a `flex-box` component. The display's intended use case is to embed it in a web page.

Try the following example with four `media-chat` instances in four different display values: hangout, filmstrip, messenger, and videocity, respectively.

```
<media-chat ... display="hangout" showheader="false">
    <toolbar-buttons ...>...</toolbar-buttons>
    <overlay-menu ...>...</overlay-menu>
    <user-roster ...></user-roster>
    <flex-box ... disallow="dragmove"></flex-box>
    <text-chat ...>...</text-chat>
</media-chat>
<media-chat ... display="filmstrip">
    <toolbar-buttons ...>...</toolbar-buttons>
    <overlay-menu ...>...</overlay-menu>
    <flex-box ... disallow="dragmove,dblclick"></flex-box>
    <user-roster ...></user-roster>
    <text-chat ...></text-chat>
</media-chat>
<media-chat ... display="messenger">
    <toolbar-buttons ...>...</toolbar-buttons>
    <overlay-menu ...>...</overlay-menu>
    <flex-box ... disallow="dragmove"></flex-box>
    <text-chat ...></text-chat>
    <user-roster ...></user-roster>
</media-chat>
<media-chat ... display="videocity">
    <toolbar-buttons ...>...</toolbar-buttons>
    <overlay-menu ...>...</overlay-menu>
    <flex-box ... disallow="dragmove"></flex-box>
    <text-chat ...></text-chat>
    <user-roster ...></user-roster>
</media-chat>
```



These examples allow resizing the components to see the layout update, especially for hangout display, which auto-hides the sidebar on small width. If the `showchat` attribute is set, then resize does not change the sidebar display. Certain features such as dragmove and dblclick of the included `flex-box` components are disabled in different display modes. The dragmove usually interferes with animation, and dblclick is already used to flip the view in the filmstrip display.

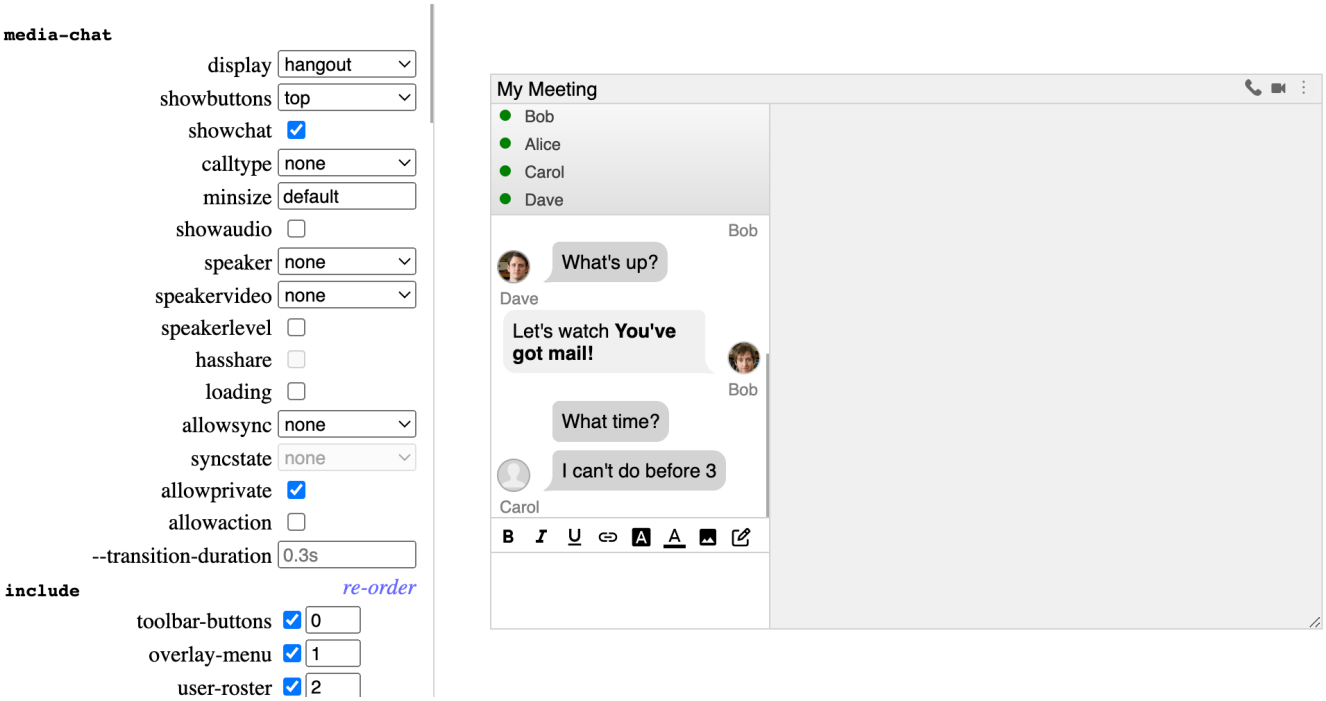
In the examples above, the `toolbar-buttons` component is shown by default at the top for all displays, except for videocity, where it appears at the bottom. The toolbar shows the optional topic, and includes some buttons to initiate or terminate an audio or video call. It can optionally include a menu item, in which case the separate `overlay-menu` component is shown when clicked. The filmstrip display should include a flip view button, and should not include audio call button.

Additionally, it can show a button to clear the text chat. If the menu item is included, then the clear button is replaced by the menu button in the examples below, which when clicked shows a dropdown menu defined by the `overlay-menu` component. The menu contains other options besides clearing the text chat. For example, it allows turning on or off devices such as microphone or webcam. It allows sharing screen or tab or window. It also allows popping out the videos box in a separate window.

The display of a received video depends on the display property: in messenger, received videos are not shown unless the local user is also joined with video; in hangout, received videos are shown if joined with audio or video; and in filmstrip or videocity, received videos are shown even if not joined with audio or video, as soon as another user enables the video. The display also affects when the screen share can be enabled. For example, in messenger, it can be enabled after joining with video; in hangout or filmstrip, it can be enabled after joining with audio or video; but in videocity, it can be enabled without joining the call.

The `showchat` property can control whether to show the chat view. When display is filmstrip, it shows either the chat view or the flipped video view. When display is hangout, chat and roster appear in the sidebar, and the display can also change on clicking the toggle button, or automatically on resize depending on the width of the component. In hangout display, the toggle button can be click-dragged to resize the chat versus videos area.

Try the following example to see the various properties of various connected components in action. It also allows changing the toolbar and menu items.



The left side in the above example allows changing various properties and styles. The right side shows the component in action. There are some pre-configured items in the user-roster and text-chat for demonstration purpose. The left side also allows sending a sample text message from another user.

33.2 toolbar-buttons and overlay-menu

The `toolbar-buttons` and `overlay-menu` components are used in the previous examples to customize the toolbar buttons and the overlay menu. The overlay menu is shown when the menu button in the toolbar is clicked.

The `toolbar-buttons` component can include other elements such as `button` or `span`. An included button can be customized by the application. Pre-configured customization of certain buttons and actions is already implemented, and is configured using the `name`, `toggle` and `show-if` attributes. Additionally, if `toggle` is set, then `selected` attribute can make it on by default.

The following example shows a toolbar with four items - a static text for title, and three buttons -

with pre-configured display and action.

```
<toolbar-buttons ...>
    <span>Weekly status sync</span>
    <button name="audio" toggle title="start/stop an audio call"></button>
    <button name="video" toggle title="start/stop a video call"></button>
    <button name="menu" title="more actions"></button>
</toolbar-buttons>
```

The `overlay-menu` component, if included, is automatically shown when the menu button is clicked in the toolbar. It can include other `span` elements for customization. The included span can be customized by the application. Pre-configured customization of certain actions is already implemented, and is configured using the `name`, `toggle` and `show-if` attributes. Additionally, if `toggle` is set, then `checked` attribute can make it on or off by default.

Unlike a toggle button with two display states, the menu item can be shown in three states - checked, crossed, or no marking (neither checked or crossed). If the `toggle` attribute is included without any value, then the menu item allows checked or no marking states only. If the `toggle` attribute is set with value of true, then the menu item allows checked or crossed states only. These differences are useful in representing states of different activities or features, e.g., toggle="true" is used to show camera or microphone state, whereas toggle is used to show screen share or full screen state.

The following example shows a menu with six items. Some of the items have implicit display constraints, e.g., screenshare or popout is not shown unless video call is active in the messenger display.

```
<overlay-menu slot="menu">
    <span name="microphone" toggle="true" checked="true">Microphone</span>
    <span name="camera" toggle="true" checked="true">Webcam</span>
    <span name="screenshare" toggle>Share screen</span>
    <span name="clear">Clear text chat</span>
    <span name="popout">Popout videos</span>
    <span name="fullscreen" toggle>Full screen</span>
</overlay-menu>
```

The `show-if` attribute, if present on the items included in the toolbar or menu, controls when that button or menu item is shown. The attribute value is a condition that can use some pre-defined state variables. The following example shows that the screenshare menu item is shown when calltype is not "none", and popout is shown when calltype is "video" and popout does not already exist. This attribute's value must be assigned during element initialization, and must not be changed later.

```
<overlay-menu slot="menu">
    ...
    <span name="screenshare" toggle show-if="calltype!='none'">Share
screen</span>
    <span name="popout" show-if="!popout && calltype=='video'">Popout
videos</span>
</overlay-menu>
```

The pre-defined state variables are as follows: display, calltype, popout, hasmenu, selfvideo, othervideos. The display and calltype string variables correspond to the same named properties of the `media-chat` component. The popout and hasmenu boolean variables indicate whether popout already exists, and whether `overlay-menu` component exists, respectively. The selfvideo boolean variable is true when a publishing `video-io` component for local audio and/or video exists, and the othervideos boolean variable is true when one or more subscribing `video-io` components exist.

For pre-configured items in toolbar or menu, the `toggle` state is also pre-defined, and must be used accordingly. The following table shows all the pre-configured items and their behavior.

Feature	Description
`roster`	(toggle) show or hide the user roster, applicable only when display="videocity".
`chat`	(toggle) show or hide the text chat, applicable only when display="videocity".
`video`	(toggle) start or stop a video call from this client.
`audio`	(toggle) start or stop an audio call from this client.
`upload`	(not yet implemented) Upload some media or file to share with others.
`camera`	(toggle=true) Enable or disable local webcam.
`microphone`	(toggle=true) Enable or disable local microphone.
`sound`	(toggle) Enable or disable speaker sound.
`flip`	Change the view between chat-roster and videos, applicable only when display="filmstrip".
`settings`	(not yet implemented) show device and/or client settings.
`layout`	Change the display property of the included flex-box to cycle through flex, grid, pip, page, and inline-block.
`fullscreen`	(toggle) enable or disable the full screen mode.
`screenshare`	(toggle) start or stop screen or window share.
`clear`	Clear the text chat history locally.
`menu`	Show the included overlay-menu component.

The example shown previously allows experimenting with various buttons and menu items in different displays. In particular, the order of the items in these components determines the display order within the toolbar or menu. The `showbuttons` attribute of `media-chat` component determines where and how the toolbar appears, e.g., top or bottom, none or a special value of float. If set to float, then the toolbar auto-hides after few seconds when the mouse is not over the component.

33.3 Active speaker

The `speaker` and `speakervideo` properties control how to display active speakers or talkers. The included `user-roster` component can highlight the active speaker by changing the background color, icon, shadow on the icon, or the display order of users in the roster. This is controlled using the `speaker` property. On the other hand, the `speakervideo` property allows highlighting active speaker in the videos display, e.g., by slowly zooming in, setting a border color, making the speaker video as float in the `flex-box` component, or changing non-speakers to monochrome color.

33.4 Sound level

The `volume-level` component can be used to display the sound activity level of the microphone or speaker sound, as well as to display and control the volume or gain. The examples shown earlier with display of "videocity" demonstrate this. Internally, the microphone level is captured using the included publishing `video-io` component, whereas the speaker level is captured by aggregating the sound levels of all the subscribed `video-io` components included in the `media-chat` component. Note that the `speakerlevel` property of the component must be set for this to work.

33.5 Private text message

By default, entering a text message in the `media-chat` component's included `text-chat` component, sends it to the text chat channel, and is viewable by all the participants. Using the `allowprivate` property, it also supports sending a private text message, by prefixing the message with the special @ character, e.g., "@alice How are you?" will be sent to only the user with identifier alice from the roster. Such private messages are not stored in chat history of the storage, and hence, are not available on reload, or if the target user is not yet joined. In the user interface, clicking on the user item in the roster automatically puts the prefix in the text input area to allow sending the private message. The text chat display also labels the private messages by including sender and receiver both, instead of just sender name for public messages.

33.6 Custom command on text input

If the `allowaction` property is set, then text input starting with forward slash / character is treated as an action command, and an event is dispatched to the application instead of sending that text on the

text chat channel. This allows intercepting such actions, e.g., the text entered as "/join video" could be interpreted in the application to join the call with video. More concrete examples of such actions will be shown later.

33.7 Synchronized layout

The `allowsync` and `syncstate` properties control and indicate how the layout of the videos part is synchronized among the participants. Note that this is not supported when display is filmstrip. In all other cases, it can choose to optionally synchronize layout - from loose to strict modes - where one participant becomes the owner of the layout, and shares layout attributes with others, who then attempt to synchronize their layout with the received attributes. In loose synchronization, high level attributes such as which video is float in the flex-box and/or what display is used, is shared, whereas in strict mode, relative positions and sizes of all the boxes in flex-box are shared.

33.8 media-chat

The following table describes all the properties of the `media-chat` component.

Name	Type and description
`display`	string, default is "messenger" Controls the display layout of the various features. Allowed values are messenger, hangout and filmstrip.
`showbuttons`	string, default is "top" Controls and indicates how to show toolbar buttons. The float value should be used only when display is hangout or videocity
`showchat`	bool, default is true Controls and indicates whether to show the chat and roster view when display is hangout or filmstrip.
`calltype`	string, default is "none" Indicates the active or pending call type. Allowed values are "none", "audio"

or "video". It can only set calltype to or from none, and to set from audio to video or vice-versa, first set this to none.

`videos-ratio` number, default is 1.778

Controls the aspect ratio of the videos box when display is messenger. Its height is adjusted based on the width and this aspect ratio.

`minsize` string, default is "default"

Sets the minimum size of the component. Example: "300x200". If set to "default", then a reasonable value is picked based on the display property. If the actual size is smaller than this, then it applies zoom to shrink it proportionally. This is useful to display the component where size could become too small for it to be displayed correctly.

See `display`

`showaudio` bool, default is false

Controls whether to show a video box for participants that joined with audio. Note that it is already shown for participants that join with video.

`speaker` string, default is "none"

Controls whether and how to show the active speaker in the roster display. Allowed values are none, color, icon, iconshadow. If set to color, then the speaker's background color is changed. If set to icon, then the speaker's icon is altered to a speaker icon. If set to iconshadow, then the speaker's icon shows a drop-shadow. There may be zero or more active speaker at any time. If set to order, then speaker's are shown before non-speakers. This last value is not yet implemented.

`speakervideo` string, default is "none"

Controls whether and how to show the active speaker in the videos display. Allowed values are none, float, zoom, color, border. If set to float, then a speaker's video, if any, is set as float in the included flex-box. If set to zoom, then the speaker's video is zoomed in slightly. If set to color, then speaker's video is shown with default colors and non-speaker video is turned into

greyscale. If set to border, then a border is shown on the speaker's video. There may be zero or more active speaker at any time. If the property is set to float, then only one video can be float. In that case, the last speaker is kept as float unless it is no longer a speaker for some time, and another speaker is active. The most reset speaker is picked to be float when needed.

`speakerlevel` bool, default is false

Controls whether to detect sound level for publish and subscribe videos. This must be set to true, if the toolbar-buttons include volume-control for miclevel and/or soundlevel, and the sound level is to be displayed there.

`hasshare` bool (read-only), default is false

Indicates whether the videos box includes a non-video share item. This can be used as condition to show popout or other toolbar-buttons or overlay-menu items.

`loading` bool, default is false

Controls whether the component is in a loading state or not. The user interface is altered to indicate loading state.

`devices` object, default is null

Controls the default devices to pick for microphone, sound and webcam. If not set, then it does not explicitly select the devices. If set to an object of the form {audioinput: {deviceId: ...}, videoinput: {deviceId: ...}, audiooutput: {deviceId: ...}} then those device identifiers are used. If a device type is missing, then the default for that is picked.

`allowsync` string, default is "none"

Controls whether and how to synchronize the layout of the videos view of this participant's client with other connected participants' clients. Allowed values are none, float, display and strict. If set to none, then the feature is disabled, and any received sync is ignored. For any other value, this client can control the layout, by calling startsync, and can update the videos view layout based on received sync. If set to float, the only the float item in the

flex-box is changed based on the received sync. If set to display, then in addition to float, other display related attributes are also changed for the flex-box and its children, based on the received sync. If set to strict, then the client strictly follows the layout of the sync sender including to disallow the local user to change the layout on double click, to preserve the order and attributes of child elements, and to remove the child items such as media-share with container videos that are missing in the received sync.
See `syncstate`

`syncstate` string (read-only), default is "none"
Indicates the current state of videos view layout synchronization. Note that the state is always none, if the display is filmstrip or the allowsync property is none. Additionally, if the layout sync is currently not active, then the state is none, too.
See `allowsync`, method `startsync`

`allowprivate` bool, default is true
Controls whether to allow sending and receiving private chat messages. If enabled, then it interprets text messages starting with @ as private and sends to only one target. For example, "@bob Hello there" will be sent only to user bob with text "Hello there". A sent or received private message is displayed with the appropriate label such as "Alice to Bob". Note that the private message is not stored in the attached storage, but is only exchanged via real-time notification, hence will not be available in the message history if the chat is reloaded. If disabled, then no special interpretation is done for messages starting with @, and received private messages are ignored. It is risky to disable this property without proper indication or user notification, as the user might attempt to send a private message without knowing that it will not be private and that it will be sent to everyone.

`allowaction` bool, default is false
Controls whether to allow triggering actions from chat input area. If enabled,

	then it interprets text messages starting with / as action commands, and dispatches the action event instead of sending the text message. For example, "/survey 'Do you like this? [Yes][No]'" will trigger the event {type: "action", value: "survey Do you like this? [Yes][No]"}. The action texts are not stored in the message history and are not visible to other participants. It is risky to disable this property without proper indication or user notification, as the user might attempt to trigger an action without knowing that it will not be interpreted as action, and will be sent to everyone.
`displayname`	string (read-only) Indicates the display name of the self instance from the associated data model if any.
`self`	string (read-only) Indicates the identifier of the self instance from the associated data model if any.
`data`	object underlying data model component instance.
`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `media-chat` component.

Function	Signature and description
`startshare`	media.startshare({type: "whiteboard", ...}) Start the app share by sending the shared app data to all the other connected components using the underlying data model. It adds the from and fromid

	attributes to the supplied data.
`stopshare`	media.stopshare("...") Stop the app share by removing the shared app data using the underlying data model. If no id is suppied, then it removes all the shared app data previously shared usig startshare by this or other connected clients.
`addshare`	media.addshare("...", {...}, div, "feed") Add an app view to the display using the supplied information. This is implicitly called on receiving the shared app data, if the application event handler of addshare supplies a app view. When invoked this way, an additional last argument is supplied as MessageChannel for communication among all connected shared app instances using the storage of the underlying data model.
`removeshare`	media.removeshare("...") Removes the app view from the display.

The following table shows all the events dispatched by the `media-chat` component.

Event	Example and description
`addvideo`	{type: "addvideo", id: ..., video: ...} Dispatched when a new video-io element is about to be added. The DOM element is supplied as the video attribute.
`removevideo`	{type: "removevideo", id: ..., video: ...} Dispatched when a video-io element is removed. The DOM element is supplied as the video attribute.
`calltype`	{type: "calltype"} Dispatched when the calltype property changes.
`change`	{type: "change"} Dispatched on any change in this component, that could affect the position,

	size or display of a child element. This is useful for repositioning an external shared-editor with the included text-chat.
`syncstate`	{type: "syncstate"} Dispatched when the syncstate property changes.
`action`	{type: "action", value: "start whiteboard"} Dispatched when allowaction is set, and an action command is entered in the text chat input area, starting with the forward slash character /, such as "/start whiteboard".
`addshare`	{type: "addshare", id: ..., data: ..., container: ..., port: ...} Dispatched when a shared app data is received. This gives an opportunity to the application to set an app view or to ignore the data. To set the app view, the application sets the view property of the event to a DOM element. The additional properties in the event object are similar to the addshare method arguments, except that the container property is optional and only indicates the desired container if any, which the application can change if needed. If the container is not already set, then the application must set the container.
`removeshare`	{type: "removeshare", id: ..., view: ..., data: ..., container: ..., port: ...} Dispatched when a shared app data is removed. The extra informtion is similar to the addshare event, except that an additional view property indicates the previously created view element as part of the addshare processing. Note that port is optional, and only present if previously a message channel was used during addshare.

The user interface of the `media-chat` component can be customized using the following styles.

Style	Description and default
`--transition-duration`	Default `0.3s` transition-duration for size change animation of various components. The transition-duration for flip when display is

filmstrip is three times this value.

The following table describes all the properties of the `media-chat-data` component.

Name	Type and description
`feed`	object (read-only) A reference to the underlying text-feed-data component instance.
`roster`	object (read-only) A reference to the underlying user-roster-data component instance.
`displayname`	string, default is "Anonymous" Controls the display name of the self instance.
`self`	string, default is "" Controls the identifier of the self instance. This must be unique among all the instances of the media-chat with the same storage path.
`path`	string, default is "" Storage path of the list data representing the media chat, e.g., "sessions/conf123". Internally, it assigns the sub-paths of "users" and "messages" to the included user-roster and text-chat components. Please see those for the interpretation of the data.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is "" Use this to set the id of the external shared storage DOM element. See `storage`

`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `media-chat-data` component.

Function	Signature and description
`add_call`	data.add_call("...", {...}) Add a new participant in the call.
`remove_call`	data.remove_call("...") Remove a participants from the call.
`add_share`	const id = await data.add_share({...}) Add a share item, and returns a promise that resolves to the id of the share item.
`remove_share`	data.remove_share("...") Remove a share item by id.
`add_info`	data.add_info("...") Add a text info message on the chat feed.
`set_user`	data.set_user({...}) Set the self user data in the roster.
`set_user_attrs`	data.set_user_attrs({...}) Update the attributes on the self user data in the roster.

The following table shows all the events dispatched by the `media-chat-data` component.

Event	Example and description
`addself`	Dispatched when the storage is ready and path, self and displayname are set.

`addcall`	{type: "addcall", id: "...", value: {...}} Dispatched when a user is added to the call.
`removecall`	{type: "removecall", id: "..."} Dispatched when a user is removed from the call.

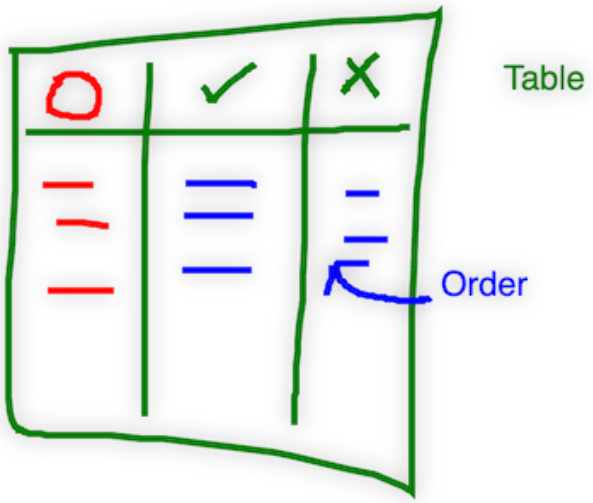
The `media-chat` component described here is versatile and customizable using its various properties such as display, speakervideo, allowsync, allowaction, and others. Later, we will further explore how to share custom apps with other participants in a chat.

34. How to use a shared whiteboard or notepad?

Shared white board and notepad are important collaboration tool. The `white-board` component implements a simple white board which can be attached to a `white-board-data` data model to enable shared white board.

Try the following example to see the `white-board` component in action.

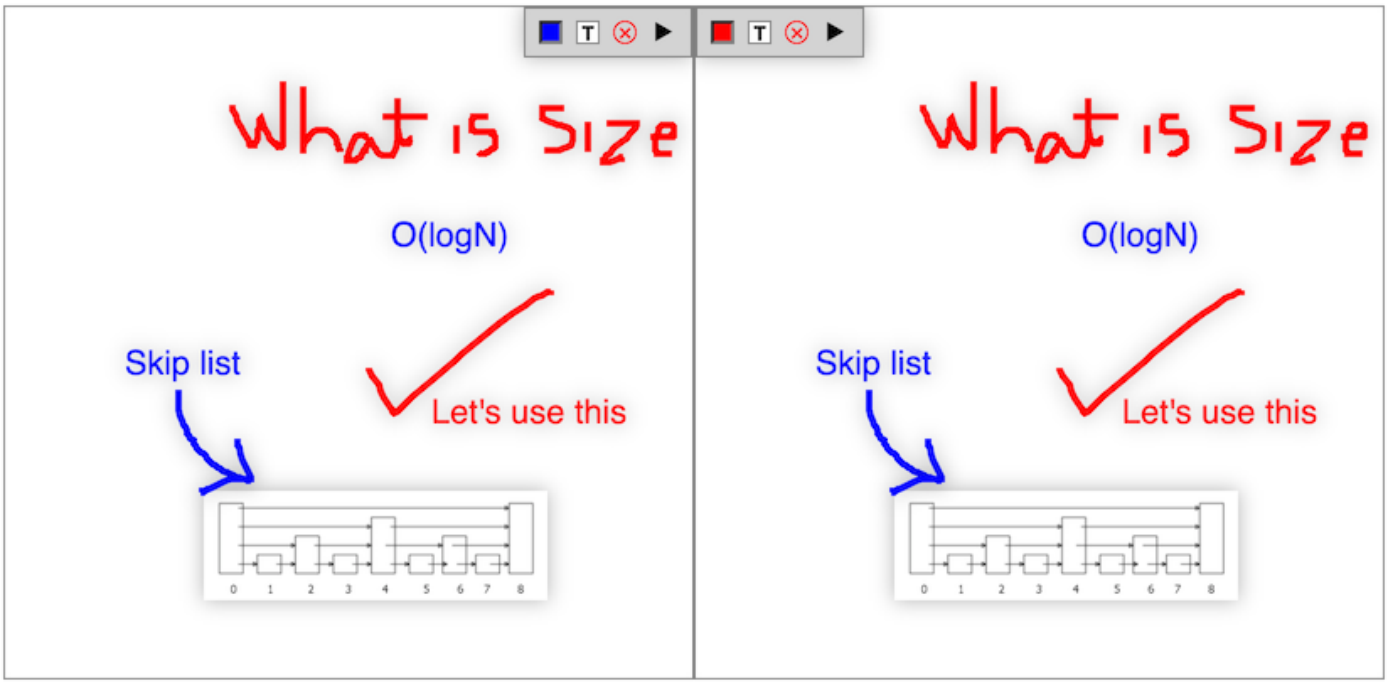
```
<white-board></white-board>
```



Besides drawings and text inserts, it also allows drag and drop of image files.

Try the following example of two shared `white-board` instances attached to the same storage path using two separate `white-board-data` instances, representing two collaborating users.

```
<white-board-data id="data1" for-storage="..." path="..." ></white-board-data>
<white-board for-data="data1"></white-board>
```



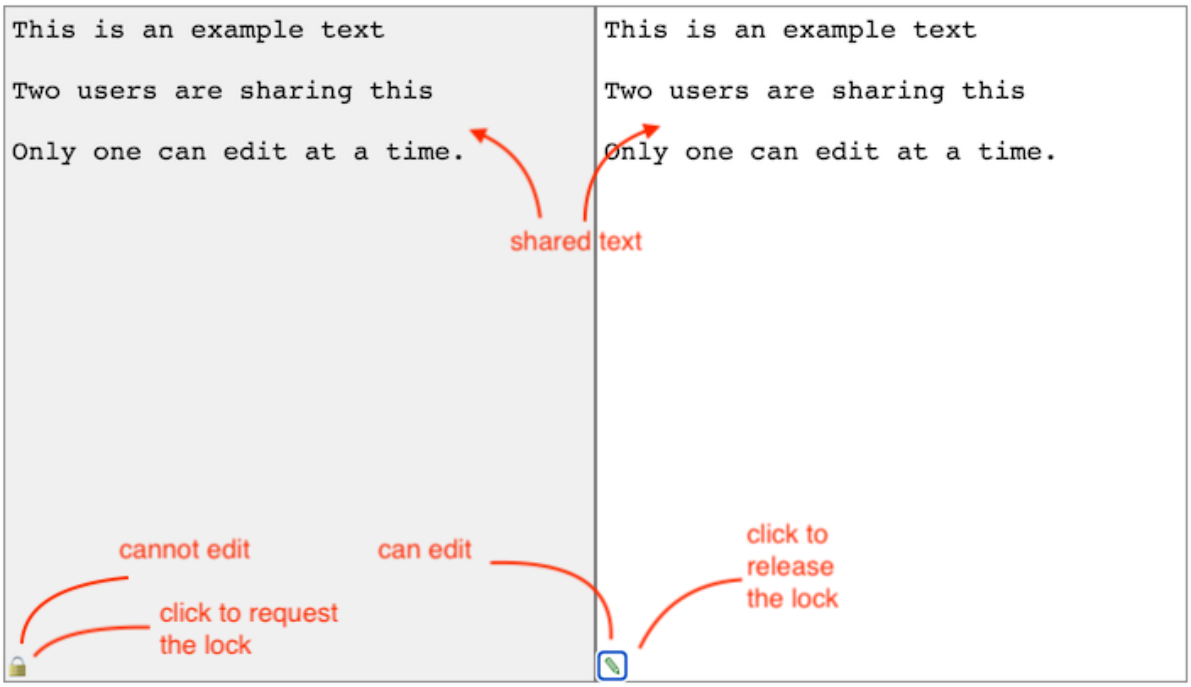
The data architecture uses a list of drawings, text or content information in the shared storage. The ordering of the list items is important. The item data includes all the information needed to render the drawing, text or content.

The `locked-notepad` component implements a text editor that can be locked for editing to avoid conflict. It can be attached to a `locked-notepad-data` data model to enable shared notepad.

```
<locked-notepad></locked-notepad>
```

Try the following example of two `locked-notepad` instances attached to the same path on storage using two separate `locked-notepad-data` instances, representing two collaborating users.

```
<locked-notepad-data id="data1" self="alice" for-storage="..." path="..."
></locked-notepad-data>
<locked-notepad for-data="data1"></locked-notepad>
```



Only one user may have the editing lock at any time. Note that editing is allowed only when lock is acquired, as indicated by the pencil icon. To gain the lock, click on the lock icon at the bottom. If the lock is actively used by the other user, that user must release the lock first by clicking on the pencil icon. On inactivity, the lock is automatically released. The identifier of the user indicated by the `self` attribute is used to store the lock in the storage.

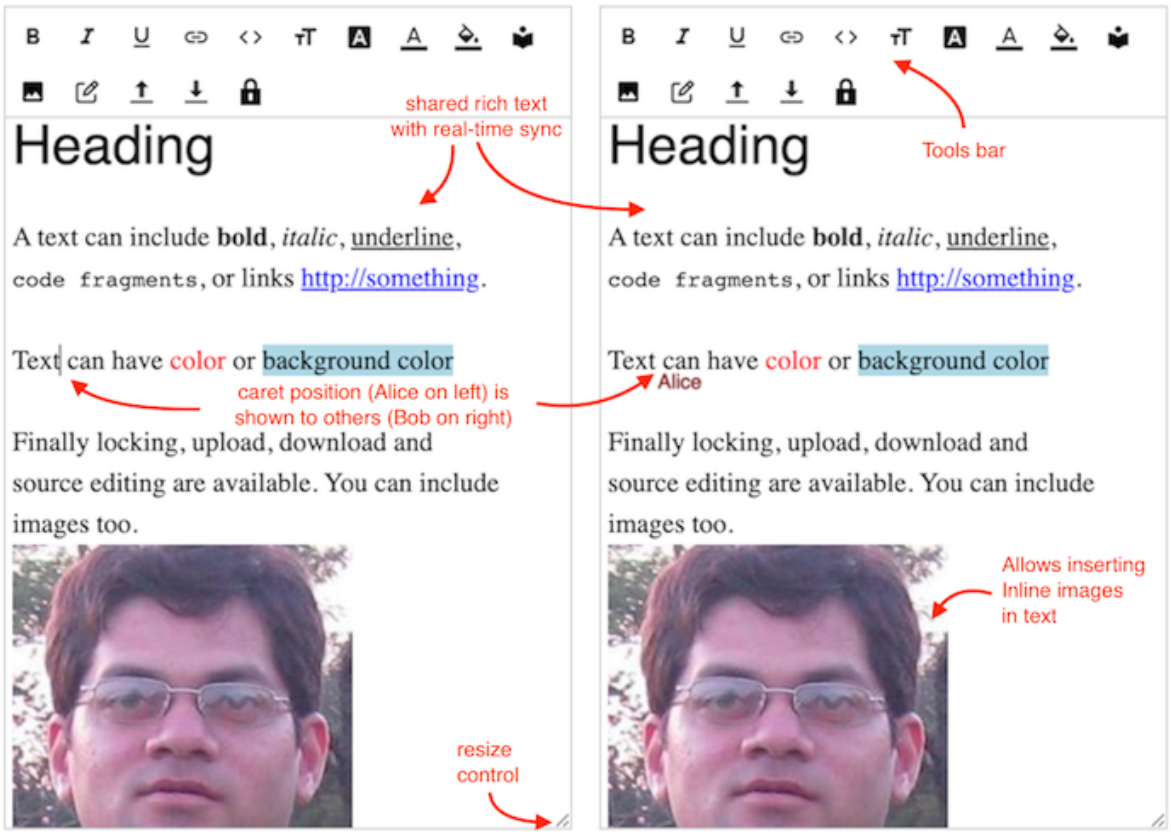
The component also supports various non-trivial forms for editing such as copy, cut and paste. The editing is propagated to other instances on the storage path using the notification messages of the shared storage. The data architecture uses the last commited copy of the entire text followed by delta changes of the current editing session. Once the editing lock is released by this user, or acquired by another user, the delta changes are merged and the commited copy is updated.

The `shared-editor` component, on the other hand, includes a rich-text-editor. Unlike the previous component, this one does not require locking to edit the text, although locking is supported to avoid conflict. Like the previous component, this one can also be attached to a data model, `shared-editor-data`, and a shared storage to enable shared editing.

```
<shared-editor></shared-editor>
```

Try the following example of two `shared-editor` instances attached to the same path on storage, representing two collaborating users.

```
<shared-editor-data id="data1" self="alice" for-storage="..." path="..."
></shared-editor-data>
<shared-editor for-data="data1"></shared-editor>
```



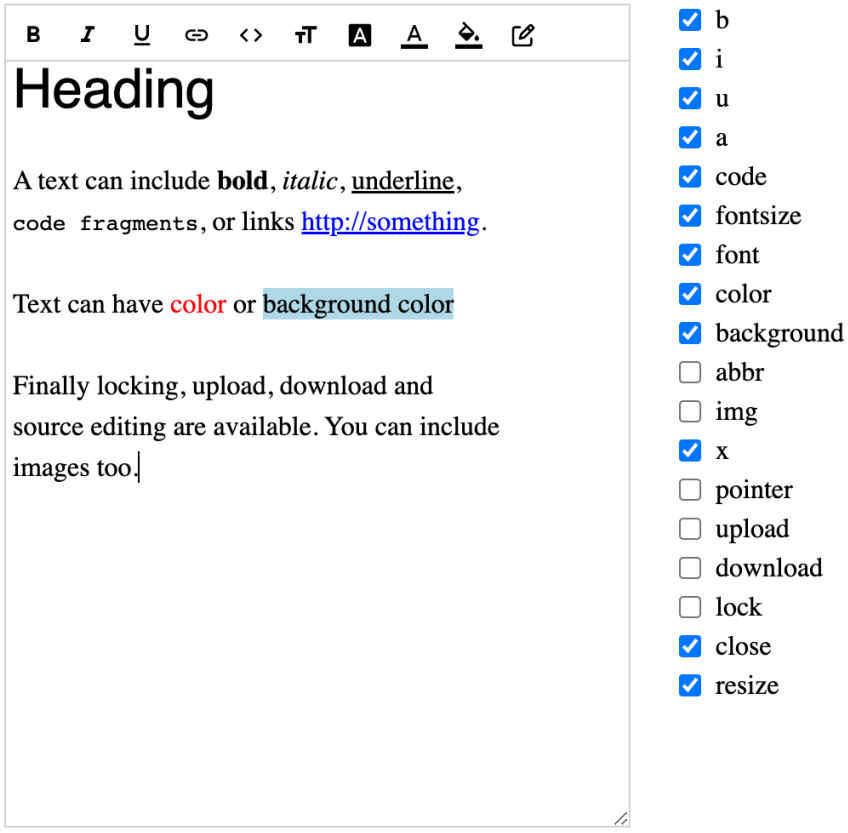
Our implementation has only some of the basic rich text editing support. Moreover, the real-time synchronization of the shared text can have inconsistencies due to conflicts in simultaneous editing on connected instances. However, it shows the concept, and in the future, the consistency may be improved using operational transforms.

In the current implementation, to work around the inconsistencies, we provide a feature to perform locked editing and upload. When the editor is locked, only the owner can edit the shared text, and others see a copy of it. When the owner unlocks the editor, he can upload her local edited copy to the shared storage, which gets delivered to other connected instances.

At most one user may have the editing lock at any time. However, if no user has the editing lock, then any user can edit the shared text.

The tools bar includes several rich text editing options, in addition to other functions such as to upload the text to shared storage or to download the text from shared storage. The source text is stored as HTML. Inserting an image is allowed. Clicking on an inserted image allows adjusting the size. However, the size change is not propagated implicitly to the shared storage or other users, because there is no easy way to identify the same image on the receiver side. This may get fixed in the future. The tools bar size is reduced when the component size falls below some threshold in width or height. You can try that by resizing the component.

The component can be used as a standalone rich text editor without a shared storage. Try the following example of a standalone editor, with various features enabled or disabled.



When a data model is attached, it uses the data model for the baseline text, incremental changes, and the editing lock, if any. The caret and/or cursor position of the remote users on the shared editor is also shown. Similar to the previous component, this one commits the incremental changes on certain events such as when the upload button is clicked, or the source HTML editing is completed.

34.1 white-board

The following table describes all the properties of the `white-board` component.

Name	Type and description
`controls`	bool, default is true Controls whether to enable the user interface elements to allow drawings and other items.

`position` string, default is "top-left"
Position of the controls if enabled. Allowed values are bottom-right, top-right, bottom-left and top-left.

`strokecolor` string, default is "green"
Controls the pen color of the drawing initiated by user interaction in this component.
See `strokewidth`

`strokewidth` number, default is 4
Controls the pen width of the drawing initiated by user interaction in this component.
See `strokecolor`

`droppable` bool, default is true
Controls whether the user can drop an image file on this component to add the image.

`imageratio` number, default is 0.5
Controls the ratio of the image to add when dropped. Use less than 1.0 to scale down.
See `droppable`

`sizelimit` number, default is 6000000
Controls the maximum file size in bytes of the image that can be dropped.

`content` string
Content of the white board drawings as string in SVG format. Setting the content is allowed only when not attached to a data model. This is because setting the content to an arbitrary SVG string is not easy to share in a structured way.

`cursor` bool, default is false
Controls whether mouse cursor position is shared with others or not. This is useful in real-time collaboration.

	See `label`
`label`	string, default is `""` Controls the label shown on the cursor of this instance, when viewed on other connected instances, when cursor position is shared. If not set, it uses the self property as default.
`items`	object (read-only) Contains the current list of all the drawings and other items. The application should not modify the content of this property.
`data`	object underlying data model component instance.
`for-data`	string, default is `""` Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The user interface of the `white-board` component can be customized using the following styles.

Style	Description and default
`--filter-controls`	Default `drop-shadow(0px 0px 6px rgba(0,0,0,0.3))` Any CSS filter to apply to controls. Default is a drop-shadow.
`--filter-content`	Default `drop-shadow(0px 0px 6px rgba(0,0,0,0.3))` Any CSS filter to apply to drawings and other content. Default is a drop-shadow.

The following table describes all the properties of the `white-board-data` component.

Name	Type and description
`self`	string (read-only), default is "" Indicates the identifier of the self instance. This may be used by the application to avoid collision of item changes
`path`	string, default is "" Storage path of the drawing data to store and show the from, e.g., "sessions/wb123". Each item in the storage must be a JSON object of the form {type: "draw", sender: "...", d: "...svg path...", strokecolor: "..."}. If type is "draw", then d and strokecolor must be present. If type is "text" then text, x, y, font-size, font-family and fill must be present. If type is "image" then filename, filetype, dataurl, x, y, width, height must be present.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is "" Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `white-board-data` component.

Function	Signature and description
`add`	data.add({...}, id => {...}) Add an item to storage. The supplied value is sent in the add event to connected

	instances. Invoke the success callback with the item id, when done.
`remove`	data.remove("...") Remove the item from storage, based on the supplied id. This will trigger the remove event to connected instances.
`removeall`	data.removeall() Remove all the items from this storage. This will trigger zero or more remove events to the connected instances.
`cursor`	data.cursor({...}) Send the cursor position and label. This will trigger the cursor event on the connected instances.

The following table shows all the events dispatched by the `white-board-data` component.

Event	Example and description
`add`	{type: "add", id: "...", value: {...}, offline: true} Dispatched when an item is added.
`remove`	{type: "remove", id: "..."} Dispatched when an item is removed.
`cursor`	{type: "cursor", datatype: "...", sender: "...", cursor: {...}, mine: false} Dispatched when cursor position and label are received. The datatype is one of mouseover, mousemove or mouseout.

34.2 locked-notepad

The following table describes all the properties of the `locked-notepad` component.

Name	Type and description
`controls`	bool, default is true

	Controls whether to enable the user interface elements to lock or unlock. A lock is needed for editing the text pad.
`locked`	bool, default is false Controls and indicates whether the text pad is locked for local editing or not?
`autounlock`	number, default is 30000 Controls the time in milliseconds to auto-unlock on no activity.
`content`	string (read-only) The current text shown by the text pad.
`data`	object underlying data model component instance.
`for-data`	string, default is `""` Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `locked-notepad` component.

Function	Signature and description
`togglelock`	notepad.togglelock() Toggle the lock of the component by this user See method `lock`, method `unlock`
`lock`	notepad.lock(() => {... completed }) Get the lock by this user
`unlock`	notepad.unlock() Release the lock by this user

The user interface of the `locked-notepad` component can be customized using the following styles.

Style	Description and default
`--font-family`	Default `monospace` font-family of the text
`--font-size`	Default `1rem` font-size of the text
`--color`	Default `black` color of the text
`--background-color-locked`	Default `white` background-color when locked and editing is allowed
`--background-color-unlocked`	Default `#f0f0f0` background-color when not locked and editing is not allowed

The following table describes all the properties of the `locked-notepad-data` component.

Name	Type and description
`self`	string, default is `""` Controls the identifier of the self instance. This must be unique among all the instances of shared notepad connected to the same storage path.
`path`	string, default is `""` storage path of the text and other data related to this component.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object

	underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `locked-notepad-data` component.

Function	Signature and description
`read_lock`	data.read_lock().then(...).catch(...) Returns a promise that resolves when lock exists with an object containing name of the lock owner, or rejects when the lock does not exist.
`create_lock`	data.create_lock({name: "..."}).then(...).catch(...) Returns a promise that resolves when lock is created with the supplied data.
`delete_lock`	data.delete_lock().then(...).catch(...) Returns a promise that resolves when the lock is deleted.
`send_status`	data.send_status("...") Send a status notification to either a specific instance or to all the connected instances on the same path.
`set_text`	data.set_text("...") Update the editor text in storage. Once successfully updated, it removes all the incremental changes, and calls the supplied callback.
`post_change`	data.post_change({...})

If storage is ready and path and self are set, then add the supplied change to storage.

The following table shows all the events dispatched by the `locked-notepad-data` component.

Event	Example and description
`ready`	Dispatched when the storage is ready
`text`	{type: "text", data: {text: "..."}} Dispatched when the editor text is updated in the storage. The data object may be empty if the text is deleted.
`change`	{type: "change", data: {...}} Dispatched when a incremental change is added.
`status`	{type: "status", data: "..."} Dispatched when a status notification is received.
`unlock`	{type: "unlock"} Dispatched when the lock is deleted on the path.

34.3 shared-editor

The complete list of features in the tools bar are as follows:

Feature	Example and description
`Bold`	`This is <strong>bold</strong>` Bold text using the tag. Select some text and click on button. If the selection is already a part of an existing such tag, then the tag is removed. Shortcut is ctrl+B
`Italic`	`This is <em>italic</em>`

Italic text using the tag. Select some text and click on button. If the selection is already a part of an existing such tag, then the tag is removed. Shortcut is ctrl+I

`Underline` `This is <u>underline</u>`

Underline text using the <i> tag. Select some text and click on button. If the selection is already a part of an existing such tag, then the tag is removed. Shortcut is ctrl+U.

`Link` `This is a <a href="http://something">link text</a>`

Anchor link using the <a href="..."> tag. If the button is clicked, it converts the selected URL text if any to a link. If non-URL text is selected, it prompts to enter the URL. If no text is selected, it prompts to enter the URL and inserts that as link text. If the selection is already part of an existing such tag, then only the href attribute is changed. Empty value entered in the prompt causes removal of the tag. Shortcut is ctrl+L.

`Source`

Clicking this button toggles the view between rich text editor view and source HTML view. In the rich text editor view, any update is immediately propagated to the shared storage, and to other connected instances. In the source HTML view, editing is not propagated immediately. When the button is clicked again in the source HTML view, at that time the locally edited source HTML text is saved in the shared storage, and it switches to the rich text editor view. If the editor is locked by another connected instance, and saving the text is not allowed at the moment, then it indicates that state, and remains in the source HTML view. However, if the close button is clicked, the local changes in the source HTML view are discarded without saving. Shortcut is ctrl+X.

`Code` `This is <code>code format</code>`

Pre-formatted text using the <code> tag. Select some text and click on button. If the selection is already a part of an existing such tag, then the tag is

removed.

`Font Size` `<span style="font-size: 150%">some text</span>`

When the button is clicked, the font size of the selected text is changed, and applied using the tag. The selection is changed on subsequent clicks in round robin, to these values: 125%, 150%, 200%, 300%, 25%, 50%, 75% and back to 100%.

`Font Face` `<span style="font-family: arial,sans-serif">some text</span>`

When the button is clicked, the font family of the selected text is changed, and applied using the tag. The selection is changed on subsequent clicks in round robin, to these values: Arial, Times New Roman, Georgia, Verdana, Tahoma, Trebuchet, Courier New, and Fantasy.

`Color` `<span style="color: red">some text</span>`

When the button is clicked, it prompts for the text color name or code, and applies that to the selected text using the tag. User can enter color name recognized in CSS, such as red, blue, darkgreen, redorange, etc., or can enter the code such as #ff8080. If the selection is already a part of an existing such tag, then only the style is changed. Empty value entered in the prompt causes removal of the style or the tag.

`Background` `<span style="background-color: lightblue">some text</span>`

When the button is clicked, it prompts for the text background color name or code, and applies that to the selected text using the . Similar to previous, the user can enter the color name or code, recognized in CSS. If the selection is already a part of an existing such tag, then only the style is changed. Empty value entered in the prompt causes removal of the style or the tag.

`Abbreviation` `This uses <abbr title="cascading style sheet">CSS</abbr>`

When the button is clicked, it prompts for the meaning or content for the

abbreviated text, and applies it to the selected text using the <abbr title="..."> tag. If the selection is already a part of an existing such tag, then only the title attribute is changed. Empty value entered in the prompt causes removal of the tag.

`Image` `<img alt="" src="data:image/jpg;...">`

When the button is clicked, it opens the file selection dialog box to select an image file, and inserts it in the text, using the <img alt="" src="..."> tag. It uses a data URL for the `src` attribute. If the selection is already part of an existing such tag, then only the `src` attribute is changed.

`Pointer`

Clicking the button toggles the mouse pointer display state. When enabled, it sends the mouse pointer's coordinates to all the other instances, which then display the mouse pointer annotated with its label. This feature allows pointing to a part of the editor text, and the pointer is visible to other connected instances' users. Note that text editing caret display state is enabled by default.

`Upload`

When the button is clicked, it uploads the local editor's text to the shared storage, so that other connected instances are synced to this instance's text. It may override other connected instances' text. It also cleans up the shared storage, so that the incremental changes are collapsed, and only the final text copy is saved.

`Download`

When the button is clicked, it downloads the text from the shared storage, and updates the local editor's text with that. It may override and discard local editor's content and unsaved changes. It first loads the text, and then applies any incremental changes, to the local editor's text. This operation is allowed even when the editing is locked by another instance.

`Lock`

When the button is clicked, it attempts to toggle the lock state of the editor. If the editor is not locked, then it grabs the lock, thus preventing other connected instances from editing the text. If the editor is already locked by this instance, then it releases the lock, thus allowing other connected instances to edit or grab the lock. If the editor is already lock by another instance, then it delivers a message to that instance about the lock request. The lock button's icon turns red or green depending on the state of locked by another instance or locked by self, respectively.

`Close`

In the source HTML view, an additional close button is shown. When the button is clicked, it discards any local editing in the source HTML view, and goes back to the rich text editor view, without saving the changes to the shared storage.

`Resize`

This is not in the tools bar, but appears as a resize control at the bottom right corner of the editor. Click-and-drag on this control allows resizing the editor's user interface.

The following table describes all the properties of the `shared-editor` component.

Name	Type and description
`lockstate`	string (read-only), default is `""` Indicates the lock state of the editor as one of '', 'editable', 'readonly'. An empty string indicates that the editor is not locked. If the editor is locked by this instance, the state is editable. If locked by another instance, the state is readonly. See `lockable`
`autounlock`	number, default is 30000 Controls the time in milliseconds to auto-unlock on no activity. Any keyboard

activity when the focus is in the editor, resets the timer.
See `lockstate`

`content` string
The current text shown by the editor, as an HTML string. If the editor is locked by another instance, then setting the value also switches the editor view to source HTML mode before update. If in source HTML view, then content is not uploaded to the data model implicitly, otherwise it is uploaded too. There is no event dispatched on content change, because the property is updated on demand when read.

`text` string
The current text shown by the editor, as a plain text string, not HTML. Similar to the content property, if the editor is locked by another instance, then setting the value also switches the editor view to source HTML mode before update. If in source HTML view, then content is not uploaded to the data model implicitly, otherwise it is uploaded too. There is no event dispatched on text change, because the property is updated on demand when read.

`cursor` bool, default is false
Controls whether the mouse position and label of this instance is shown on the other connected instances. If set to false, then this instance's mouse cursor and its label are not shown when viewed on other instances.

`caret` bool, default is true
Controls whether the caret position and label of this instance is shown on the other connected instances. If set to false, then this instance's caret and its label are not shown when viewed on other instances.
See `label`

`label` string, default is ""
Controls the label shown on the caret of this instance, when viewed on other connected instances. If not set, it uses the self property as default.

See `caret`, `labelcolor`

`labelcolor` string

Controls the color of the caret and label when applicable. Default is to pick a random color from the list of red, blue, darkgreen, redorange, or brown. It can be set to color string such as "red" or a color code in string such as "#ff8080".

`wraptext` bool, default is false

Controls whether the text in the editor wraps automatically or not. Wrapping the text should not be enabled in shared editing when caret or cursor positions are shared with others, because that could result in wrong position. Wrapping the text should be enabled when this component is used as a standalone instance for text chat input, without an attached data model.

`disabled` string

Comma separated list of features in the tools that are disabled. The list of features include: b (bold), i (italic), u (underline), a (anchor), x (source), code, font, fontsize, color, background, abbr, img, upload, download, pointer, lock, close, resize. If disabled is set, then all features are enabled except those in the disabled list. For example, if set to "upload,download,link,pointer,x,img,close,lock" then those advanced features are not shown, and only editing features such as b, i or code are shown. Note that only the tools is altered, but the underlying operations for those disabled features may still be allowed, e.g., to correctly display color added by another instance when this instance has it disabled. Setting this property, also alters the enabled property.

See `enabled`

`enabled` string

Comma separated list of features in the tools that are enabled, and all others are disabled. For example, if set to "b,i,u,code,font,fontsize" then the editor shows only those buttons in the tools, and not others such as color or abbr. The list of features are same as those listed for the disabled property. If enabled is set, then

	all features are disabled, except those in the enabled list. Setting this property, also alters the disabled property. See `disabled`
`buttons`	array (read-only) List of objects representing buttons in the component in the same order as the display. Each object has the name, title and visible (bool) attributes for a button. See `enabled`, `disabled`
`embedded`	bool, default is false Controls whether this component is embedded in another component, in which case certain adjustments are made to the associated rich-text-editor, such as to remove border-left and border-right and to set z-index.
`data`	object underlying data model component instance.
`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `shared-editor` component.

Function	Signature and description
`lock`	editor.lock(() => {... completed }) Get the exclusive editing lock by this user. Once obtained, it presents other connected instances from editing, until this instance releases the lock, either explicitly using unlock method, or implicitly after autounlock timeout.
`unlock`	editor.unlock()

	Release the exclusive editing lock by this user. Once released, any connected instance can edit, unless some other instance is waiting for the lock, in which case it is locked again by that other instance.
`upload`	editor.upload() Upload the content of the editor to the data model. This updates the content of other connected editors. This methods fails with a 'not allowed' exception, if the editor is locked by another instance.
`download`	editor.download() Download the content from the data model to the editor. This updates the content of this editor.

The following table shows all the events dispatched by the `shared-editor` component.

Event	Example and description
`enter`	Dispatched when enter key is pressed. It is not dispatched if shift+enter is pressed.
`lockchange`	Dispatched when lockstate is changed.
`typing`	{type: "typing", value: true} Dispatched when the content becomes non-empty or empty to indicate change in typing state. This is only dispatched if this component is used as a standalone editor instance not attached to a data model. This event can be used for typing indicator when this component is used for text chat input.
`change`	{type: "change"} Dispatched when the position or size of the component is changed. If the position and size is controlled by the application, it should dispatch this event to trigger re-positioning of the attached editor.

The following table describes all the properties of the `shared-editor-data` component.

Name	Type and description
`self`	string, default is `""` Controls the identifier of the self instance. This must be unique among all the instances connected to the same storage path.
`path`	string, default is `""` storage path of the text and other data related to this component.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `shared-editor-data` component.

Function	Signature and description
`read_lock`	data.read_lock().then(...).catch(...) Returns a promise that resolves when lock exists with an object containing name of the lock owner, or rejects when the lock does not exist.
`create_lock`	data.create_lock({name: "..."}).then(...).catch(...) Returns a promise that resolves when lock is created with the supplied data.

`delete_lock`	data.delete_lock().then(...).catch(...) Returns a promise that resolves when the lock is deleted.
`send_status`	data.send_status("...") Send a status notification to either a specific instance or to all the connected instances on the same path.
`set_text`	data.set_text("...") If storage is ready and path is set, then update the editor text. Once successfully updated, it removes all the incremental changes.
`post_change`	data.post_change({...}) If storage is ready and path and self are set, then add the supplied change to storage.
`download`	data.download() Read and refresh the editor text and incremental changes from the storage. It dispatches the text and change events as needed.

The following table shows all the events dispatched by the `shared-editor-data` component.

Event	Example and description
`text`	{type: "text", data: {sender: "...", text: "..."}} Dispatched when editor text is updated in the storage. The data object may be empty if the text is deleted.
`change`	{type: "change", data: {...}} Dispatched when a incremental change is added.
`status`	{type: "status", data: "..."} Dispatched when a status notification is received.
`lock`	{type: "lock", state: "readonly"} Dispatched when the lock is created on the path. The state attribute is either editable or readonly, depending on whether this instance or some other instance, respectively,

owns the lock.

`unlock` {type: "unlock"}
Dispatched when the lock is deleted on the path.

35. How to do shared games?

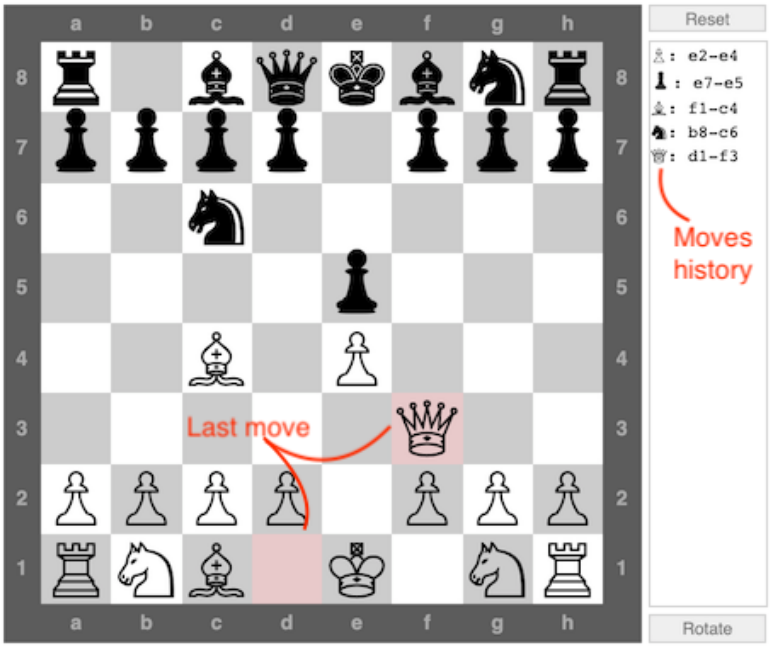
The collaboration tools described previously such as for text chat, notepad or whiteboard are examples of endpoint driven applications. The shared storage based data models for these tools enable collaboration. The shared storage based collaboration is not limited to these use cases, but can be expanded to others that need shared state among participants such as shared games.

Here, we describe two components to enable shared Chess and Ludo board games. The concept can be easily applied to other multiplayer games.

35.1 chess-board

Try the following example to see the `chess-board` component in action. It is a clean slate chess board, with no restrictions or rules on how the pieces move. Click on a piece and then click on another position to move the piece. The movement is recorded on the right side. The last move is highlighted. The buttons on the right allow you to reset the board and to rotate the board, if needed.

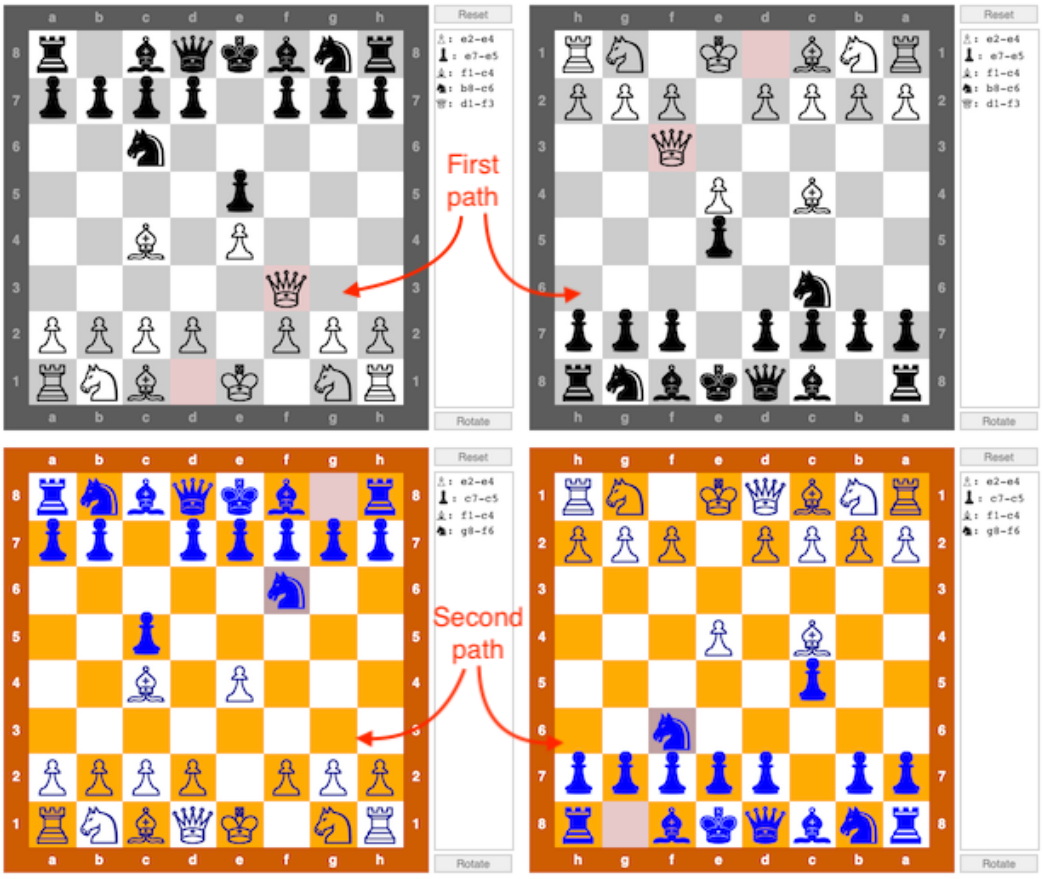
```
<chess-board></chess-board>
```



The component can be attached to a data model, which can be based on storage, such as `chess-board-data`. In that case it stores all the moves in the list data on the storage, and updates the user interface when a move is detected.

```
<chess-board-data id="data" for-storage="..." path="..." ></chess-board-data>
<chess-board for-data="data"></chess-board>
```

Try the following example with four `chess-board` instances, covering two separate games, by attaching to two separate paths on the storage. The styles for the third and fourth instances are altered from their defaults. The second and fourth instances are rotated once to appear as the opponent side view. See the `rotate` function described later.



The following table describes all the properties of the `chess-board` component.

Name	Type and description
`controls`	bool, default is true Controls whether to enable the user interface elements to make the moves on the board.
`moves`	object (read-only) Contains the current list of moves on the chess board. The application should not modify the content of this property.
`data`	object underlying data model component instance.

`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `chess-board` component.

Function	Signature and description
`move`	board.move({from: "4b", to: "4d"}) Move a piece from one place to another, e.g., move("d2", "e3"). If the data model is set, it updates it with the new move, and updates the local board only after the data model is updated. This ensures that, if the data model is attached to shared storage, then it will keep the states in sync. See event `move`
`rotate`	board.rotate() Flip or rotate the chess board. The effect is as if the two people playing the game have switched their positions.
`clear`	board.clear() Clear or reset the check board to initial position. If the data model is set, then it updates it to remove all the moves too, and sends a notification to clear the board. See event `clear`

The following table shows all the events dispatched by the `chess-board` component.

Event	Example and description
`move`	{type: "move", from: "4b", to: "4d"} When a piece is moved. The from and to properties store the mode.

See method `move`

`clear` {type: "clear"}
When the chess board is cleared to the initial position.
See method `clear`

The user interface of the `chess-board` component can be customized using the following styles.

Style	Description and default
`--background-color-corner`	Default `#5c5c5c` The background color of the sides and corners
`--color-corner`	Default `#acacac` The text color of the labels on sides
`--background-color-white`	Default `white` The background color of the white places on the board
`--background-color-black`	Default `#ccc` The background color of the black places on the board
`--background-color-clicked`	Default `#4cff4c` The background color of the place when clicked
`--background-color-lastmove-white`	Default `#e8c9c9` The background color of the white place on the board to indicate the last move
`--background-color-lastmove-black`	Default `#c0a1a1` The background color of the black place on the board to indicate the last move
`--color-piece-white`	Default `black`

	The border color of the white pieces
`--color-piece-black`	Default `black` The inner color of the black pieces

The following table describes all the properties of the `chess-board-data` component.

Name	Type and description
`path`	string, default is `""` Storage path of the list data to store and show the moves from, e.g., "sessions/chess123". Each item in the storage must be a JSON object of the form {from: "g1", to: "h2", created: ...timestamp...}. The created value may be a numeric timestamp or a string representing date/time.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `chess-board-data` component.

Function	Signature and description
`add`	data.add({...})

	If storage is ready and path is set, then it adds the move item to the storage.
`clear`	data.clear() If storage is ready and path is set, then it notifies all the connected instances on the same path to clear the board, and removes all the previous move items from the storage.

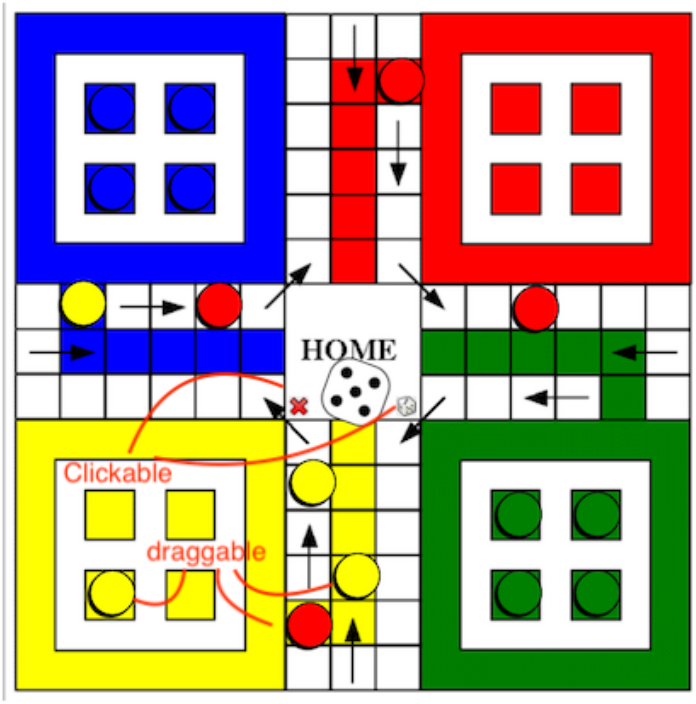
The following table shows all the events dispatched by the `chess-board-data` component.

Event	Example and description
`reset`	Dispatched when the storage is ready.
`move`	{type: "move", value: {from: ..., to: ...}} Dispatched when a move item is added
`clear`	Dispatched when a clear notification is received from another connected instance.

35.2 ludo-board

Try the following example to see the `ludo-board` component in action. It is a clean slate board with no restrictions or rules imposed. It is upto the players to follow and impose the rules.

```
<ludo-board></ludo-board>
```



There are two buttons near the center of the board. One is to clear the board to the initial state. The other is to roll the dice using the random function in JavaScript to generate the dice value. The pieces can be moved by drag-and-drop to any location.

When the board instance is attached to a storage based data model, `ludo-board-data`, it can use the storage to keep track of positions of the pieces and to notify the dice value from the last dice roll. The component instance then uses the storage to update the local user interface.

```
<ludo-board-data id="data" for-storage="..." path="..." ></ludo-board-data>
<ludo-board for-data="data"></ludo-board>
```

Try the following example with two `ludo-board` instances, attached to the same path on storage. You can notice the synchronized dice roll and piece movements.

The following table describes all the properties of the `ludo-board` component.

Name	Type and description

`controls`	bool, default is true Controls whether to enable the user interface elements to make the moves on the board.
`data`	object underlying data model component instance.
`for-data`	string, default is "" Use this to set the id of the external data model DOM element. See `data`
`ready`	bool (read-only), default is false Whether the data model is set and is ready to be used? See `data`

The following table shows all the methods of the `ludo-board` component.

Function	Signature and description
`roll`	board.roll() Roll the dice randomly. Update the data model if set.
`clear`	board.clear() Clear or reset the board to initial position. Update the data model if set, by resetting the positions of all the pieces.

The following table describes all the properties of the `ludo-board-data` component.

Name	Type and description
`path`	string, default is "" Storage path of the list data to store and show the dice value and pieces moves from, e.g., "sessions/ludo123". It assumes sub-path of ".../dice" and ".../piece" under this. The dice object is of the form {"iterations": ..., "value": ...} and piece list item is of the form {"x": ..., "y":...} indicating the position. The piece

	list item id is of the form color-index, e.g., red-3.
`persistent`	bool, default is false Controls the persistence of storage data.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `ludo-board-data` component.

Function	Signature and description
`move`	data.move(id, data) If storage is ready and path is set, then set the position of a piece.
`dice`	data.dice({value: 4, iterations: 467}) If storage is ready and path is set, then update the storage with the supplied dice value.

The following table shows all the events dispatched by the `ludo-board-data` component.

Event	Example and description
`reset`	Dispatched when storage is initialized
`move`	{type: "move", value: {...}, id: ...}

Dispatched when a piece position is set. Position is in value, and piece is identified by id.

`dice` {type: "dice", value: {iterations: ..., value: ...}}
Dispatched when the dice value is set. The value property contains the iterations and dice value.

36. How to share custom app in a chat?

The `media-chat` component allows sharing text, audio, video, screen or an app window with other participants. It also has methods such as `startshare`, `stopshare`, `addshare` and `removeshare`, which are used to share custom apps such as those described previously, with other participants.

36.1 Participants survey

Our first example is about a survey app - one participant sends a survey question in the chat, gathers responses from everyone, and closes the survey to display the results to everyone. First, we add a new button in the toolbar and a new item in the menu, to launch this feature.

```
<media-chat ...>
  <toolbar-buttons ...>
    <button name="survey" title="start participants survey">
      <img src="... path to an icon ..."/>
    </button>
  </toolbar-buttons>
  <overlay-menu ...>
    <span name="survey">Participants survey</span>
  </overlay-menu>
  ...
</media-chat>
```

Next, when the button or menu item is clicked, we display a box to enter and edit survey question. The `addshare` method is used to add the view element to either the videos `flex-box` or the chat `text-feed` or `text-feed-bubbles` component.

```
button.onclick = span.onclick = event => {
  const div = ... // create the view element
  ...
  media.addshare("survey", {}, div, "feed");
  ...
};
```

When an app view is added to the component, a wrapper `media-share` component instance is used to wrap the supplied view element. This wrapper has certain attributes and properties to control its behavior, e.g., to center the display or to disable the popout feature. If changes are desired, then those can be applied to the parent element as follows.

```
setTimeout(() => {
    div.parentNode.setAttribute("display", "center");
    div.parentNode.setAttribute("popout", "none");
});
```

Within the view element, there could be a button, which when clicked actually shares the app data with other participants using the `startshare` method. But first, the previous view should be removed using the `removeshare` method, and the same identifier as before.

```
share.onclick = event => {
  media.removeshare("survey");
  media.startshare({type: "survey", topic: "Do you like this?", buttons: ["Yes",
"No"]});
};
```

Note that `from` and `fromid` are automatically added to the app data supplied in `startshare` internally. The app data is then received by all the connected clients, including the sender client, and delivered to the application using the `addshare` event. The `media-chat` component creates a bi-directional communication channel to exchange messages about this shared app between the application and the app instances running on various connected clients.

The `data` property of the event contains the app data supplied in `startshare`. The `id` property is a system generated unique identifier for this app instance. The `container` property is the desired container of videos, feed or a new dialog box, if any. The application can set this value to force a specific container for this app view. Finally, the `port` property is a port of the underlying `MessageChannel` instance.

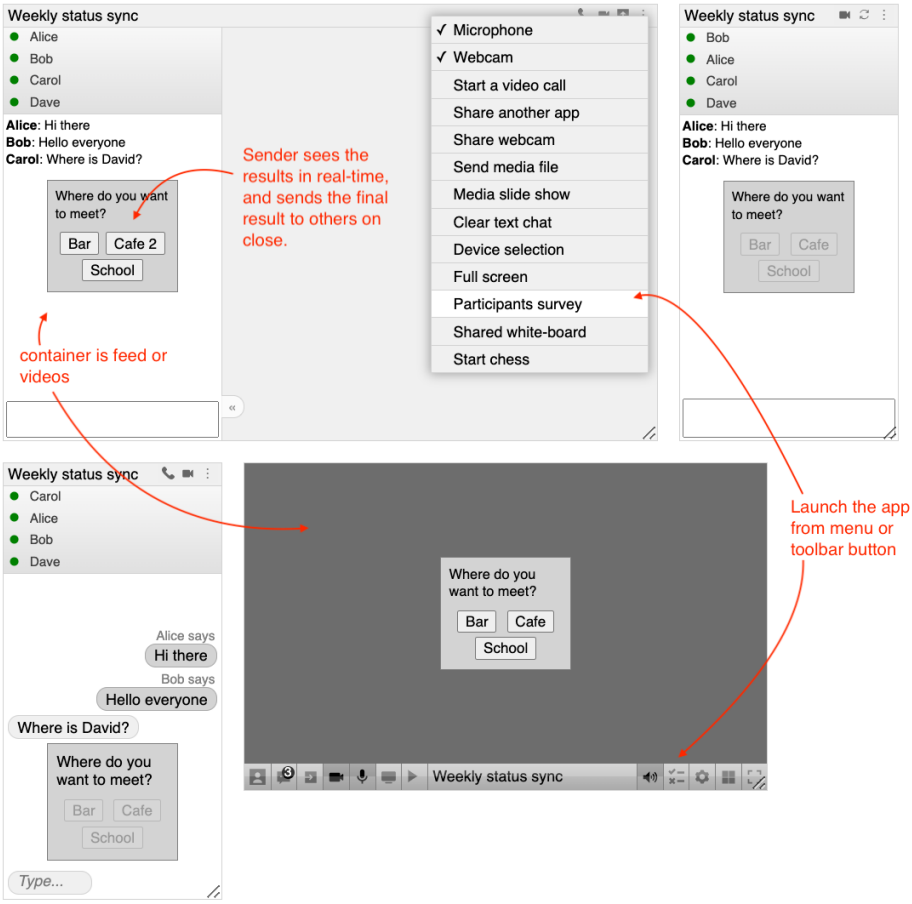
```
media.addEventListener("addshare", event => {
  const {id, data, container, port} = event;
  if (data.type == "survey") {
    const div = ... // create view element
    setTimeout(() => { /* set display and popout */ ... });
    event.container = "feed";
    // whether this client initiated the app
    const owner = data.fromid == media.self;
    port.onmessage = ev => {
        const {fromid, data} = ev.data;
        // ... process message from other client
    };
    ...
    buttons.forEach(button => {
      button.onclick = event => {
        const data = ... // data to send
        port.postMessage(data);
      };
    });
  }
});
```

By carefully crafting the view element and the data exchange among the app instances, the survey question and answers are conveyed and displayed among different connected clients. Using owner detection, different views are shown to different participants, i.e., the survey sender versus the responders.

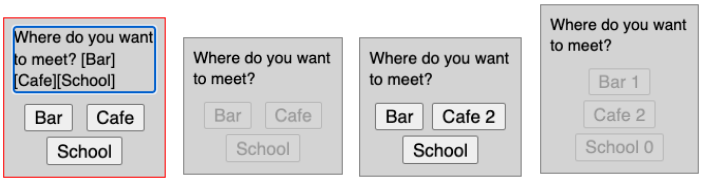
When the user clicks on the close button of the shared app to remove it, the `removeshare` event is automatically dispatched to the application. In this example, the client can close the survey app if the owner closes its app.

```
media.addEventListener("removeshare", event => {
  const {id, data, view, port} = event;
  if (data.type == "survey") {
    const owner = data.fromid == media.self;
    if (owner) {
        port.postMessage({type: "close", ...});
    }
  }
});
...
media.addEventListener("addshare", event => {
  ...
  port.onmessage = ev => {
    const {fromid, data} = ev.data;
    if (data.type == "close") {
      ... // close the survey view
    }
  };
  ...
});
```

Try the following example that includes the survey app in the menu of the first client, and the toolbar of the last client. It also includes several other apps, that are described later in this section. The complete application code is included in the example.



When the first client launches the survey app, it gets the editable view of the app (see the first image below). The editor allows entering a question, and a bunch of answer buttons. On enter, the editable app is closed, and the question and buttons data is used to launch the app on all the clients. When an answer button is clicked, the app becomes disabled to prevent more clicks (second image). The selection on a non-sender client is delivered to the sender client, so that the sender can see all the results in real-time (third image), and can decide when to close the survey. When the sender closes the survey app, the current results are delivered to all the other clients, which then display the results (fourth image). If the non-sender client did not yet select an answer, it gets disabled anyways. Any non-sender client can close the app at any time, without affecting the app on the other clients.



Another way to launch the survey app is using the action command on the text chat. If the user enters a text such as "/survey Do you like this? [Yes][No]", then that is intercepted in the above examples to launch the survey app with the provided question and answers.

```
media.addEventListener("action", event => {
  const action = event.value;
  if (action.startsWith("survey ")) {
    let question, answers = [];
    ... // extract question and answers using regexp
    media.startshare({type: "survey", question, answers});
  }
});
```

Next, we describe other shared apps included in the previous example.

36.2 File viewer and slide show

The `slide-show` component can display one or more files with page navigation. Unlike other storage based components, this one does not depend on storage. It uses `MessageChannel`'s port to communicate with the application, such as to send or receive commands for page navigation, video seek, or PDF navigation.

The previously shown example app includes two menu items that use this component. The "Send media file" item is used to upload and send one or more files to all the participant clients, so that the clients can display them. In that mode, the sender does not control the navigation, and each client can independently navigate, control or close the shared app. The "Media slide show" item is used to provide a synchronized slide show experience, where the sharer controls and navigates the app on all the receiver clients. In this mode, typically, the navigation controls are disabled or not shown on the

receiving client or non-owner app instance.

First, the `upload_files` function is used to gather a list of files using the file selection dialog box. This list is then sent to all the clients using `startshare`. Additional flag can indicate whether synchronized control is desired or not.

```
menuitem.onclick = async event => {
  const files = await upload_files({
    accept: "image/*,video/*,application/pdf", multiple: ""
  });
  const value = files.map(file => {
    const {name, type, size, url} = file;
    return {name, type, size, url};
  });
  media.startshare({type: "files", value});
};
```

On receiving the `addshare` event, the application creates a `slide-show` app. Its owner property, if set, makes it behave in a synchronized control mode.

```
media.addEventListener("addshare", event => {
  ...
  if (data.type == "files") {
    const div = event.view = ... // new slide-show element
    div.owner = data.fromid == media.self;
    div.port = port; // for communication
    div.data = data.value; // list of files received
  }
});
```

If PDF file is included in the list of files, then the component uses another `pdf-viewer` component internally to display the file. It has external dependency on the pdfjs project, and requires certain initialization to be done in the application. Please see the source code of the previous example application to learn more about this.

The `slide-show` component is capable of handling image, video and PDF files. The page navigation control appear on the left and right, and allow navigating among files. In synchronized control mode, the navigation from the owner app is sent to all the other connected apps, using the port. Additionally, for video display, changes in the player control of the owner such as play or pause, or seek, are sent to the connected app, so that all the other clients can emulate the same player control. For PDF file viewer, the page navigation within that file is sent to all the connected apps.

When a file is shared via the text chat or drag-and-drop in the text input area, the chat history data contains the full content of the file. When such a file share link is clicked from the text chat component, it dispatches the `openurl` event, which bubbles up to the application. The application can listen to this, and decide to use the `slide-show` component to show the file inline, instead of doing download, for certain file types.

```
media.addEventListener("openurl", event => {
  const {url, data} = event;
  if (data.type.startsWith("image/") || data.type.startsWith("video/")) {
    event.url = "";
    const div = ... // new slide-show element
    div.data = [{name: data.download, type: data.type, url}];
    media.addshare("openurl", {}, div, "dialog");
    ...
  }
});
```

Note that resetting the `url` property of the event causes the underlying text chat component to not process the event further. Otherwise, it would attempt to download the file as its default processing.

36.3 Share multiple webcam, screen or window

The `media-chat` component already includes support for sharing webcam, screen (or window) as demonstrated earlier, by joining the call with video, and/or starting screen share from menu or toolbar button. The component maintains a single state for such sharing.

To enable sharing of multiple webcams or screens from the same client, the application can wrap the corresponding `video-io` component as a shared app. The previous example includes menu items to share another app or to share webcam. When sharing another app, the sharing client sets the `publish` and `screen` properties of the `video-io` component, and the other clients set the `subscribe` property. The display property of the parent `media-share` component is set to `zoom`, and the container is set to `videos`. Additionally, the `named-stream` information is also provided by the sharer to other clients, so that all the clients can connect to the same named stream. Such tricks to quickly enable new sharing apps is possible due to loose coupling among the client apps, and the flexible and versatile video-io and named-stream components.

```
media.addEventListener("addshare", event => {
  const {id, data, container, port} = event;
  if (data.type == "shareapp") {
    const div = event.view = ... // new video-io element
    ...
    div.srcObject = ... // stream for this app
    if (data.fromid == media.self) {
      div.screen = true;
      div.publish = true;
    } else {
      div.subscribe = true;
    }
    event.container = "videos";
    setTimeout(() => {
        div.parentNode.display = "zoom";
        div.parentNode.popout = "none";
    });
  }
});
```

When sharing a webcam, similar process is done, except that the `device-selector` component is launched first on the sharer client, to select the webcam to share. The device identifier of the selected webcam is then used by the sharer's publishing `video-io`.

```
menuitem.onclick = event => {
  const div = ... // new device-selector element
  div.mirrored = div.showsave = div.autosize = true;
  div.microphone = div.sound = false;
  ...
  media.addshare("device-selector", {}, div, "dialog");
  ...
  div.addEventListener("save", ev => {
    const device = div.videoinput?.deviceId;
    media.removeshare("device-selector");
    ...
    media.startshare({type: "sharewebcam", {device, ...}});
  });
};
media.addEventListener("addshare", event => {
  ...
  if (data.type == "sharewebcam") {
    ...
    div.camname = data.value.device;
    div.microphone = div.sound = false;
    ...
  }
});
```

When `removeshare` is dispatched, the application should cleanup the named stream and the `video-io` component associated with the shared app.

36.4 Share whiteboard or chess game

We have already seen the collaboration applications such as whiteboard, shared editor, notepad and games such as chess and ludo. Such external component implementations can be easily wrapped as a shared app in `media-chat`. Just like before, a menu item or toolbar button is added, which when clicked, invokes the `startshare` method. If multiple instances are desired then separate storage paths are picked by the sharer, and sent to other participants, otherwise a fixed path based on the parent component's path can be used.

```
menuitem.onclick = event => {
  media.startshare({type: "whiteboard"});
};
media.addEventListener("addshare", event => {
  ...
  if (data.type == "whiteboard") {
    const wb_data = ... // new white-board-data element
    wb_data.storage = media.data.storage;
    wb_data.path = media.data.path + "/wb123";
    ...
    const wb = ... // new white-board element
    wb.position = "top-left";
    wb.label = media.displayname;
    wb.data = wb_data;
    ...
  }
});
```

The parent `media-share` component's display property should be used prudently depending on the wrapped app view. Furthermore, the style attribute of the app can be set as needed.

When the app is removed, the app view and corresponding data elements can be removed from the document, to cleanup.

The text chat action is installed in the previous example to start these apps from the text chat input area too. For example, typing "/start whiteboard" or "/start chess" are interpreted to launch those apps.

36.5 media-share, slide-show, pdf-viewer

The following table describes all the properties of the `media-share` component.

Name	Type and description
`container`	string

Controls the container type of this component.

`display` string

Controls how the slotted element is displayed. If set to default, then no extra adjustment is made. If set to center, then it assumes the content is smaller, and is center aligned. If set to zoom, then it assumes the content size is fixed, and zooms in or out to fit in the available space.

`popout` string, default is "button"

Controls whether and how to enable popout of content in a separate window. Note that popout with dblclick is not allowed when container is videos, because flex-box already implements a different dblclick semantics.

The following table describes all the properties of the `slide-show` component.

Name	Type and description
`owner`	bool or undefined, default is "undefined" Controls whether to enable synchronized controls (true or false) or not (undefined). Note that true means owner and false means non-owner when synchronized controls is used.
`container`	string, default is "feed" This defines the container of the parent media-share element, and is used to style this component differently as needed.
`data`	object Controls the array of objects, each describing a file. Each object should include name, type, size and url properties for the file. The type property is used to pick an img, video or pdf-viewer element to display that file.
`port`	object To be compatible with media-share and related application logic, this component uses a message channel port for all communication with the other connected components. The messages sent by the component is an

	object with type of navigate, video-play, -pause or -seeked, or pdf-seeked. Additionally, index, and optionally, currentTime or pageNum is included depending on the type. The received message on the port includes this object in the data property of the event, in addition to the fromid indicating the sender of the object.
`minsize`	string, default is "200x200" Sets the minimum size of the component. If the actual size is smaller than this, then it applies zoom to shrink it proportionally. This is useful to display the component where size could become too small for it to be displayed correctly.
`naturalWidth`	number (read-only) Indicates the actual width of the currently displayed img, video or pdf-viewer element. See `naturalHeight`
`naturalHeight`	number (read-only) Indicates the actual height of the currently displayed img, video or pdf-viewer element. See `naturalWidth`

The following table shows all the events dispatched by the `slide-show` component.

Event	Example and description
`loading`	{type: "loading", value: true} Dispatched only if the underlying currently displayed element is video, and it is loading or has completed loading. The value property indicates which.

The following table describes all the properties of the `pdf-viewer` component.

Name	Type and description
`src`	string

Controls the source URL including any dataurl for the PDF file.

`size` object (read-only)

Indicates the current size of the displayed PDF page without scaling in the form of {width: ..., height: ...}.

`pageNum` number, default is 1

Controls and indicates the currently displayed page number in the file. Once the file is loaded initially, it sets to display the first page by default, unless this property is set before loading.

`controls` bool, default is true

Controls whether navigation buttons are displayed or not.

The following table shows all the events dispatched by the `pdf-viewer` component.

Event	Example and description
`seeked`	{type: "seeked"} Dispatched when the previous or next page navigation control is clicked. The application should use the pageNum property of the component to find the current page.

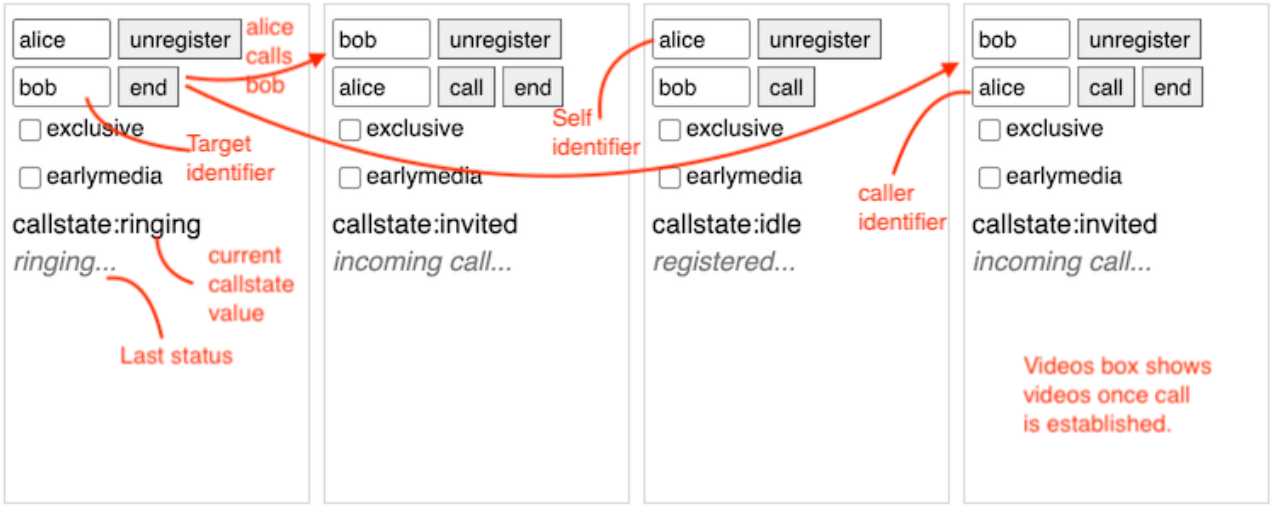
37. What is a phone state?

Earlier in How to do two-party video call? we described and illustrated state machines for single line and multiple line video phone device engaged in a call. Later in How to do multi-party video conference? we described and illustrated join-leave as well as invite-answer models for conference signaling. Those examples used state machines in the application, while using the shared storage for exchange of signaling and media negotiation messages. Here, we will describe a few web components that implement a generic state machine for phone calls and conferences, using audio and/or video.

The `phone-state` component implements the state machine for phone registration and call. The `conference-state` component implements the state machine for conference join and leave membership, and maintains a list of active members in the conference.

Applications that use phone or conference state machines still need some common set of functions independent of the specific state machine, e.g., to add or remove `video-io` instances when a call is connected or when a conference is joined or when a member joins or leaves a conference. Such features are enabled in the `videos-control` component. It acts as a controller to connect a `phone-state` or `conference-state` or a similar component with one or more `video-io` elements to create a call or conference experience.

Try the following example with four `phone-state` instances, representing four phone devices. Each can register and make/receive calls. Make sure to enter after typing the text to update any property.



The actual media is outside the scope of this component, and is implemented in the application using the `videos-control` component supplied with two fixed `video-io` elements per phone instance. The `exclusive` determines whether the phone device registers exclusively for a name, and must be set before registering. The `earlymedia` property determines whether the media is started early, before the call is established, when applicable.

37.1 phone-state

The following table describes all the properties of the `phone-state` component.

Name	Type and description
`registered`	bool (read-only), default is false Whether the local entity is registered to send or receive calls. See `selfpath`, `callstate`
`active`	bool (read-only), default is false Whether a call is currently active or not. If true, then callstate is also "active". See `callstate`, `registered`
`callstate`	string (read-only), default is "idle"

The call state is one of "idle", "inviting", "invited", "ringing", "active", "terminating".
See `registered`, `otherpath`

`exclusive` bool, default is false
Controls whether the local entity is registered exclusively, so that registration fails if another registration exists for that value of selfpath. If false, then multiple registrations for the same path is allowed, similar to multiple line presence on some phones.
See `selfpath`

`earlymedia` bool, default is false
Controls whether the media start event is dispatched early or not. Default (false) is to dispatch when call is established, for both self and other. If set to true, then dispatch for self when call attempt is being made, or call invitation is received; and dispatch for other when call is answered or invitation is received.

`inviteid` string (read-only), default is ""
Indicates the current call identifier that is being used for a pending or active call. It applies to both inbound and outbound call. The value is unique for the pair of selfpath and otherpath at any given time, i.e., no two calls between the same pair of entity paths will have the same call identifier.
See `callstate`

`selfdata` object, default is null
Optional data sent to the other instance in call invite or answer.

`otherdata` object, default is null
Optional data obtained from other side in call invite or answer.

`selfpath` string, default is ""
Storage path of the local entity. This must be set before initiating a registration. This is used to receive notifications related to the phone call

	signaling such as to invite, cancel, answer, decline or terminate a call. The notification data is of the form {type: ..., inviteid: ..., ...} where a unique inviteid is used for all the related messages of a single call attempt. See `otherpath`
`otherpath`	string, default is `""` Storage path of the remote entity. This must be set before initiating a call, and is automatically set on an incoming call in an idle state. Similar to the selfpath, this is used to send notifications related to the phone call signaling, in the same format. See `selfpath`
`waiting`	number (read-only) Indicates numbder of pending or outstanding outbound call invites that have not yet been answered. When the invite is sent, the sender knows how many receivers got the notification. It then waits either for answer or decline to confirm the transaction. The property number indicates the number of outstanding receivers that have not yet responded.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `phone-state` component.

Function	Signature and description

`register`	phone.register() Initiate registration of local entity to receive calls.
`unregister`	phone.unregister() Unregister the local entity to stop receiving incoming calls. Any ongoing or active call is not affected.
`call`	phone.call() Either initiate an outgoing call, or answer an incoming call invite.
`end`	phone.end() Depending on the callstate, either end an active call, or cancel in outgoing call invite, or decline an incoming call invite.
`send`	phone.send({text: "Hello there"}) Send generic application-level data. If the call state is not active, it queues the data to be sent after call becomes active. See event `receive`

The following table shows all the events dispatched by the `phone-state` component.

Event	Example and description
`callstate`	{type: "callstate", value: "invited", old: "idle"} Indicates a change in the callstate property
`active`	{type: "active", value: true, scopepath: "..."} Indicates a change in the active property. The scopepath attribute contains a path that may be used to identify this call.
`status`	{type: "status", text: "registering..."} Indicates the status change of the device
`error`	{type: "error", reason: "failed to register"} Indicate any error

`receive`	{type: "receive", frompath: "...", data: {...}} Some generic application-level data is received. See method `send`
`missed`	{type: "missed", frompath: "..."} Indicates a missed incoming call. It may be used by the application to initiate a callback later.
`start`	{type: "start", direction: ..., streampath: ...} Indicates media can be started for a stream. The direction attribute is either publish or subscribe.
`stop`	{type: "start", direction: ..., streampath: ...} Indicates media can be stopped for a stream. The direction attribute is either publish or subscribe.

37.2 videos-control

The following table describes all the properties of the `videos-control` component.

Name	Type and description
`srcObject`	Element Either a phone-state or conference-state or similar instance. The start and stop events are captured, and video-io elements are added or removed in response.
`videos`	Element or Array Either a container element such as flex-box to hold zero or more video-io elements, or a node-list or array of one or more video-io elements. If a node-list or array is used to set this property, then the number of video boxes displayed is limited by that array length.
`oncreatevideo`	Function

If the videos property was set to a container element, then the component invokes this function to create a new video-io element in the application. If this property is not set, then a default video-io element is created. The application may set this property to a function that returns a video-io element instance.

`oncreatestream` Function

When a video is added, and a named stream does not exist, then the component invokes this function to create a new named stream element in the application. If this property is not set, then a local named-stream element is created, and works only for demonstration purpose. The application may set this property to a function that takes a stream path string and returns a named stream element instance.

The following table shows all the events dispatched by the `videos-control` component.

Event	Example and description
`start`	{type: "start", video: ..., stream: ..., direction: ..., streampath: ...} Dispatched when a video-io element is started. The attributes include the video-io element, named stream element, direction of publish or subscribe, and the stream path string
`stop`	{type: "stop", video: ..., stream: ..., direction: ..., streampath: ...} Dispatched when a video-io element is stopped. The attributes include the video-io element, named stream element, direction of publish or subscribe, and the stream path string

38. What is a conference state?

The `conference-state` component has a simple state machine with only one boolean flag indicating whether the user has joined the conference or not. Internally it also maintains the membership information, and allows setting the member data item in the conference. The data is shared among all the members.

Try the following example with four `conference-state` instances, representing four conference users. Make sure to enter after typing the text to update the property.

The self identifier, if missing, is picked automatically and randomly, before joining the conference. A `videos-control` element is used per user to facilitate media display using the four fixed `video-io` instances per user view. Alternatively, a `flex-box` component may be used.

38.1 conference-state

The following table describes all the properties of the `conference-state` component.

Name	Type and description
`loopback`	bool, default is false Controls whether a send will dispatch the receive event for sender side also or not?
`active`	bool (read-only), default is false

	Whether joined the conference as member or not?
`selfdata`	object, default is null Controls the membership data to be added on join as the object value under the storage path. If not set, then an empty object is used as data. Application can add attributes such as displayname or other information to this, before join is called.
`self`	string, default is "" Indicates the unique member identifier that was used to join as a member. This is automatically assigned, and is unique among all the instances with the same storage path. If this is set by the application before calling join, then that value is used, or the join fails if another instance exists with the same name. If the value is automatically assigned on join, then it gets automatically cleared on leave, otherwise it remains intact.
`path`	string, default is "" Storage path of the conference membership. This must be set before initiating a join. This is used to receive notifications related to the conference membership.
`storage`	object underlying shared-storage instance. See `path`
`for-storage`	string, default is "" Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `conference-state` component.

Function	Signature and description
`get_member`	conf.get_member("alice") Returns the conference member item data for the member identifier
`is_empty`	conf.is_empty() Indicates whether there is another member in the conference other than self or not
`join`	conf.join() Initiate a join as a member to the conference
`leave`	conf.leave() Leave the conference as a member
`send`	conf.send({text: "Hello there"}) Send generic application-level data. If the join state is not active, it queues the data to be sent after the state becomes active. If loopback property is not set, then the sender suppressed the receive event for this sent data. If the other parameter is set then the data is sent only to that one specific other member identifier. Otherwise, it is sent to all the members. See event `receive`

The following table shows all the events dispatched by the `conference-state` component.

Event	Example and description
`active`	{type: "active", value: true} Indicates a change in the active property
`receive`	{type: "receive", from: ..., data: ..., unicast: false} Some generic application-level data is received. The unicast attribute indicates whether the other param was set in the sender's send method. If true, then the data was sent only to this member, otherwise to all members in the conference. See method `send`

`add` {type: "add", id: ..., data: ...}
When a new member is added to the conference. The member identifier and item data are in the attributes.

`remove` {type: "remove", id: ..., data: ...}
When an existing member is removed from the conference. The member identifier and existing member item data are in the attributes

`update` {type: "update", id: ..., old: ..., data: ...}
When a member item data is updated in the conference. The member identifier, old item data and new item data are in the attributes.

`start` {stype: "start", direction: ..., streampath: ...}
Indicates media can be started for a stream. The direction attribute is either publish or subscribe.

`stop` {stype: "stop", direction: ..., streampath: ...}
Indicates media can be stopped for a stream. The direction attribute is either publish or subscribe.

39. How to do click-to-call?

The telephony use case related components described previously such as `phone-state` or `conference-state` are largely independent of the media features. An application typically need to connect these state machines with collaboration related components such as `videos-control`, `white-board`, or `text-chat`.

However, a number of telephony related applications use a few well defined scenarios, such as click-to-call, click-to-join or call queues. The `click-to-call` component is a general purpose implementation for several of such scenarios including click to call or answer, click to join or leave, queue incoming calls, or distribute outbound calls.

The `click-to-call` component includes zero or more instances of the `phone-state` or `conference-state` components. At least one state component is needed for proper functioning. The number and type of the state components, together with some other attributes, determine the behavior of the component in various scenarios. The high level scenarios are shown below.

Scenario	Description
`Phone`	One phone-state This acts as a single line phone device. It registers to receive incoming calls. It can make outgoing calls.
`Conference`	One conference-state This acts as a single attendee in a conference. It can join or leave a conference.
`Invited conference`	One conference-state and one phone-state This acts as a single attendee in a conference. But it also allows inviting other users to that conference, and getting invited by other users to a conference.
`Call queue`	Multiple phone-state, queue="true" This acts as an incoming call queue. It registers to receive incoming

	calls. When a call is answered, more incoming calls get queued, and can be answered or declined after the current call completes.
`Call distribute`	Multiple phone-state, distribute="sequence" or "parallel" This acts as an outgoing call distributor to multiple distinct targets. When any of the target user answers, the call is completed, and the remaining steps are stopped. The call may be distributed in sequence or parallel, with or without timeouts.

To be consistent with a simple click-to-call user experience, a single button in the component facilitates most of the user interactions. For example, once the target is set, and the component is in idle phone state, then clicking on the button initiates an outgoing call. When the phone state is inviting or ringing or active, clicking on the button terminates the pending or active call. When the phone state is invited, for incoming call, clicking on the button can launch another confirmation box to answer or decline the call. Alternatively, the `answer` property can be set to click-and-hold to answer versus click to decline.

For a conference scenario, the single button can be used to join a conference if the conference state is idle, or to leave the conference if it is not. For an invited conference scenario, the behavior of the button is heuristically determined based on the phone and conference states. For example, in an idle state, it could first join the conference, and if the other target user is set, then send a call invite to that user as well. For an incoming call invite, it could answer the call and join the conference after confirmation. For an active or pending call or conference, clicking the button terminates the call invite or leaves the conference or both.

With multiple phone states, the behavior becomes more intriguing. For example, for the call distribution use case, clicking on a pending state with sequential distribution cancels the current call, and goes to the next target in the sequence. For the call queue scenario, clicking on an active call terminates the call, and launches the confirmation for the next incoming call in the queue, if any.

By default, `calltype` is audio, and must be set to video, to support video calls. In a conference or invited conference scenario, different attendees may use different `calltype` values - some join with

audio only, and some with audio and video. However, in a phone scenario, both sides must use the same `calltype`. Typically, a call invite from an audio-only caller is delivered to both the video and audio-only receiver, and if the video receiver answers, that receiver just does not use the video media type. However, a call invite from a video caller is automatically rejected with missed call indication from an audio-only receiver, so that if the caller's intention is a video call, then it does not get picked by an audio-only receiver.

The phone and invited conference scenarios use the same phone state protocol for signaling. However, they are not compatible with each other. For example, a user in the invited conference scenario may not engage in a phone call with a user in the phone scenario, and vice-versa. However, a user in the conference and the invited conference scenarios using the same conference state protocol are compatible with each other - no matter how the conference invitation was sent, both can join the same conference. The call queue and call distribution scenarios are compatible with the phone scenario.

Some examples of the component used in various scenarios are shown below. The `storage` property or `for-storage` attribute in the state machine components, `phone-state` and `conference-state`, are required.

```
// allow outbound and inbound call
    <click-to-call self="bob" other="alice" calltype="video">
        <phone-state for-storage="..."></phone-state>
    </click-to-call>
// anonymous click-to-call
    <click-to-call other="alice">
        <phone-state ...></phone-state>
    </click-to-call>
// call distributor in sequence
    <click-to-call self="carol" other="alice,bob" distribute="sequence"
incoming="false">
        <phone-state ...></phone-state>
        <phone-state ...></phone-state>
    </click-to-call>
// call queue
    <click-to-call self="carol" queue="true" outgoing="false">
        <phone-state ...></phone-state>
        <phone-state ...></phone-state>
        <phone-state ...></phone-state>
    </click-to-call>
// conference join
    <click-to-call self="bob" join="conf123" calltype="video">
        <conference-state ...></conference-state>
    </click-to-call>
// invited anonymous conference
    <click-to-call self="alice" other="bob">
        <phone-state ...></phone-state>
        <conference-state ...></conference-state>
    </click-to-call>
// invited conference anonymous caller
    <click-to-call other="bob" join="conf123">
        <phone-state ...></phone-state>
        <conference-state ...></conference-state>
    </click-to-call>
```

To see these in action, try the following example with several `click-to-call` instances. Some are configured with one `phone-state`, some with one `conference-state`, some with one `phone-state`

and one `conference-state`, and some with multiple `phone-state` components. Clicking on the attribute allows you to edit them and reconfigure the component. Most of the instances use the inline videos shown in the box, but some use the `open` feature to launch a separate browser window or tab for the videos. All the behavior of the component is customizable using the various properties and methods described later.

39.1 click-to-call

The following table describes all the properties of the `click-to-call` component.

Name	Type and description
`topic`	string, default is "" Controls the topic used for the call. This must be set before outbound call invite, and is automatically set on incoming call invite.
`calltype`	string, default is "audio" Controls and indicates the active or pending call type. Allowed values are "none", "audio" or "video". If "none" then video-io components are not used, and application is responsible for establishing any media path.
`displayname`	string, default is "" Controls the display name of the self instance.
`incoming`	bool, default is true Controls whether incoming call invites are allowed. If not, then received invites are declines internally with "not available".
`outgoing`	bool, default is true Controls whether outgoing call invites are allowed. If not, then click does not have any effect unless there is an incoming call invite.
`answer`	string, default is "confirm" Controls what user interaction is used to answer or decline a received call invite. Allowed values are "confirm", "hold", or "decline": confirm - show a confirmation prompt; hold - click and hold for at least half second to answer, or click to decline; decline - automatically decline.
`declineafter`	number, default is null Controls when to decline receive call invite automatically after some time. Value is interpretaed as valid positive number representing milliseconds.
`cancelafter`	number, default is null

	Controls when to cancel a sent call invite automatically after some time, if not answered or declined. Value is interpretaed as valid positive number representing milliseconds.
`distribute`	string, default is `""` Controls whether to distribute the call attempt to more than one target in sequence or parallel (default).
`queue`	bool, default is "false" Controls whether to queue incoming call invite.
`call-src`	string Set the file path for an alternate image of the call button
`end-src`	string Set the file path for an alternate image of the end button
`ringback-src`	string Set the file path for an alternate sound (mp3) of ringback, in outgoing call scenario.
`ringing-src`	string Set the file path for an alternate sound (mp3) of ringing, in incoming call scenario.
`missed-src`	string Set the file path for an alternate sound (mp3) of the missed call notification
`title`	string The title or tooltip shown on the button See event `titlechange`
`onopen`	Function The application can set this to a function which returns a DOM element under which the video-io elements are added. If not set, then internal and hidden div element is used for audio-only scenarios. To launch a separate

window or tab for video, the application can use the open method.
See method `open`

`oncreatevideo` Function
The component invokes this function, if set, to create a new video-io element in the application. If this property is not set, then a default video-io element is created. The application may set this property to a function that returns a video-io element instance.

`oncreatestream` Function
When a video is added, and a named stream does not exist, then the component invokes this function to create a new named stream element in the application. If this property is not set, then a local named-stream element is created, and works only for demonstration purpose. The application may set this property to a function that takes a stream path string and returns a named stream element instance.

`self` string, default is ""
Controls the identifier of the self instance. This must be unique among all the instances with the same storage path.

`other` string, default is ""
Controls or indicates the identifier of the other instance in pending or active call. This must be set before outbound call invite, and is automatically set on incoming call invite.

`join` string, default is ""
Controls or indicates the conference identifier. This must be set before outbound join, and is automatically set on incoming call invite to a conference.

`path` string, default is "phone-call/instances"
Root storage path under which the self and other identifiers are used.

`storage` object

	underlying shared-storage instance. See `path`
`for-storage`	string, default is `""` Use this to set the id of the external shared storage DOM element. See `storage`
`ready`	bool (read-only), default is false Whether the storage is set and is ready to be used? See `storage`

The following table shows all the methods of the `click-to-call` component.

Function	Signature and description
`open`	call.open("", "width=300,height=300") Return a DOM element with flex-box component in an external window object. It also wires up internal data such that the return value can be cleaned up. See property `onopen`

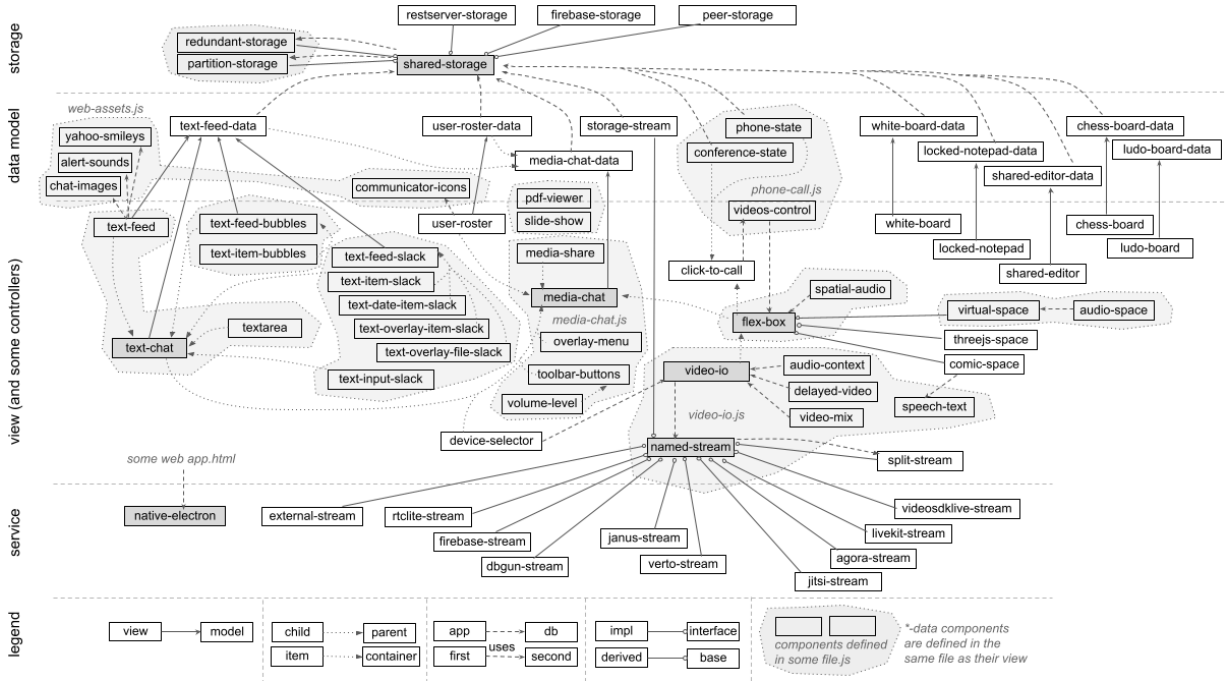
The following table shows all the events dispatched by the `click-to-call` component.

Event	Example and description
`titlechange`	{type: "titlechange", value: "Click to call alice"} Dispatched when the title property changes.

40. Summary

This project has a number of new web components that are useful in implementing a wide range of communicating applications such as video call, broadcast, conference, and so on. This document includes many code snippets and sample applications to get started quickly, as well as to try new things by extending the existing applications.

The following diagram shows all the web components included in the project, how they are related to each other, and how they interact with each other.



The components and classes are summarized below.

Component	Description

video-io Include video-io.js

This is the main video box which can be in publish or subscribe mode. The publish mode is used for webcam view and/or for sending local audio/video to other end. And the subscribe mode is used to display and listen to remote audio/video.

Additional component	Description
video-mix	Include video-io.js

This allows manipulating video using canvas such as for background removal, tile layout or other image processing. It can be attached to a video-io component, for example, to display locally, or to send to remote.

delayed-video Include video-io.js

This allows delayed playback of audio and video using internal recording of the source media stream. It can be attached to a video-io component or a media stream.

audio-context Include video-io.js

This allows wide range of audio signal processing such as delay, gain, biquad-filter, convolver, wave shaper and such, unsing the Web Audio API. It can be attached to a video-io component or a MediaStream directly.

speech-text Include video-io.js

This allows speech recognition and speech synthesis using built-in JavaScript APIs.

device-selector Include device-selector.js

This displays user interface to select devices such as microhone, speaker and camera.

named-stream Include video-io.js

The base named stream abstraction is used for local demonstrations only. For real applications, use a derived component from the list below, or create your own for some other service. The named stream works with the `video-io` component to publish or subscribe.

Derived component	Description
rtclite-stream	Include rtclite-stream.js

Uses my `rtclite` project for notifications over websocket.

janus-stream Include janus-stream.js

Uses the popular Janus media server, and also uses SFU for media path.

verto-stream Include verto-stream.js

Uses the popular Freeswitch media server, and also uses MCU for media path.

firebase-stream Include firebase-stream.js

Uses the popular Cloud Firestore project.

dbgun-stream Include dbgun-stream.js

Uses the Graph Universe Node distributed database project.

jitsi-stream Include jitsi-stream.js

Uses Jitsi-as-a-Service for conferencing service.

agora-stream Include agora-stream.js

Uses Agora video conference service.

livekit-stream Include livekit-stream.js

Uses LiveKit video conference service.

videosdklive-stream Include videosdklive-stream.js

Uses VideoSDK.live conference service.

external-stream Include external-stream.js

Allows using external web app.

split-stream Include split-stream.js

Allows splitting a publish stream into multiple.

storage-stream Include storage-stream.js, shared-storage.js

Uses the `shared-storage` component for notifications.

shared-storage Include shared-storage.js

The base shared storage abstraction in the form of the shared-storage component and the SharedStorage class. These are used for implementing various endpoint-driven application logic. For real applications, use a derived class such as RestserverStorage or PeerStorageImpl, or specify the implementation via the `src` attribute of shared-storage.

Class or Component	Description

SharedStorage Include shared-storage.js

Base class using local storage for demonstration only.

RestserverStorage Include restserver-storage.js

Uses my `restserver` project for storage and notifications over websocket.

restserver-storage Include restserver-storage.js

Uses my `restserver` project for storage and notifications over websocket.

PeerStorageImpl Include peer-storage.js

Uses peer-to-peer network for storage and notifications using data channel and external signaling to create the peer-to-peer network.

peer-storage Include peer-storage.js

Uses peer-to-peer network for storage and notifications using data channel and external signaling to create the peer-to-peer network.

FirebaseStorage Include firebase-storage.js

Uses the popular Cloud Firestore real-time database service.

firebase-storage Include firebase-storage.js

Uses the popular Cloud Firestore real-time database service.

redundant-storage Include redundant-storage.js

Allows redundant storage for reliability.

partition-storage Include partition-storage.js

Allows partitioned storage for scalability.

flex-box Include flex-box.js

The flexible layout container component that can work in fixed, grid or flexible mode for a wide range of layout requirements of multi-party video conferencing.

Additional component	Description
threejs-space Include threejs-space.js	

The 3D space container for layout of multi-party video conferencing elements, that supports simple cube and rectangle layout of `video-io` in a 3D space using the popular three.js project.

virtual-space Include virtual-space.js

The 3D space container for layout of various elements including `video-io` components, in a 3D space, using standard CSS transforms.

speech-bubble Include speech-bubble.js

The speech bubble based conversation tracking container component focussed towards text chat and speech recognition based conversations.

comic-space Include comic-space.js

Another speech bubble based container, which removes background and comicifies the participant images.

spatial-audio Include flex-box.js

Spatial audio using 2D position of sound sources of attached flex-box items, and a fixed listener position.

audio-space Include virtual-space.js

Spatial audio using 3D position and cone panner orientation of sound sources of the attached virtual-space items, and a moving and flexible listener orientation and position based on the camera or viewer position.

`collaboration`

Components for text chat, media chat, white board, locked notepad, and games. All these work with the shared-storage component.

Component **Description**

text-feed Include text-chat.js

Displays list of messages in real-time and/or from history using an underlying list data on the data model.

`text-feed-data` Include text-chat.js
Data model for text-feed, text-chat, and others, using shared storage.

`alerts-sounds` Include web-assets.js

Web assets for alert sounds to be used by text-feed or others.

`yahoo-smileys` Include web-assets.js

Web assets for similey images to be used by text-feed or others.

text-chat Include text-chat.js

Useful for multiparty text chat, includes a text-feed component and a text input areal, and also supports file sharing via drag-and-drop to the input area.

text-feed-bubbles Include text-chat-bubbles.js

Displays text chat as speech bubbles for a multi-party text chat using an underlying list data on a shared storage path.

text-item-bubbles Include text-chat-bubbles.js

Displays an individual chat message as child of text-feed-bubbles. Various attributes are used to customize the message.

`chat-images` Include web-assets.js

Web assets for border image of chat bubbles.

text-feed-slack Include text-chat-slack.js

Displays Slack style text chat feed.

`text-item-slack` Include text-chat-slack.js

Used by text-feed-slack to display a single chat item.

`text-date-item-slack` Include text-chat-slack.js

Displays a date/time item.

`text-over-item-slack` Include text-chat-slack.js

Displays overlay buttons for chat item.

Input controls for entering a text message.

user-roster Include user-roster.js

Displays a list of users and their attributes from a data model for contact list or attendee list.

`user-roster-data` Include user-roster.js

Data model for user-roster, using shared storage.

media-chat Include media-chat.js

Useful for multiparty multimedia conference, and includes the text-chat, user-roster and flex-box with zero or more video-io components.

`media-chat-data` Include media-chat.js

Data model for media-chat, using shared storage.

communicator-icons Include web-assets.js

Web assets for icons to be used by media-chat or others.

toolbar-buttons Include media-chat.js

Customizable toolbar buttons to be used in media-chat.

overlay-menu Include media-chat.js

Customizable overlay menu to be used in media-chat.

volume-level Include media-chat.js

Sound activity and volume control to be used in media-chat.

white-board Include white-board.js

Implements white board, allows drawings, texts and drag-and-drop images, and if attached to a data model, enables shared white board.

`white-board-data` Include white-board.js

Data model for white-board, using shared storage.

locked-notepad Include locked-notepad.js

Implements locked text editor, and if attached to data model, enables shared notepad.

`locked-notepad-data` Include locked-notepad.js

Data model for locked-notepad, using shared storage.

shared-editor Include shared-editor.js

Implements rich text editor, and if attached to a data model, enables shared editing.

`shared-editor-data` Include shared-editor.js

Data model for shared-editor, using shared storage.

chess-board Include chess-board.js

Display a chess board, allows playing without restriction, and if attached to a data model, enables shared game.

`chess-board-data` Include chess-board.js

Data model for chess-board, using shared storage.

ludo-board Include ludo-board.js

Display a ludo board, allows playing without restriction, and if attached to a data model, enables shared game.

`ludo-board-data` Include ludo-board.js

Data model for ludo-board, using shared storage.

media-share Include media-chat.js

Internally used to wrap shared app within media-chat.

slide-show Include slide-show.js

Displays one or more image, video or PDF document files, with navigation controls. Can be used as shared app in media-chat.

pdf-viewer Include slide-show.js

Display PDF document using external library. Can be used by slide-show component.

`telephony`

Components for phone and conference states and various forms of telephony scenarios. Many of

these work with the shared-storage component.

Component	Description
phone-state	Include phone-call.js State machine for phone registration and call, using the shared storage.
conference-state	Include phone-call.js State machine for conference join and leave, and membership, using the shared storage.
videos-control	Include phone-call.js Used by phone-state or conference-state or similar to start and stop media using the video-io element when needed.
click-to-call	Include click-to-call.js Displays a single clickable button, includes one or more of phone-state or conference-state, and using the shared storage, supports wide range of telephone scenarios such as click-to-call, click-to-join, call queue and call distribution.
native-electron	Include native-electron.js This component works with an external Native Electron app to support native features such as TCP and UDP sockets, raw DNS, system information, and customized or frameless windows.