Web of Things
Scripting API

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Web of Things: Application Layer

Internet of Things: Connectivity

IEEE 802.15.4, Ethernet, Wi-Fi, Bluetooth, LoRa, ...
<table>
<thead>
<tr>
<th><strong>Application [scripts]</strong></th>
<th>Define Thing behaviour in terms of their properties, actions and events that use internal APIs for controlling sensor and actuator hardware.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Things</strong></td>
<td>Software objects representing abstract or physical devices and state. Abstract Thing to Thing interaction. Semantics and Metadata, Data models and Data.</td>
</tr>
<tr>
<td><strong>Transfer</strong></td>
<td>Bindings of abstract messages to mechanisms provided by each protocol, including choice of communication pattern, e.g. pull, push, pub-sub, peer to peer, etc.</td>
</tr>
<tr>
<td><strong>Connectivity (Phy+Link+Network)</strong></td>
<td>REST based protocols, e.g. HTTP, CoAP Pub-Sub protocols, e.g. MQTT, XMPP Others, including non IP transports, e.g. Bluetooth</td>
</tr>
</tbody>
</table>
WoT is not another IoT platform, but a framework to describe and integrate IoT platforms through the Web.

Web technologies are used on addressing, discovery, access control, data transfer, scripting.

**WoT Concepts: Web vs WoT**

- Web page → Thing
- URL → URI
- HTTP → HTTP, CoAP, BLE, WS
- HTML → Thing Description
- ECMAScript → WoT Script
- Web search → Discovery
- Served page → Exposed Thing
- Rendered page → Consumed Thing
WoT Building Blocks

**Thing Description (TD)**
Metadata describing the data model, security & interactions.

**Scripting API**
A standardized API to control Thing interactions and implement behaviour.

**Protocol Bindings**
Describes how to translate WoT interactions to the underlying protocols.

**Security & Privacy**
Ensures that all building blocks provide means to describe the security and privacy mechanisms used in underlying platforms.
WoT Servient with & without Scripting
Native Applications

- **Platform API**
- **Interaction Model**
- **Protocol Bindings**

Use cases:

- **HTTP**, **CoAP**, **OCF**, **CoAP**
- **OneM2M**, **CoAP**
Gateways Can Automatically Adapt to New Devices

Use cases

Thing
- Application
- Platform API
- Interaction Model
- Protocol Bindings

WoT Gateway [scripts]

HTTP, CoAP, OCF, CoAP

OneM2M
CoAP
BACnet
A WoT Gateway can download a TD that describes an existing device.
- If the protocol is already supported, scripts can already use the device.
- Otherwise the WoT Servient needs updated with the protocol binding (e.g. npm).
Coexisting Scripting APIs & implementations

- Simplify application development
- Portable across vendors
- Deployable within the WoT network
W3C WoT Big Picture

Cloud Mirrors

Semantic metadata (Thing Description)

Web integration

Web Browser

Device Shadow
- Application
- Scripting API
- Interaction Model
- Protocol Bindings

Remote access

Virtual Thing
- Application
- Scripting API
- Interaction Model
- Protocol Bindings

Local Hubs

Standardized APIs for portable application logic (Scripting API)

Use cases

Direct Thing-to-Thing

Complementing existing devices and platforms

Existing Device + Powerful and constrained Things

Thing

(Web Description, Binding Templates)

Direct Thing-to-Thing

Web integration

Web Browser

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Local Hubs

Standardized APIs for portable application logic (Scripting API)
WoT Stack

**Processes**
- WoT Runtime
- Script execution contexts
- Bindings, System adapters
- System APIs / OS Kernel

**Special Things**
- Script Manager Thing
- System Access Things
  - expose API objects
  - have TDs ⇒ discoverable (introspection)

**System APIs**
- Protocol stack/services
  - (CoAP, HTTP, BLE, OCF, ...)
- file system
- secure storage
- local sensors
- Local HW API

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![Servient architecture diagram](image-url)
WoT Runtime

Script Execution Context (SEC)
- Single event loop
- Call stack, callback queue
- Runs a single script
- Serialized execution
- Hosts multiple Thing instances

SEC Definitions
- For ECMAScript (in browsers):
  - Multiple SEC
  - One SEC executed at a time
- For WoT: more like in Node.js
  - SEC may be sandboxed
  - SEC may run in separate containers
  ⇒ SECs may run in parallel

WoT Runtime
- Process hosting all structures
  - WoT API objects
  - Bindings plugin host
  - Script Manager Thing
  - System Things
- May spawn new SECs
- Security enforcement point (trusted)

Scripting API: Discovery, Client, Server

WoT Runtime (Agent)
- Interactions implementation
- Security Configurations

Scheduling
System API bindings
Special Things
WoT Script deployment

**Scripts** use the Scripting API to interact with
- local and remote Things
- special Things:
  - System APIs, via System Things + bindings
  - Script Manager Thing: save, delete, run, stop, make persistent, ...

Scripts can get to a device by:
1. Provisioned (e.g. flashed to the device)
2. Using the Script Manager Thing client interface
3. By consuming a TD (idea for future development)*

(*)Theoretically, **TDs may contain scripts**

Most deployments will probably use pre-provisioned scripts or no scripts (constrained devices), but gateways/servients could implement Script Manager and System Things.

In practice, most scripts will be deployed to gateways in order to add business logic to use the connected simpler Things.
Request to run a script

network → system/socket → binding → runtime →
→ manager/action
  → run script → API → runtime
  → [fetch TD: system APIs →
  → bindings → socket →
  → runtime → API → TD] →
  → create Thing + bind to RT
→ manager/reply
  → bindings → system/socket → network.

Scripts typically produce:
- Thing Descriptions
- runtime-bound Thing instances, each having:
  - Properties + getters/setters
  - Event handlers (*)
  - Action handlers (*)
  - Mappings to Protocol Bindings

(*) Integrated with the Execution Context event loop.

Request to access a Thing

network → socket → OS → binding → runtime → dispatcher
→ Thing (process, reply)
→ API → binding → OS → socket → network
Scripting API details

WOT object: discover and create Things
Client API: interact with Things
Server API: create & expose local Things
Examples
Web of Things (WoT) Scripting API
W3C Editor’s Draft 12 April 2019

This version:
https://w3c.github.io/wot-scripting-api/

Latest published version:
https://www.w3.org/2019/wot/scripting-api/

Latest editor’s draft:
https://w3c.github.io/wot-scripting-api/

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Abstract

The key Web of Things (WoT) concepts are described in the WoT Architecture document. The Web of Things is made of entities (Things) that can describe their capabilities in a machine-interpretable format, the Thing Description (TD) and expose these capabilities through the WoT Interface, that is, network interactions modeled as Properties (for reading and writing values), Actions (to execute remote procedures with or without return values) and Events (for signaling notifications).

Scripting is an optional “convenience” building block in WoT and it is typically used in gateways that are able to run a WoT Runtime and script management, providing a convenient way to extend WoT support to new types of endpoints and implement WoT applications such as Thing Directory.

This specification describes a programming interface representing the WoT Interface that allows scripts to discover and operate Things and to expose locally defined Things characterized by WoT Interactions specified by a script.
interface WOT {
    ConsumedThing consume(ThingDescription td);
    ExposedThing produce(ThingDescription td);
    ThingDiscovery discover(optional ThingFilter filter);
};

typedef (USVString or object) ThingDescription;
typedef object ThingInstance;

[Constructor(optional ThingFilter filter), SecureContext, Exposed=(Window, Worker)]
interface ThingDiscovery {
    readonly attribute ThingFilter? filter;
    readonly attribute boolean active;
    readonly attribute boolean done;
    readonly attribute Error? error;
    void start();
    Promise<object> next();
    void stop();
};

typedef DOMString DiscoveryMethod;
dictionary ThingFilter {
    (DiscoveryMethod or DOMString) method = "any";
    USVString? url;
    USVString? query;
    object? fragment;
};
callback WotListener = void(any data);
dictionary InteractionOptions {
    object urlVariables;
};

[SecureContext, Exposed=(Window, Worker)]
interface ConsumedThing: EventTarget {
    Promise<any> readProperty(DOMString propertyName, optional InteractionOptions options);
    Promise<object> readAllProperties(optional InteractionOptions options);
    Promise<object> readMultipleProperties(sequence<DOMString> propertyNames, optional InteractionOptions options);
    Promise<void> writeProperty(DOMString propertyName, any value, optional InteractionOptions options);
    Promise<void> writeMultipleProperties(object valueMap, optional InteractionOptions options);
    Promise<any> invokeAction(DOMString actionName, optional any params, optional InteractionOptions options);
    Promise<void> subscribeProperty(DOMString name, WotListener listener);
    Promise<void> unsubscribeProperty(DOMString name);
    Promise<void> subscribeEvent(DOMString name, WotListener listener);
    Promise<void> unsubscribeEvent(DOMString name);
    readonly attribute ThingInstance instance;
    attribute EventHandler onchange;
};

[Constructor(ThingInstance instance), SecureContext, Exposed=(Window, Worker)]
interface ExposedThing: ConsumedThing {
    ExposedThing setPropertyReadHandler(DOMString name, PropertyReadHandler readHandler);
    ExposedThing setPropertyWriteHandler(DOMString name, PropertyWriteHandler writeHandler);
    ExposedThing setActionHandler(DOMString name, ActionHandler action);
    void emitEvent(DOMString name, any data);
    Promise<void> expose();
    Promise<void> destroy();
};
callback PropertyReadHandler = Promise<any>(any value);
callback PropertyWriteHandler = Promise<void>(any value);
callback ActionHandler = Promise<any>(any parameters);
To create and expose a Thing, we need a TD.
try {
    let res = await fetch('https://tds.mythings.biz/sensor11');
    // ... additional checks possible on res.headers
    let td = await res.json(); // could also be res.text()
    let thing = WOT.consume(td);
    console.log("Thing name: " + thing.instance.name);
} catch (err) {
    console.log("Fetching TD failed", err.message);
}
Discovery API

**[Constructor](optional ThingFilter filter), SecureContext, Exposed=(Window, Worker)**

```javascript
interface ThingDiscovery {
    readonly attribute ThingFilter? filter;
    readonly attribute boolean active;
    readonly attribute boolean done;
    readonly attribute Error? error;
    void start();
    Promise<object> next();
    void stop();
};
```

typedef DOMString DiscoveryMethod;
// "any", "local", "directory", "multicast"

dictionary ThingFilter {
    (DiscoveryMethod or DOMString) method = "any";
    USVString? url;
    USVString? query;
    object? fragment;
};

Discovery provides TDs:
- Things exposed in the local WoT Runtime
- Things listed in a directory service
- Things exposed in a local network.
Discovery examples

// Discover Things exposed by local hardware
let discovery = WOT.discover({ method: "local" });

do {
    let td = await discovery.next();
    console.log("Found Thing Description for " + td.name);
    let thing = WOT.consume(td);
    console.log("Thing name: " + thing.instance.name);
} while (!discovery.done);

// Multicast discovery
let discovery = WOT.discover({ method: "multicast" });

setTimeout( () => {
    discovery.stop();
    console.log("Stopped open-ended discovery");
}, 10000);

do {
    let td = await discovery.next();
    console.log("Found Thing Description for " + td.name);
    let thing = WOT.consume(td);
    console.log("Thing name: " + thing.instance.name);
} while (!discovery.done);

if (discovery.error) {
    console.log("Discovery stopped.");
    console.log("Discovery error: " + error.message);
}
Client API

```javascript
[Constructor(ThingInstance instance), SecureContext, Exposed=(Window,Worker)]
interface ConsumedThing: EventTarget {
    Promise<any> readProperty(DOMString propertyName,
                               optional InteractionOptions options);
    Promise<object> readAllProperties(optional InteractionOptions options);
    Promise<object> readMultipleProperties(sequence<DOMString> propertyNames,
                                              optional InteractionOptions options);
    Promise<void> writeProperty(DOMString propertyName, any value,
                               optional InteractionOptions options);
    Promise<void> writeMultipleProperties(object valueMap,
                                             optional InteractionOptions options);
    Promise<any> invokeAction(DOMString actionName, optional any params,
                               optional InteractionOptions options);
    Promise<void> subscribeProperty(DOMString name, WotListener listener);
    Promise<void> unsubscribeProperty(DOMString name);
    Promise<void> subscribeEvent(DOMString name, WotListener listener);
    Promise<void> unsubscribeEvent(DOMString name);
    readonly attribute ThingInstance instance;
    attribute EventHandler onchange;
}

callback WotListener = void(any data);
dictionary InteractionOptions {
    object uriVariables;
};
```

Once a Thing is found, scripts can
- observe it using events
- change it using properties and actions.

The client needs access rights, but provisioning is out of scope.
try {
    let res = await fetch("https://tds.mythings.org/sensor11");
    let td = res.json();
    let thing = new ConsumedThing(td);

    await thing.subscribeProperty("temperature", value => {
        console.log("Temperature changed to: " + value);
    });

    await thing.subscribeEvent("ready", eventData => {
        console.log("Ready; index: " + eventData);
        await thing.invokeAction("startMeasurement", {
            units: "Celsius"
        });
        console.log("Measurement started.");
    });
} catch(e) {
    console.log("Error: " + error.message);
}
Server API

```typescript
[Constructor(ThingInstance instance), SecureContext, Exposed=(Window, Worker)]

interface ExposedThing: ConsumedThing {
    ExposedThing setPropertyReadHandler(DOMString name, PropertyReadHandler readHandler);
    ExposedThing setPropertyWriteHandler(DOMString name, PropertyWriteHandler writeHandler);
    ExposedThing setActionHandler(DOMString name, ActionHandler action);
    void emitEvent(DOMString name, any data);
    Promise<void> expose();
    Promise<void> destroy();
}
```

callback PropertyReadHandler = Promise<any>();
callback PropertyWriteHandler = Promise<void>(any value);
callback ActionHandler = Promise<any>(any parameters);

A server Thing can
- programmatically create a TD
- define behavior for client requests:
  - get/set Property
  - invoke Action
  - observe Events.
try {
    // note that produce() fails if the TD contains an error
    let thing = WOT.produce(thingDescription);
    // Interactions were added from TD
    // WoT adds generic handler for reading any property
    // Define a specific handler for a Property
    thing.setPropertyReadHandler("prop1", () => {
        return new Promise((resolve, reject) => {
            let examplePropertyValue = 5;
            resolve(examplePropertyValue);
        }
    });
    await thing.expose();
} catch (err) {
    console.log("Error creating ExposedThing: " + err);
}
ExposedThing with a simple property

```javascript
let temperaturePropertyDefinition = {
    type: "number",
    minimum: -50,
    maximum: 10000
};

let tdFragment = {
    properties: {
        temperature: temperaturePropertyDefinition
    },
    actions: {
        reset: {
            description: "Reset the temperature sensor",
            input: {
                temperature: temperatureValueDefinition
            },
            output: null,
            forms: []
        },
    },
    events: {
        onchange: temperatureValueDefinition
    }
};

try {
    let thing1 = WOT.produce(tdFragment);
    // Here add customized service handlers
    await thing1.expose();
} catch (err) {
    console.log("Error creating ExposedThing: " + err);
}

// The Thing can be used right away.
setInterval( async () => {
    let mock = Math.random()*100;
    let old = await thing1.readProperty("temperature");
    if (old < mock) {
        await thing1.writeProperty("temperature", mock);
    }
}, 1000);
```
Add an object Property

```javascript
try {
  // Create a deep copy of thing1 instance
  let instance = JSON.parse(JSON.stringify(thing1.instance));
  try {
    catch (err) {
      console.log("Error cloning Thing: " + err);
    }

  // Create an object that describes a Property
  const statusValueDefinition = {
    type: "object",
    properties: {
      brightness: {
        type: "number",
        minimum: 0.0,
        maximum: 100.0,
        required: true
      },
      rgb: {
        type: "array",
        "minItems": 3,
        "maxItems": 3,
        items: {
          "type": "number",
          "minimum": 0,
          "maximum": 255
        }
      }
    },
  },
  instance.properties["brightness"] = {
    type: "number",
    minimum: 0.0,
    maximum: 100.0,
    required: true
  },
  instance.properties["status"] = statusValueDefinition;
  instance.actions["getStatus"] = {
    description: "Get status object",
    input: null,
    output: {
      status: statusValueDefinition
    },
    forms: [...]}
  instance.events["onstatuschange"] = statusValueDefinition;
  instance.forms = [...] // update
  } catch (err) {
    console.log("Error creating ExposedThing: " + err);
  }
}
```

// Create a new Thing based on instance.

```javascript
try {
  var thing2 = WOT.produce(instance);
  // Add customized service handlers here.
  // thing2.instance is now different than instance
  await thing2.expose();
})
```
```javascript
} catch (err) {
  console.log("Error creating ExposedThing: " + err);
}
```
node-wot

One implementation of the Scripting API
Dual W3C and Eclipse license
The *de-facto* reference implementation
node-wot **a** Scripting API implementation

- node-wot is an open-source implementation of the WoT Scripting API
  [http://www.thingweb.io](http://www.thingweb.io)

- The project can be fully customized using various packages
  - td-tools
  - core
  - bindings (HTTP, CoAP, MQTT, WebSockets, ...)
    - Other binding protocols can be added by fulfilling a give API
    - Content codecs (besides JSON, text, and octet-stream) can be added
  - Miscellaneous: demos, command-line interface

- **Facts**
  - NodeJS implementation in TypeScript
  - Development on GitHub: [https://github.com/eclipse/thingweb.node-wot/](https://github.com/eclipse/thingweb.node-wot/)
  - Dual-licensed: [Eclipse Public License v. 2.0](https://www.eclipse.org/legal/epl-2.0/) and [W3C Software Notice and Document License](https://www.w3.org/Consortium/Legal/2015/copyright-software-doclicense)
  - Available through NPM (packages such as core, td-tools, ...)

Implementations
node-wot - Demos and Tools

• Web UI
  ○ node-wot can be used as a browser-side JavaScript library (~160kB JS code)
  ○ http://plugfest.thingweb.io/webui/

• TD Playground
  ○ Tool to check the validity of a TD
  ○ Performs both syntactic checks and semantic checks
  ○ http://plugfest.thingweb.io/playground/

• TD Directory
  ○ REST interface to add, update and query TDs for discovery purposes
  ○ http://plugfest.thingweb.io
Contributions welcome!

- **Thing Description**
  - Examples, recipes, etc

- **Security**
  - The work just got started
  - Interoperability between deployments
  - Best practices

- **Runtime and Scripting**
  - Implementations
  - Examples
  - Browser use cases

- **Applications**