

Web of Things (WoT) Scripting API

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Abstract

The main [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 [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, operate [Things](#) and to expose locally defined [Things](#) characterized by [WoT Interactions](#) specified by a script.

The specification deliberately follows the [WoT Thing Description specification](#) closely. It is possible to implement simpler APIs on top of this API, or implementing directly the WoT network facing interface (i.e. the [WoT Interface](#)).

EDITOR'S NOTE

This specification is implemented at least by the [Thingweb](#) project also known as [node-wot](#), which is considered the reference open source implementation at the moment. Check its [source code](#), including [examples](#). Other, closed source implementations have been made by WG member companies and tested against [node-wot](#) in plug-fests.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current W³C publications and the latest revision of this technical report can be found in the [W³C technical reports index](#) at <https://www.w3.org/TR/>.

Implementers need to be aware that this specification is considered unstable. Vendors interested in implementing this specification before it eventually reaches the Candidate Recommendation phase should subscribe to the [repository](#) and take part in the discussions.

EDITOR'S NOTE: The W3C WoT WG is asking for feedback

Please contribute to this draft using the [GitHub Issue](#) feature of the [WoT Scripting API](#) repository. For feedback on security and privacy considerations, please use the [WoT Security and Privacy Issues](#).

This document was published by the [Web of Things Working Group](#) as an Editor's Draft.

Comments regarding this document are welcome. Please send them to public-wot-wg@w3.org ([archives](#)).

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This document is governed by the [1 March 2019 W3C Process Document](#).

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1. Introduction §

WoT provides layered interoperability based on how [Things](#) are used: "consumed" and "exposed", as [defined](#) in [[WOT-ARCHITECTURE](#)].

By [consuming a TD](#), a client [Thing](#) creates a local runtime resource model that allows accessing the [Properties](#), [Actions](#) and [Events](#) exposed by the server [Thing](#) on a remote device.

Exposing a [Thing](#) requires:

- defining a [Thing Description](#) (TD),
- then instantiating a software stack that implements the [WoT Interface](#) specified by the [TD](#) in order to serve requests for accessing the exposed [Properties](#), [Actions](#) and [Events](#),
- then eventually publishing the [Thing Description](#) (for instance to a [Thing Directory](#) directory for easier discovery).

This specification describes how to expose and consume [Things](#) by a script. Also, it defines a generic API for [Thing](#) discovery.

NOTE

Typically scripts are meant to be used on bridges or gateways that expose and control simpler devices as WoT [Things](#) and have means to handle (e.g. install, uninstall, update etc.) and run scripts.

NOTE

This specification does not make assumptions on how the [WoT Runtime](#) handles and runs scripts, including single or multiple tenancy, script deployment and lifecycle management. The API already supports the generic mechanisms that make it possible to implement script management, for instance by exposing a manager [Thing](#) whose [Actions](#) (action handlers) implement script lifecycle management operations.

2. Use Cases §

This section is non-normative.

The following scripting use cases are supported in this specification:

2.1 Consuming a Thing §

- [Consume a TD](#), i.e. create a programmatic object from a [Thing Description](#) that exposes [WoT Interactions](#):
 - Read the value of a [Property](#) or a set of properties.
 - Set the value of a [Property](#) or a set of properties.
 - Observe value changes of a [Property](#).
 - Invoke an [Action](#).
 - Observe WoT [Events](#) emitted by the [Thing](#).
 - Introspect the [Thing Description](#), including the list of linked resources based on the [Thing Description](#).

2.2 Exposing a Thing §

- Exposing the [Thing](#) includes generating the protocol bindings in order to access lower level functionality.
- Create a local [Thing](#) to be exposed, based on a [Thing Description](#) provided in string serialized format, or out of an existing [Thing](#) object.
- Add a [Property](#) definition to the [Thing](#).
- Remove a [Property](#) definition from the [Thing](#).
- Add an [Action](#) definition to the [Thing](#).
- Remove an [Action](#) definition from the [Thing](#).
- Add a WoT [Event](#) definition to the [Thing](#).
- Remove a WoT [Event](#) definition from the [Thing](#).
- Emit a WoT [Event](#), i.e. notify all subscribed listeners.
- Register service handlers for external requests:
 - to retrieve a [Property](#) value;
 - to update a [Property](#) value;
 - to invoke an [Action](#): take the parameters from the request, execute the defined action, and return the result;

2.3 Discovery §

- Discover [Things](#) in a network by sending a broadcast request.
- Discover [Things](#) running in the local [WoT Runtime](#).
- Discover nearby [Things](#), for instance connected by NFC or Bluetooth.
- Discover [Things](#) by sending a discovery request to a given registry.
- Discover [Things](#) filtered by filters defined on [Thing Descriptions](#)
- Discover [Things](#) filtered by semantic queries.
- Stop or suppress an ongoing discovery process.
- Optionally specify a timeout to the discovery process after which it is stopped/suppressed.

3. Conformance §

As well as sections marked as non-normative, all authoring guidelines, diagrams, examples, and notes in this specification are non-normative. Everything else in this specification is normative.

The key words *MAY*, *MUST*, and *SHOULD* in this document are to be interpreted as described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

This specification describes the conformance criteria for the following classes of *user agent (UA)*.

Due to requirements of small embedded implementations, splitting WoT client and server interfaces was needed. Then, discovery is a distributed application, but typical scenarios have been covered by a generic discovery API in this specification. This resulted in using 3 conformance classes for a [UA](#) that implements this API, one for client, one for server, and one for discovery. An application that uses this API can introspect for the presence of the `consume()`, `produce()` and `discover()` methods on the [WoT API object](#) in order to determine which conformance class the [UA](#) implements.

***WoT Consumer* [UA](#)**

Implementations of this conformance class *MUST* implement the [ConsumedThing](#) interface and the `consume()` method on the [WoT API object](#).

***WoT Producer* [UA](#)**

Implementations of this conformance class *MUST* implement [ExposedThing](#) interface and the `produce()` method on the [WoT API object](#).

***WoT Discovery* [UA](#)**

Implementations of this conformance class *MUST* implement the [ThingDiscovery](#) interface and the `discover()` method on the [WoT API object](#).

These conformance classes *MAY* be implemented in a single [UA](#).

This specification can be used for implementing the WoT Scripting API in multiple programming languages. The interface definitions are specified in [[WEBIDL](#)].

The [UA](#) may be implemented in the browser, or in a separate runtime environment, such as [Node.js](#) or in small embedded runtimes.

Implementations that use ECMAScript executed in a browser to implement the APIs defined in this document *MUST* implement them in a manner consistent with the ECMAScript Bindings defined in the Web IDL specification [[WEBIDL](#)].

Implementations that use TypeScript or ECMAScript in a runtime to implement the APIs defined in this document *MUST* implement them in a manner consistent with the TypeScript Bindings defined in the TypeScript specification [[TYPESCRIPT](#)].

4. The *ThingDescription* type §

WebIDL

```
typedef object ThingDescription;
```

Represents a Thing Description (TD) as defined in [WOT-TD]. It is expected to be a parsed JSON object that is validated using JSON schema validation.

4.1 Fetching a Thing Description §

Fetching a TD given a URL should be done with an external method, such as the Fetch API or a HTTP client library, which offer already standardized options on specifying fetch details.

EXAMPLE 1: Fetching a Thing Description

```
try {  
  let res = await fetch('https://tds.mythings.biz/sensor11');  
  // ... additional checks possible on res.headers  
  let td = await res.json();  
  let thing = new ConsumedThing(td);  
  console.log("Thing name: " + thing.getThingDescription().title);  
} catch (err) {  
  console.log("Fetching TD failed", err.message);  
}
```

4.2 Expanding a Thing Description §

Note that [WOT-TD] allows using a shortened Thing Description by the means of defaults and requiring clients to expand them with default values specified in [WOT-TD] for the properties that are not explicitly defined in a given TD.

To *expand a TD* given *td*, run the following steps:

1. For each item in the TD default values table from [WOT-TD], if the term is not defined in *td*, add the term definition with the default value specified in [WOT-TD].

4.3 Validating a Thing Description §

The [WOT-TD] specification defines how a [TD](#) should be validated. Therefore, this API expects the [ThingDescription](#) objects be validated before used as parameters. This specification defines a basic [TD](#) validation as follows.

To *validate a TD* given *td*, run the following steps:

1. If *td* is not an object, [throw](#) a "[TypeError](#)" and abort these steps.
2. If any of the mandatory properties defined in [WOT-TD] for [Thing](#) that don't have [default definitions](#) are missing from *td*, [throw](#) a "[TypeError](#)" and abort these steps.
3. If [JSON schema validation](#) fails on *td*, [throw](#) a "[TypeError](#)" and abort these steps.

5. The *WoT API object* §

Defines the API entry point exposed as a singleton and contains the API methods.

5.1 The *WOT* interface §

WebIDL

```
[SecureContext, Exposed=(Window,Worker)]  
interface WOT {  
    // methods defined in UA conformance classes  
};
```

NOTE

Browser implementations should use a namespace object such as [navigator.wot](#). Standalone runtimes may expose the API object through mechanisms like [require\(\)](#) or [import](#).

5.2 The *consume()* method §

WebIDL

```
partial interface WOT {
  Promise<ConsumedThing> consume(ThingDescription td);
};
```

Belongs to the WoT Consumer conformance class. Expects an *td* argument and returns a Promise that resolves with a ConsumedThing object that represents a client interface to operate with the Thing. The method *MUST* run the following steps:

1. Return a Promise *promise* and execute the next steps in parallel.
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a SecurityError and abort these steps.
3. Run the validate a TD steps on *td*. If that fails, reject *promise* with SyntaxError and abort these steps.
4. Let *thing* be a new ConsumedThing object constructed from *td*.
5. Set up the WoT Interactions based on introspecting *td* as explained in [WOT-TD] and [WOT-PROTOCOL-BINDINGS]. Make a request to the underlying platform to initialize the Protocol Bindings.

EDITOR'S NOTE

Implementations encapsulate the complexity of how to use the Protocol Bindings for implementing WoT interactions. In the future elements of that could be standardized.

6. Resolve *promise* with *thing*.

5.3 The **produce()** method §

WebIDL

```
partial interface WOT {
  Promise<ExposedThing> produce(ThingDescription td);
};
```

Belongs to the WoT Producer conformance class. Expects a *td* argument and returns a Promise that resolves with an ExposedThing object that extends ConsumedThing with a server interface, i.e. the ability to define request handlers. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Let *thing* be a new [ExposedThing](#) object constructed with *td*.
4. Resolve *promise* with *thing*.

5.4 The **discover()** method §

WebIDL

```
partial interface WOT {  
    ThingDiscovery discover(optional ThingFilter filter = null);  
};
```

Belongs to the [WoT Discovery](#) conformance class. Starts the discovery process that will provide [ThingDescription](#) objects for [Thing Descriptions](#) that match an optional *filter* argument of type [ThingFilter](#). The method *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a "[SecurityError](#)" and abort these steps.
2. Construct a [ThingDiscovery](#) object *discovery* with *filter*.
3. Invoke the [discovery.start\(\)](#) method.
4. Return *discovery*.

6. Handling interaction data §

As specified in [\[WOT-TD\]](#), [WoT interactions](#) extend [DataSchema](#) and include a number of possible [Forms](#), out of which one is selected for the interaction. The [Form](#) contains a **contentType** to describe the data. For certain content types, a [DataSchema](#) is defined, based on [JSON schema](#), making possible to represent these contents as JavaScript types and eventually set range constraints on the data.

6.1 The **InteractionInput** type §

WebIDL

```
typedef any DataSchemaValue;  
typedef (ReadableStream or DataSchemaValue) InteractionInput;
```

Belongs to the WoT Consumer conformance class and represents the WoT Interaction data provided by application scripts to the UA.

DataSchemaValue is an ECMAScript value that is accepted for DataSchema defined in [WoT-TD] (i.e. null, boolean, number, string, array, or object).

ReadableStream is meant to be used for WoT Interactions that don't have a DataSchema in the Thing Description, only a Form's **contentType** that can be represented by a stream.

In practice, any ECMAScript value may be used for WoT Interactions that have a DataSchema defined in the Thing Description, or which can be mapped by implementations to the Form's **contentType** defined in the Thing Description.

The algorithms in this document specify how exactly input data is used in WoT Interactions.

6.2 The **InteractionOutput** interface §

Belongs to the WoT Consumer conformance class. An **InteractionOutput** object is always created by the implementations and exposes the data returned from WoT Interactions to application scripts.

This interface exposes a convenience function which should work in the vast majority of IoT use cases: the value() function. Its implementation will inspect the data, parse it if adheres to a DataSchema, or otherwise fail early, leaving the underlying stream undisturbed so that application scripts could attempt reading the stream themselves, or handling the data as ArrayBuffer.

WebIDL

```
[SecureContext, Exposed=(Window,Worker)]  
interface InteractionOutput {  
  readonly attribute ReadableStream? data;  
  readonly attribute boolean dataUsed;  
  readonly attribute Form? form;  
  readonly attribute DataSchema? schema;  
  Promise<ArrayBuffer> arrayBuffer();  
  Promise<any> value();  
};
```

The **data** property represents the raw payload in [WoT Interactions](#) as a [ReadableStream](#), initially **null**.

The **dataUsed** property tells whether the [data](#) stream has been [disturbed](#). Initially **false**.

The **form** attribute represents the [Form](#) selected from the [Thing Description](#) for this [WoT Interaction](#), initially **null**.

The **schema** attribute represents the [DataSchema](#) (defined in [\[WoT-TD\]](#)) of the payload as a [JSON](#) object, initially **null**.

The **[[value]]** internal slot represents the parsed value of the [WoT Interaction](#), initially **undefined** (note that **null** is a valid value).

6.2.1 The **value()** function §

Parses the data returned from the [WoT Interaction](#) and returns a value with the type described by the [DataSchema](#) of the interaction if that exists, or by the **contentType** of the [Form](#) used for the interaction. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If the value of the **[[value]]** [internal slot](#) is not **undefined**, resolve *promise* with that value and abort these steps.
3. If the value of the *data* property is not a [ReadableStream](#) or if *dataUsed* is **true**, or if *form* is **null** or if *schema* or its *type* are **null** or **undefined**, reject *promise* with [NotReadableError](#) and abort these steps.
4. If *form*'s *contentType* is not **application/json** and if a mapping is not available in the [Protocol Bindings](#) from *form*'s *contentType* to [JSON-SCHEMA], reject *promise* with [NotSupportedError](#) and abort these steps.
5. Let *reader* be the result of [getting a reader](#) from *data*. If that threw an exception, reject *promise* with that exception and abort these steps.
6. Let *bytes* be the result of [reading all bytes](#) from *data* with *reader*.
7. Set *dataUsed* to **true**.
8. If *form*'s *contentType* is not **application/json** and if a mapping is available in the [Protocol Bindings](#) from *form*'s *contentType* to [JSON-SCHEMA], transform *bytes* with that mapping.
9. Let *json* be the result of running [parse JSON from bytes](#) on *bytes*. If that throws, reject *promise* with that exception and abort these steps.

10. Set `[[value]]` to the result of running [check data schema](#) on *json* and *schema*. If that throws, reject *promise* with that exception and abort these steps.
11. Resolve *promise* with `[[value]]`.

6.2.2 The ***arrayBuffer()*** function §

When invoked, *MUST* run the following steps:

1. Return a ***Promise*** *promise* and execute the next steps [in parallel](#).
2. If *data* is not ***ReadableStream*** or if *dataUsed* is ***true***, reject *promise* with ***NotReadableError*** and abort these steps.
3. Let *reader* be the result of [getting a reader](#) from *data*. If that threw an exception, reject *promise* with that exception and abort these steps.
4. Let *bytes* be the result of [reading all bytes](#) from *data* with *reader*.
5. Set *dataUsed* to ***true***.
6. Let *arrayBuffer* be a new ***ArrayBuffer*** whose contents are *bytes*. If that throws, reject *promise* with that exception and abort these steps.
7. Resolve *promise* with *arrayBuffer*.

6.2.3 The *check data schema* algorithm §

To run the [check data schema](#) steps on *payload* and *schema*,

1. Let *type* be *schema*'s *type*.
2. If *type* is ***"null"*** and if *payload* is not ***null***, throw ***TypeError*** and abort these steps, otherwise return ***null***.
3. If *type* is ***"boolean"*** and *payload* is a falsey value or its byte length is 0, return ***false***, otherwise return ***true***.
4. If *type* is ***"integer"*** or ***"number"***,
 1. If *payload* is not a number, throw ***TypeError*** and abort these steps.
 2. If *form*'s *minimum* is defined and *payload* is smaller, or if *form*'s *maximum* is defined and *payload* is bigger, throw ***RangeError*** and abort these steps.
5. If *type* is ***"string"***, return *payload*.
6. If *type* is ***"array"***, run these sub-steps:

1. If *payload* is not an array, throw [TypeError](#) and abort these steps.
2. If *form*'s *minItems* is defined and *payload*'s *length* is less than that, or if *form*'s *maxItems* is defined and *payload*'s *length* is more than that, throw [RangeError](#) and abort these steps.
3. Let *payload* be an array of items obtained by running the [check data schema](#) steps on each element *item* of *payload* and *schema*'s *items*. If this throws at any stage, re-throw that exception and abort these steps.
7. If *type* is "object", run these sub-steps:
 1. If *payload* or *schema*'s *properties* is not an object, throw [TypeError](#) and abort these steps.
 2. For each property *key* in *payload*,
 1. Let *prop* be the value of *key*.
 2. Let *propSchema* be the value of *key* in *interaction*'s *properties*.
 3. Let *prop* be the result of running the [check data schema](#) steps on *prop* and *propSchema*. If this throws, re-throw that exception and abort these steps.
 3. Let *required* be *schema*'s *required* if that is an array or an empty array otherwise.
 4. For each *key* in *required*, if *key* is not present in *payload*, throw [SyntaxError](#) and abort these steps.
8. Return *payload*.

6.2.4 The *create interaction data* algorithm §

For a given [ConsumedThing](#) object *thing*, in order to [create interaction data](#) given *source*, *form* and *schema*, run these steps:

1. Let *idata* be a new an [InteractionOutput](#) object whose *form* is set to *form*, whose *schema* is set to *schema*, whose *[[value]]* [internal slot](#) is **undefined** and whose *data* is **null**.
2. If *source* is a [ReadableStream](#) object, let *idata*'s *data* be *source*, return *idata* and abort these steps.
3. If *schema* and its *type* are defined and not **null**, run these sub-steps:
 1. If *type* is "null" and *source* is not, throw [TypeError](#) and abort these steps.
 2. If *type* is "boolean" and *source* is a falsy value, set *idata*'s *[[value]]* *value* to **false**, otherwise to **true**.
 3. If *type* is "integer" or "number" and *source* is not a number, or if *form*'s *minimum* is defined and *source* is smaller, or if *form*'s *maximum* is defined and *source* is bigger, throw [RangeError](#) and abort these steps.

4. If *type* is **"string"** and *source* is not a string, let *idata*'s `[[value]]` be the result of running serialize JSON to bytes on *source*. If that is failure, throw SyntaxError and abort these steps.
5. If *type* is **"array"**, run these sub-steps:
 1. If *source* is not an array, throw a TypeError and abort these steps.
 2. Let *length* be the length of *source*.
 3. If *form*'s *minItems* is defined and *length* is less than that, or if *form*'s *maxItems* is defined and *length* is more than that, throw RangeError and abort these steps.
 4. For each *item* in *source*, let *itemschema* be *schema*'s *items* and let *item* be the result of running the create interaction data steps on *item*, *form* and *itemschema*. If this throws, re-throw that exception and abort these steps.
 5. Set *data*'s `[[value]]` to *source*.
6. If *type* is **"object"**, run these sub-steps:
 1. If *source* is not an object, throw TypeError and abort these steps.
 2. If *schema*'s *properties* is not an object, throw TypeError and abort these steps.
 3. For each property *key* in *source*,
 1. Let *value* be the value of *key*.
 2. Let *propschema* be the value of *key* in *properties*.
 3. Let *value* be the result of running the create interaction data steps on *value*, *form* and *propschema*. If this throws, re-throw that exception and abort these steps.
 4. If *schema*'s *required* is an array, for each *item* in *required* check if *item* is a property name in *source*. If an *item* is not found in *source*, throw SyntaxError and abort these steps.
 5. Set *data*'s `[[value]]` to *source*.
4. Set *idata*'s *data* to a new ReadableStream created from *idata*'s `[[value]]` internal slot as its underlying source.
5. Return *idata*.

6.2.5 The *parse interaction response* algorithm §

For a given ConsumedThing object *thing*, in order to parse interaction response given *response*, *form* and *schema*, run these steps:

1. Let *result* be a new InteractionOutput object.
2. Let *result's schema* be *schema*.
3. Let *result's form* be *form*.
4. Let *result's data* be a new ReadableStream with the payload data of *response* as its underlying source.
5. Let *result's dataUsed* be **false**.
6. Return *result*.

6.3 Using InteractionInput and InteractionOutput §

As illustrated in the next pictures, the InteractionOutput interface is used every time implementations provide data to scripts, while InteractionInput is used when the scripts pass data to the implementation.

Reading a Property

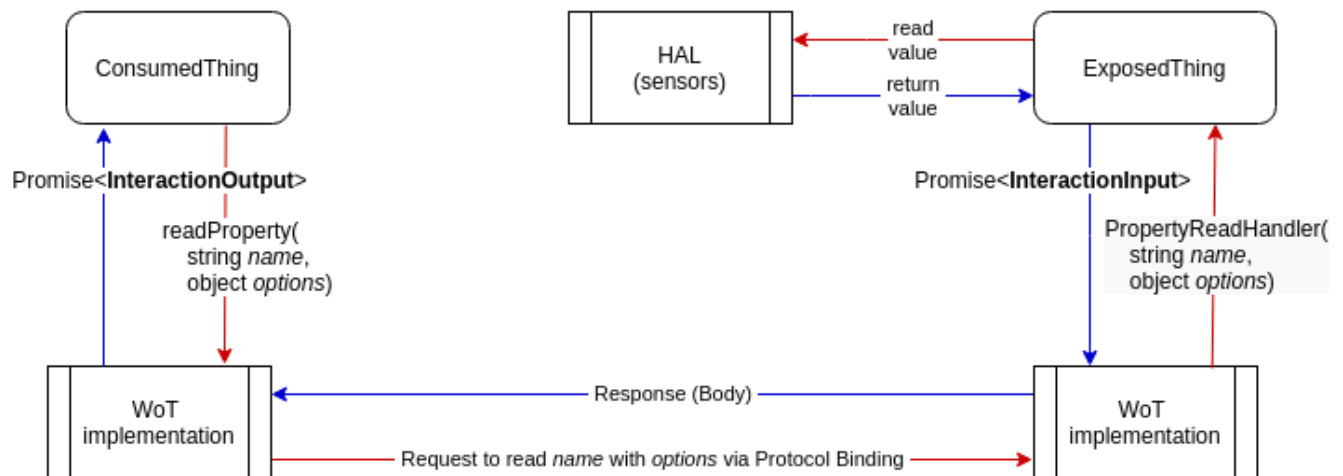


Figure 1 Data structures used when reading data

When a ConsumedThing reads data, it receives it from the implementation as an InteractionOutput object.

An ExposedThing read handler provides the read data to the implementation as InteractionInput.

Writing a Property

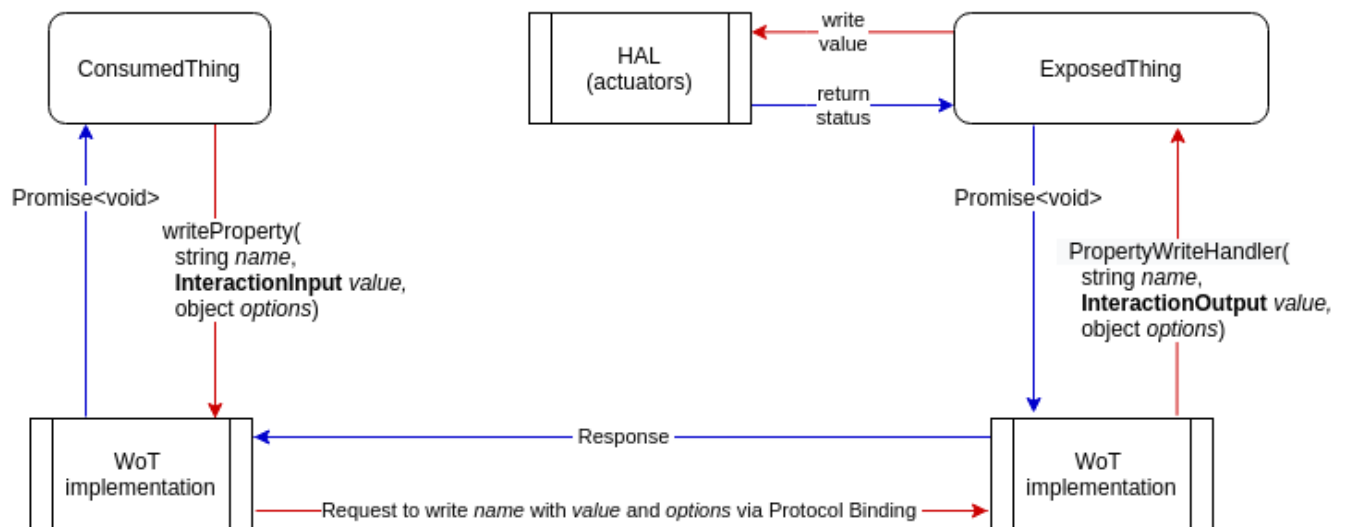


Figure 2 Data structures used when writing data

When a **ConsumedThing** writes data, it provides it to the implementation as **InteractionInput**.

An **ExposedThing** **write handler** receives data from the implementation as an **InteractionOutput** object.

Invoking an Action

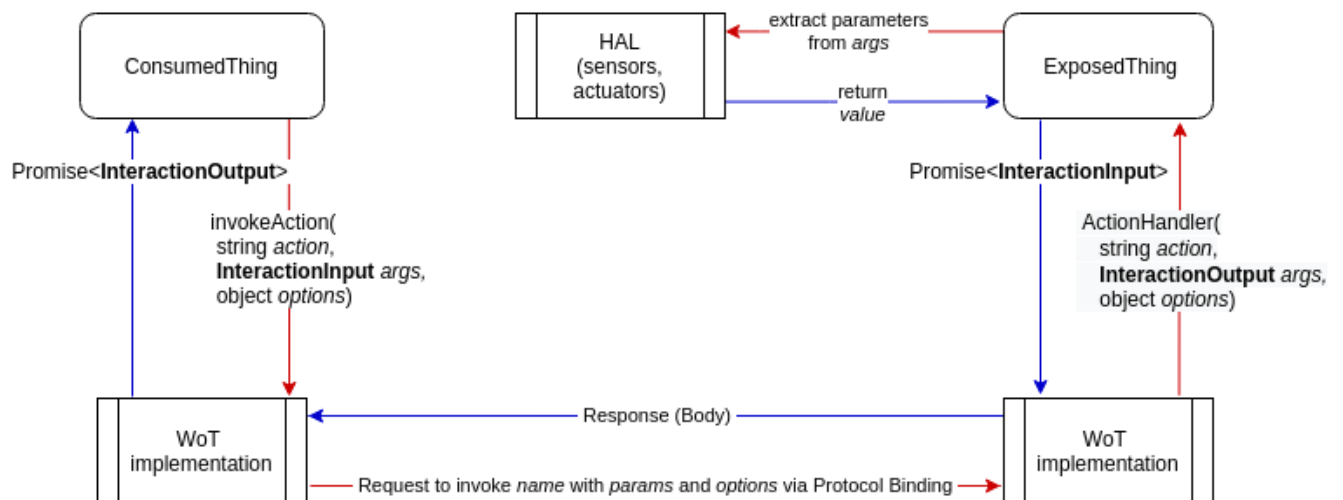


Figure 3 Data structures used when invoking an Action

When a **ConsumedThing** invokes an **Action** data, it provides the parameters as **InteractionInput** and receives the output of the **Action** as an **InteractionOutput** object.

An ExposedThing action handler receives arguments from the implementation as an InteractionOutput object and provides Action output as InteractionInput to the implementation.

7. The *ConsumedThing* interface §

Represents a client API to operate a [Thing](#). Belongs to the [WoT Consumer](#) conformance class.

WebIDL

[illegible]

```

null);
  Promise<void> unsubscribeEvent(DOMString name,
                                   optional InteractionOptions options =
null);
  ThingDescription getThingDescription();
};

dictionary InteractionOptions {
  unsigned long formIndex;
  object uriVariables;
  any data;
};

typedef object PropertyMap;

callback WotListener = void(InteractionOutput data);

```

7.1 Constructing ConsumedThing §

After fetching a Thing Description as a JSON object, one can create a ConsumedThing object.

To create ConsumedThing with the ThingDescription *td*, run the following steps:

1. Run the expand a TD steps on *td*. If that fails, re-throw the error and abort these steps.
2. Let *thing* be a new ConsumedThing object.
3. Let *|td|* be an internal slot of *thing* and let *td* be its value.
4. Return *thing*.

7.2 The getThingDescription() method §

Returns the internal slot *|td|* of the ConsumedThing object that represents the Thing Description of the ConsumedThing. Applications may consult the Thing metadata stored in *|td|* in order to introspect its capabilities before interacting with it.

7.3 The InteractionOptions dictionary §

Holds the interaction options that need to be exposed for application scripts according to the Thing Description.

The **formIndex** property, if defined, represents an application hint for which **Form** definition, identified by this index, of the [TD](#) to use for the given WoT interaction. Implementations *SHOULD* use the **Form** with this index for making the interaction, but *MAY* override this value if the index is not found or not valid. If not defined, implementations *SHOULD* attempt to use the **Form** definitions in order of appearance as listed in the [TD](#) for the given Wot Interaction.

The **uriVariables** property if defined, represents the URI template variables to be used with the WoT Interaction that are represented as [parsed JSON objects](#) defined in [\[WOT-TD\]](#).

EDITOR'S NOTE

The support for URI variables comes from the need exposed by [\[WOT-TD\]](#) to be able to describe existing [TDs](#) that use them, but it should be possible to write a [Thing Description](#) that would use [Actions](#) for representing the interactions that need URI variables and represent the URI variables as parameters to the [Action](#) and in that case that could be encapsulated by the implementations and the *options* parameter could be dismissed from the methods exposed by this API.

The **data** property if defined, represents additional opaque data that needs to be passed to the interaction.

7.4 The **PropertyMap** type §

Represents a map of [Property](#) names as strings to a value that the [Property](#) can take. It is used as a property bag for interactions that involve multiple [Properties](#) at once.

EDITOR'S NOTE

It could be defined in Web IDL (as well as [ThingDescription](#)) as a [maplike](#) interface from *string* to *any*.

7.5 The **readProperty()** method §

Reads a [Property](#) value. Takes as arguments *propertyName* and optionally *options*. It returns a [Promise](#) that resolves with a [Property](#) value represented as an [InteractionOutput](#) object or rejects on error. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).

2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *properties*'s *propertyName*.
4. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* whose *op* is [readproperty](#).
5. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
6. Make a request to the underlying platform (via the [Protocol Bindings](#)) to retrieve the value of the [Property](#) given by *propertyName* using *form* and the optional URI templates given in *options*' *uriVariables*.
7. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
8. Let *response* be the response received to the request.
9. Let *data* be the result of running [parse interaction response](#) on *response*, *form* and *interaction*. If that fails, reject *promise* with a [SyntaxError](#) and abort these steps.
10. Resolve *promise* with *data*.

7.6 The [readMultipleProperties\(\)](#) method §

Reads multiple [Property](#) values with one or multiple requests. Takes as arguments *propertyNames* and optionally *options*. It returns a [Promise](#) that resolves with a [PropertyMap](#) object that maps keys from *propertyNames* to values returned by this algorithm. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *|td|*'s *forms* array, otherwise let *form* be the first [Form](#) in *|td|*'s *forms* array whose *op* is [readmultipleproperties](#).
4. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
5. Let *result* be an object and for each string *name* in *propertyNames* add a property with key *name* and the value [null](#).
6. Make a request to the underlying platform (via the [Protocol Bindings](#)) to retrieve the [Property](#) values given by *propertyNames* with *form* and optional URI templates given in *options*'

uriVariables.

7. If this cannot be done with a single request with the [Protocol Bindings](#), reject *promise* with a [NotSupportedError](#) and abort these steps.
8. Process the response and for each *key* in *result*, run the following sub-steps:
 1. Let *value* be the value of *result*'s *key*.
 2. Let *schema* be the value of *|td|*'s *properties*'s *key*.
 3. Let *property* be the result of running [parse interaction response](#) on *value*, *form* and *schema*.
9. If the above step throws at any point, reject *promise* with that exception and abort these steps.
10. Resolve *promise* with *result*.

7.7 The [readAllProperties\(\)](#) method §

Reads all properties of the [Thing](#) with one or multiple requests. Takes *options* as optional argument. It returns a [Promise](#) that resolves with a [PropertyMap](#) object that maps keys from [Property](#) names to values returned by this algorithm. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *|td|*'s *forms* array, otherwise let *form* be the first [Form](#) in *|td|*'s *forms* array whose *op* is [readallproperties](#).
4. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
5. Make a request to the underlying platform (via the [Protocol Bindings](#)) to retrieve the value of the all the [Property](#) definitions from the [TD](#) with *form* and optional URI templates given in *options*' *uriVariables*.
6. If this cannot be done with a single request with the [Protocol Bindings](#) of the [Thing](#), then reject *promise* with a [NotSupportedError](#) and abort these steps.
7. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
8. Process the reply and let *result* be an object with the keys and values obtained in the reply.
9. Process the response and for each *key* in *result*, run the following sub-steps:
 1. Let *value* be the value of *result*'s *key*.
 2. Let *schema* be the value of *|td|*'s *properties*'s *key*.

3. Let *property* be the result of running [parse interaction response](#) on *value*, *form* and *schema*.
10. Resolve *promise* with *result*.

7.8 The ***writeProperty()*** method §

Writes a single [Property](#). Takes as arguments *propertyName*, *value* and optionally *options*. It returns a [Promise](#) that resolves on success and rejects on failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *properties*'s *propertyName*.
4. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* whose *op* is ***writeproperty***.
5. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
6. Let *data* be the result of running the [create interaction data](#) steps on *value*, *form* and *interaction*. If that throws, reject [promise](#) with that exception and abort these steps.
7. Make a request to the underlying platform (via the [Protocol Bindings](#)) to write the [Property](#) given by *propertyName* using *data* and the optional URI templates given in *options*' *uriVariables*.
8. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
9. Otherwise resolve *promise*.

EDITOR'S NOTE

As discussed in [Issue #193](#), the design decision is that write interactions only return success or error, not the written value (optionally). [TDs](#) should capture the schema of the [Property](#) values, including precision and alternative formats. When a return value is expected from the interaction, an [Action](#) should be used instead of a [Property](#).

7.9 The ***writeMultipleProperties()*** method §

Writes a multiple [Property](#) values with one request. Takes as arguments *properties* - as an object with keys being [Property](#) names and values as [Property](#) values - and optionally *options*. It returns a [Promise](#) that resolves on success and rejects on failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *|td|*'s *forms* array, otherwise let *form* be the first [Form](#) in *|td|*'s *forms* array whose *op* is [writemultipleproperties](#).
4. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
5. Let *result* be an object and for each string *name* in *propertyNames* add a property with key *name* and let its value be [null](#).
6. Let *schemas* be an object and for each string *name* in *propertyNames* add a property with key *name* and let its value be the value of *|td|*'s *properties*'s *name*.
7. For each key *key* in *properties*, take its value as *value* and run the [create interaction data](#) steps on *value*, *form* and the value for *schema*'s *key*. If that throws for any *name*, reject [promise](#) with that exception and abort these steps.
8. Make a single request to the underlying platform (via the [Protocol Bindings](#)) to write each [Property](#) provided in *properties* with optional URI templates given in *options*' *uriVariables*.
9. If this cannot be done with a single request with the [Protocol Bindings](#) of the [Thing](#), then reject *promise* with a [NotSupportedError](#) and abort these steps.
10. If the request fails, return the error received from the [Protocol Bindings](#) and abort these steps.
11. Otherwise resolve *promise*.

7.10 The [WotListener](#) callback §

User provided callback that is given an argument of type [InteractionOutput](#) and is used for observing [Property](#) changes and handling [Event](#) notifications. Since subscribing to [Events](#) are WoT interactions and might take options or even data, they are not modelled with software events.

7.11 The [observeProperty\(\)](#) method §

Makes a request for [Property](#) value change notifications. Takes as arguments *propertyName*, *listener* and optionally *options*. It returns a [Promise](#) that resolves on success and rejects on failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. If *listener* is not a [Function](#), reject *promise* with a [TypeError](#) and abort these steps.
4. Let *interaction* be the value of *|td|*'s *properties*'s *propertyName*.
5. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* array whose *op* is [observeproperty](#).
6. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
7. Make a request to the underlying platform (via the [Protocol Bindings](#)) to observe [Property](#) identified by *propertyName* with *form* and optional URI templates given in *options*' *uriVariables*.
8. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
9. Otherwise resolve *promise*.
10. Whenever the underlying platform receives a notification for this subscription with new [Property](#) value *value*, run the following sub-steps:
 - Let *reply* be the result of running [parse interaction response](#) with *value*, *form* and *interaction*. If that throws, reject *promise* with that exception and abort these steps.
 - Invoke *listener* with *reply*.

7.12 The [unobserveProperty\(\)](#) method §

Makes a request for unsubscribing from [Property](#) value change notifications. Takes as arguments *propertyName* and optionally *options*. It returns a [Promise](#) that resolves on success and rejects on failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *properties*'s *propertyName*.

4. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* array whose *op* is **unobserveproperty**.
5. If *form* is failure, reject *promise* with a **SyntaxError** and abort these steps.
6. Make a request to the underlying platform (via the [Protocol Bindings](#)) to stop observing the [Property](#) identified by *propertyName*, with *form* and optional URI templates given in *options*' *uriVariables*.
7. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
8. Otherwise resolve *promise*.

7.13 The **invokeAction()** method §

Makes a request for invoking an [Action](#) and return the result. Takes as arguments *actionName*, optionally *params* and optionally *options*. It returns a **Promise** that resolves with the result of the [Action](#) represented as an [InteractionOutput](#) object, or rejects with an error. The method *MUST* run the following steps:

1. Return a **Promise** *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a **SecurityError** and abort these steps.
3. Let *interaction* be the value of *|td|*'s *actions*'s *actionName*.
4. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* array whose *op* is **invokeaction**.
5. If *form* is failure, reject *promise* with a **SyntaxError** and abort these steps.
6. Let *args* be the result of running the [create interaction data](#) steps on *params*, *form* and *interaction*. If that throws, reject [promise](#) with that exception and abort these steps.
7. Make a request to the underlying platform (via the [Protocol Bindings](#)) to invoke the [Action](#) identified by *actionName* with parameters provided in *args* and optional URI templates given in *options*'s *uriVariables*.
8. If the request fails locally or returns an error over the network, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
9. Let *value* be the reply returned in the reply.

10. Let *result* be the result of running [parse interaction response](#) with *value*, *form* and *interaction*. If that throws, reject *promise* with that exception and abort these steps.
11. Resolve *promise* with *result*.

7.14 The ***subscribeEvent()*** method §

Makes a request for subscribing to [Event](#) notifications. Takes as arguments *eventName*, *listener* and optionally *options*. It returns a [Promise](#) to signal success or failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. If *listener* is not a [Function](#), reject *promise* with a [TypeError](#) and abort these steps.
4. Let *interaction* be the value of *|td|*'s *events*'s *eventName*.
5. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* array whose *op* is ***subscribeevent***.
6. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
7. Make a request to the underlying platform (via the [Protocol Bindings](#)) to subscribe to an [Event](#) identified by *eventName* with *form* and optional URI templates given in *options*' *uriVariables* and optional subscription data given in *options*'s *data*.
8. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
9. Otherwise resolve *promise*.
10. Whenever the underlying platform receives a notification for this [Event](#) subscription, implementations *SHOULD* invoke *listener* with the result of running [parse interaction response](#) on the data provided with the [Event](#), *form* and *interaction*.

7.15 The ***unsubscribeEvent()*** method §

Makes a request for unsubscribing from [Event](#) notifications. Takes as arguments *eventName* and optionally *options*. It returns a [Promise](#) to signal success or failure. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *events*'s *eventName*.
4. If *option*'s *formIndex* is defined, let *form* be the [Form](#) associated with *formIndex* in *interaction*'s *forms* array, otherwise let *form* be the first [Form](#) in *interaction*'s *forms* array whose *op* is [unsubscribeevent](#).
5. If *form* is failure, reject *promise* with a [SyntaxError](#) and abort these steps.
6. Make a request to the underlying platform (via the [Protocol Bindings](#)) to unsubscribe from the [Event](#) identified by *eventName* with *form* and optional URI templates given in *options*' *uriVariables* and optional unsubscribe data given in *options*'s *data*.
7. If the request fails, reject *promise* with the error received from the [Protocol Bindings](#) and abort these steps.
8. Resolve *promise*.
9. If the underlying platform receives further notifications for this [Event](#) subscription, implementations *SHOULD* silently suppress them.

7.16 ConsumedThing Examples §

The next example illustrates how to fetch a [TD](#) by URL, create a [ConsumedThing](#), read metadata (title), read property value, subscribe to property change, subscribe to a WoT event, unsubscribe.

EXAMPLE 2: Thing Client API example

```
try {
  let res = await fetch("https://tds.mythings.org/sensor11");
  let td = res.json();
  let thing = new ConsumedThing(td);
  console.log("Thing " + thing.getThingDescription().title + " consumed.")
} catch(e) {
  console.log("TD fetch error: " + e.message); },
};

try {
  // subscribe to property change for "temperature"
  await thing.observeProperty("temperature", value => {
    console.log("Temperature changed to: " + parseData(value));
  });
  // subscribe to the "ready" event defined in the TD
  await thing.subscribeEvent("ready", eventData => {
    console.log("Ready; index: " + parseData(eventData));
    // run the "startMeasurement" action defined by TD
    await thing.invokeAction("startMeasurement", { units: "Celsius" });
    console.log("Measurement started.");
  });
} catch(e) {
  console.log("Error starting measurement.");
}

setTimeout( () => {
  console.log("Temperature: " +
    parseData(await thing.readProperty("temperature")));
  await thing.unsubscribe("ready");
  console.log("Unsubscribed from the 'ready' event.");
},
10000);

async function parseData(response) {
  let value = undefined;
  try {
    value = await response.value();
  } catch(err) {
    // if response.value() fails, try low-level stream read
    if (response.dataUsed)
      return undefined; // or make a second request
  }
}
```



```

const reader = value.data.getReader();
value = null;

reader.read().then(function process({ done, chunk }) {
    if (done) {
        value += chunk;
        return value;
    }
    value += chunk;
    return reader.read().then(process);
});
}
return value;
};

```

8. The *ExposedThing* interface §

The ExposedThing interface is the server API to operate the Thing that allows defining request handlers, Property, Action, and Event interactions.

WebIDL

```

[SecureContext, Exposed=(Window,Worker)]
interface ExposedThing: ConsumedThing {
    ExposedThing setPropertyReadHandler(DOMString name,
        PropertyReadHandler handler);
    ExposedThing setPropertyWriteHandler(DOMString name,
        PropertyWriteHandler handler);
    ExposedThing setPropertyObserveHandler(DOMString name,
        PropertyReadHandler handler);
    ExposedThing setPropertyUnobserveHandler(DOMString name,
        PropertyReadHandler handler);

    ExposedThing setActionHandler(DOMString name, ActionHandler action);

    ExposedThing setEventSubscribeHandler(DOMString name,
        EventSubscriptionHandler handler);
    ExposedThing setEventUnsubscribeHandler(DOMString name,
        EventSubscriptionHandler handler);
    ExposedThing setEventHandler(DOMString name,
        EventListenerHandler eventHandler);

```

```

    void emitEvent(DOMString name, InteractionInput data);

    Promise<void> expose();
    Promise<void> destroy();
};

callback PropertyReadHandler = Promise<any>(
    optional InteractionOptions options = null);

callback PropertyWriteHandler = Promise<void>(
    InteractionOutput value,
    optional InteractionOptions options = null);

callback ActionHandler = Promise<InteractionInput>(
    InteractionOutput params,
    optional InteractionOptions options = null);

callback EventSubscriptionHandler = Promise<void>(
    optional InteractionOptions options = null);

callback EventListenerHandler = Promise<InteractionInput>();

```

8.1 Constructing ExposedThing §

The ExposedThing interface extends ConsumedThing. It is constructed from a full or partial ThingDescription object.

NOTE

Note that an existing ThingDescription object can be optionally modified (for instance by adding or removing elements on its *properties*, *actions* and *events* internal properties) and the resulting object can be used for constructing an ExposedThing object. This is the current way of adding and removing Property, Action and Event definitions, as illustrated in the examples.

NOTE

Before invoking expose(), the ExposedThing object does not serve any requests. This allows first constructing ExposedThing and then initialize its Properties and service handlers before starting serving requests.

To construct an [ExposedThing](#) with the [ThingDescription](#) *td*, run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.
2. Run the [expand a TD](#) steps on *td*. If that fails, re-[throw](#) the error and abort these steps.
3. Let *thing* be a new [ExposedThing](#) object.
4. Let *|td|* be an [internal slot](#) of *thing* and let *td* be its value.
5. Return *thing*.

8.2 Methods inherited from [ConsumedThing](#) §

The [readProperty\(\)](#), [readMultipleProperties\(\)](#), [readAllProperties\(\)](#), [writeProperty\(\)](#), [writeMultipleProperties\(\)](#), [writeAllProperties\(\)](#) methods have the same algorithmic steps as described in [ConsumedThing](#), with the difference that making a request to the underlying platform *MAY* be implemented with local methods or libraries and don't necessarily need to involve network operations.

The implementation of [ConsumedThing](#) interface in an [ExposedThing](#) provide the *default* methods to interact with the [ExposedThing](#).

After constructing an [ExposedThing](#), a script can initialize its [Properties](#) and can set up the optional read, write and action request handlers (the default ones are provided by the implementation). The script provided handlers *MAY* use the default handlers, thereby extending the default behavior, but they can also bypass them, overriding the default behavior. Finally, the script would call [expose\(\)](#) on the [ExposedThing](#) in order to start serving external requests.

NOTE

The request handlers actually implement the behavior and it is the responsibility of the developers to keep the [Thing Description](#) defined in [ExposedThing](#) synchronized with the implementation of the request handlers.

8.3 The [PropertyReadHandler](#) callback §

A function that is called when an external request for reading a [Property](#) is received and defines what to do with such requests. It returns a [Promise](#) and resolves with an [ReadableStream](#) object or an

[ECMAScript value](#) conforming to [DataSchema](#), or rejects with an error if the property is not found or the value cannot be retrieved.

8.4 The *setPropertyReadHandler()* method §

Takes as arguments *name* and *handler*. Sets the service handler that defines what to do when a request is received for reading the specified [Property](#) matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

EDITOR'S NOTE

Note that there is no need to register handlers for handling requests for reading multiple or all [Properties](#). The request and reply are transmitted in a single network request, but the [ExposedThing](#) may implement them using multiple calls to the single read handler.

The *handler* callback function should implement reading a [Property](#) and *SHOULD* be called by implementations when a request for reading a [Property](#) is received from the underlying platform.

There *MUST* be at most one handler for any given [Property](#), so newly added handlers *MUST* replace the previous handlers. If no handler is initialized for any given [Property](#), implementations *SHOULD* implement a default property read handler based on the [Thing Description](#) provided in the *|td|* [internal slot](#).

When the method is invoked given *name* and *handler*, implementations *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.
2. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
3. If a [Property](#) interaction with *name* is not found, [throw](#) [NotFoundError](#) and abort these steps.
4. Set the [internal slot](#) *|readHandler|* on *interaction* to *handler*.

8.5 Handling requests for reading a Property §

When a network request for reading [Property](#) *name* is received by the implementation with *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *value* be the result of running the **read server property** steps with *name* and *options*:
 1. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
 2. If a [Property](#) with *name* does not exist, throw [NotFoundError](#) and abort these steps.
 3. Let *handler* be **null**.
 4. If there is a user provided [internal slot](#) *|readHandler|* on *interaction*, let *handler* be that.
 5. Otherwise, if there is a default read handler provided by the implementation, let *handler* be that.
 6. If *handler* is **null**, throw [NotSupportedError](#) and abort these steps.
 7. Let *value* be the result of invoking *handler* with *options*. If that fails, throw the error and abort these steps.
 8. Return *value*.

NOTE

The *value* returned here *SHOULD* either conform to [DataSchema](#) or it *SHOULD* be an [ReadableStream](#) object created by the *handler*.

4. If the previous step has thrown an error, send the error back with the reply created by following the [Protocol Bindings](#) and abort these steps.
5. Serialize and add the returned *value* to the reply created by following the [Protocol Bindings](#).

8.6 Handling requests for reading multiple Properties §

When a network request for reading multiple [Properties](#) given in an object *propertyName* is received with *options*, run the following **read multiple properties** steps on *propertyName* and *options*:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.

3. For each property with key *name* defined in *propertyNames*,
 1. Let *value* be the result of running the [read server property](#) steps on *name* and *options*. If that throws, send back the error in the reply created by following the [Protocol Bindings](#) and abort these steps.
 2. Set the value of *propertyNames*'s *name* to *value*.
4. Reply to the request by sending a single reply created from *propertyNames* according to the [Protocol Bindings](#).

8.7 Handling requests for reading all Properties §

When a network request for reading all [Properties](#) is received with *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *properties* be an object created with all properties defined in the [Thing](#) with values set to [null](#).
4. Run the [read multiple properties](#) steps on *properties* and *options*.

8.8 The [setPropertyObserverHandler\(\)](#) method §

Takes as arguments *name* and *handler*. Sets the service handler that defines what to do when a request is received for observing the specified [Property](#) matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

The *handler* callback function should implement reading a [Property](#) and resolve with an [InteractionOutput](#) object or reject with an error.

There *MUST* be at most one handler for any given [Property](#), so newly added handlers *MUST* replace the previous handlers. If no handler is initialized for any given [Property](#), implementations *SHOULD* implement a default property read handler based on the [Thing Description](#).

When the method is invoked given *name* and *handler*, implementations *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.

2. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
3. If a [Property](#) interaction with *name* is not found, [throw NotFoundError](#) and abort these steps.
4. Set the [internal slot](#) *|observeHandler|* on *interaction* to *handler*.

8.9 Handling [Property](#) observe requests §

When a network request for observing a [Property](#) *name* is received by the implementation with *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *property* be the value of *|td|*'s *properties*'s *name*. If it does not exist, send back a [NotFoundError](#) in the reply and abort these steps.
4. Save the request sender information together with *options* to *property*'s [internal observer list](#), in order to be able to notify about [Property](#) value changes.
5. Every time the value of *property* changes, run the following sub-steps:
 1. Let *handler* be **null**.
 2. If there is an *|observeHandler|* [internal slot](#) associated with *name* on *property*, let *handler* be that.
 3. Otherwise, if there is a *|readHandler|* [internal slot](#) associated with *name* on *property*, let *handler* be that.
 4. If *handler* is **null**, abort these steps.
 5. Let *promise* be the result of invoking *handler* with *options*.
 6. If *promise* rejects, abort these steps.
 7. If *promise* resolves with *data*, then for each *observer* in *property*'s [internal observer list](#), run the following sub-steps:
 1. Let *options* be the interaction options saved with *observer*.
 2. Create a *reply* from *data* and *options* according to the [Protocol Bindings](#).
 3. Send *reply* to *observer*.

8.10 The *setPropertyUnobserveHandler()* method §

Takes as arguments *name* and *handler*. Sets the service handler that defines what to do when a request is received for unobserving the specified [Property](#) matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

The *handler* callback function should implement what to do when an unobserve request is received by the implementation.

There *MUST* be at most one handler for any given [Property](#), so newly added handlers *MUST* replace the previous handlers. If no handler is initialized for any given [Property](#), implementations *SHOULD* implement a default handler based on the [Thing Description](#).

When the method is invoked given *name* and *handler*, implementations *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.
2. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
3. If a [Property](#) interaction with *name* is not found, [throw](#) [NotFoundError](#) and abort these steps.
4. Set the [internal slot](#) *|unobserveHandler|* on *interaction* to *handler*.

8.11 Handling [Property](#) unobserve requests §

When a network request for unobserving a [Property](#) *name* with *options* is received by the implementation, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *property* be the value of *|td|*'s *properties*'s *name*. If it does not exist, send back a [NotFoundError](#) in the reply and abort these steps.
4. If there is an *|unobserveHandler|* defined for *name* on *property*, invoke that with *options*, send back a reply following the [Protocol Bindings](#) and abort these steps.
5. Let *sender* be the matching observer found in *property*'s [internal observer list](#). If not found, send back a [NotFoundError](#) in the reply and abort these steps.

6. Remove *sender* from *property*'s [internal observer list](#) and send back a reply following the [Protocol Bindings](#).

8.12 The ***PropertyWriteHandler*** callback §

A function that is called when an external request for writing a [Property](#) is received and defines what to do with such requests. Takes as argument *value* and returns a [Promise](#), resolved when the value of the [Property](#) - identified by the name provided when setting the handler has been updated -, or rejects with an error if the property is not found or the value cannot be updated.

EDITOR'S NOTE

Note that the code in this callback function can read the property before updating it in order to find out the old value, if needed. Therefore the old value is not provided to this function.

NOTE

The value is provided by implementations as an [InteractionOutput](#) object in order to be able to represent values that are not described by a [DataSchema](#), such as streams.

8.13 The ***setPropertyWriteHandler()*** method §

Takes as arguments *name* and *handler*. Sets the service handler that defines what to do when a request is received for writing the [Property](#) matched by *name* given when setting the handler. Throws on error. Returns a reference to *this* object for supporting chaining.

NOTE

Note that even for readonly [Properties](#) it is possible to specify a write handler, as explained in [Issue 199](#). In this case, the write handler may define in an application-specific way to fail the request.

There *MUST* be at most one write handler for any given [Property](#), so newly added handlers *MUST* replace the previous handlers. If no write handler is initialized for any given [Property](#), implementations *SHOULD* implement default property update if the [Property](#) is writeable and notifying observers on change if the [Property](#) is observable, based on the [Thing Description](#).

When the method is invoked given *name* and *handler*, implementations *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, throw a SecurityError and abort these steps.
2. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
3. If a Property interaction with *name* is not found, throw NotFoundError and abort these steps.
4. Set the internal slot *|writeHandler|* on *interaction* to *handler*.

8.14 Handling requests for writing a Property §

When a network request for writing a Property *name* with a new value *value* and *options* is received, implementations *MUST* run the following **update property steps**, given *name*, *value*, *options* and *mode* set to **"single"**:

1. If this operation is not supported, send back a NotSupportedError according to the Protocol Bindings and abort these steps.
2. If this operation is not allowed, send back a NotAllowedError according to the Protocol Bindings and abort these steps.
3. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
4. If a Property with *name* does not exist, return a NotFoundError in the reply and abort these steps.
5. Let *handler* be **null**.
6. If there is a user provided internal slot *|writeHandler|* on *interaction*, let *handler* be that.
7. Otherwise, if there is a default write handler provided by the implementation, let *handler* be that.
8. Otherwise, if *handler* is **null**, send back a NotSupportedError with the reply and abort these steps.
9. Let *promise* be the result of invoking *handler* with *name* and *options*. If it fails, return the error in the reply and abort these steps.
10. If *mode* is **"single"**, reply to the request reporting success, following the Protocol Bindings and abort these steps.

8.15 Handling requests for writing multiple Properties §

When a network request for writing multiple [Properties](#) given in an object *propertyNames* is received with *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. For each property with key *name* and value *value* defined in *propertyNames*, run the [update property steps](#) with *name*, *value*, *options* and *mode* set to **"multiple"**. If that fails, reply to the request with that error and abort these steps.
4. Reply to the request by sending a single reply according to the [Protocol Bindings](#).

8.16 The **ActionHandler** callback §

A function that is called when an external request for invoking an [Action](#) is received and defines what to do with such requests. It is invoked with *params* and optionally with an *options* object. It returns a [Promise](#) that rejects with an error or resolves with the value returned by the [Action](#) as [InteractionInput](#).

NOTE

Application scripts *MAY* return a [ReadableStream](#) object from an [ActionHandler](#). Implementations will then use the stream for constructing the [Action](#)'s response.

8.17 The **setActionHandler()** method §

Takes as arguments *name* and *action*. Sets the handler function that defines what to do when a request is received to invoke the [Action](#) matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

The *action* callback function will implement an [Action](#) and *SHOULD* be called by implementations when a request for invoking the [Action](#) is received from the underlying platform.

There *MUST* be at most one handler for any given [Action](#), so newly added handlers *MUST* replace the previous handlers.

When the method is invoked given *name* and *action*, run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.
2. Let *interaction* be the value of *|td|*'s *actions*'s *name*.
3. If an [Action](#) with name *name* is not found, [throw](#) a [NotFoundError](#) and abort these steps.
4. Set the [internal slot](#) *|actionHandler|* on *interaction* to *action*.

8.18 Handling [Action](#) requests §

When a network request for invoking the [Action](#) identified by *name* is received with *inputs* and optionally with *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *properties*'s *name*.
4. If an [Action](#) identified by *name* does not exist, return a [NotFoundError](#) in the reply and abort these steps.
5. Let *handler* be `null`.
6. If there is a user provided [internal slot](#) *|actionHandler|* on *interaction*, let *handler* be its value.
7. If *handler* is `null`, return a [NotSupportedError](#) with the reply created by following the [Protocol Bindings](#) and abort these steps.
8. Let *promise* be the result of invoking *handler* with *name*, *inputs* and *options*.
9. If *promise* rejects, send the error with the reply and abort these steps.
10. When *promise* resolves with *data*, use *data* to create and send the reply according to the [Protocol Bindings](#).

8.19 The [EventListenerHandler](#) callback §

A function that is called when an associated [Event](#) is triggered and provides the data to be sent with the [Event](#) to subscribers. Returns a [Promise](#) that resolves with [InteractionInput](#) value that represents the [Event](#) data, or rejects with an error.

NOTE

Applications *MAY* return ReadableStream from an EventListenerHandler Implementations will then use the stream provided in InteractionOutput when constructing the event notification.

8.20 The **EventSubscriptionHandler** callback §

A function that is called when an external request for subscribing to an Event is received and defines what to do with such requests. It is invoked with a *options* object provided by the implementation and coming from subscribers. It returns a Promise that rejects with an error or resolves when the subscription is accepted.

8.21 The **setEventSubscribeHandler()** method §

Takes as arguments *name* and *handler*. Sets the handler function that defines what to do when a subscription request is received for the specified Event matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

The *handler* callback function *SHOULD* implement what to do when an subscribe request is received, for instance necessary initializations. Note that the handler for emitting Events is set separately.

There *MUST* be at most one event subscribe handler for any given Event, so newly added handlers *MUST* replace the previous handlers.

When the method is invoked given *name* and *handler*, run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, throw a SecurityError and abort these steps.
2. Let *interaction* be the value of *|td|*'s *events*'s *name*.
3. If an Event with the name *name* is not found, throw a NotFoundError and abort these steps.
4. Set the internal slot *|subscribeHandler|* on *interaction* to *handler*.
5. Return **this**.

8.22 Handling Event subscribe requests §

When an [Event](#) subscription request for *name* is received by the underlying platform with optional *options*, run the following steps:

1. If this operation is not supported, send back a [NotSupportedError](#) according to the [Protocol Bindings](#) and abort these steps.
2. If this operation is not allowed, send back a [NotAllowedError](#) according to the [Protocol Bindings](#) and abort these steps.
3. Let *interaction* be the value of *|td|*'s *events*'s *name*.
4. If an [Event](#) with the name *name* is not found, send back a [NotFoundError](#) and abort these steps.
5. If *name* has an associated *|subscribeHandler|* [internal slot](#), invoke it with *options* and abort these steps.
6. Otherwise, if no *|subscribeHandler|* is defined, then implement the default subscriber mechanism:
 1. Let *subscriber* be a tuple formed of *options* (from which *uriVariables* and *data* may be used) and the subscriber information needed to create an [Event](#) notification response.
 2. Add *subscriber* to the [internal listener list](#) of *interaction*.

8.23 The [setEventUnsubscribeHandler\(\)](#) method §

Takes as arguments *name* and *handler*. Sets the handler function that defines what to do when the specified [Event](#) matched by *name* is unsubscribed from. Throws on error. Returns a reference to *this* object for supporting chaining.

The *handler* callback function *SHOULD* implement what to do when an unsubscribe request is received.

There *MUST* be at most one handler for any given [Event](#), so newly added handlers *MUST* replace the previous handlers.

When the method is invoked with *name* and *handler*, run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, [throw](#) a [SecurityError](#) and abort these steps.
2. Let *interaction* be the value of *|td|*'s *events*'s *name*.
3. If an [Event](#) with the name *name* is not found, [throw](#) a [NotFoundError](#) and abort these steps.
4. Set the [internal slot](#) *|unsubscribeHandler|* on *interaction* to *handler*.
5. Return [this](#).

8.24 Handling Event unsubscribe requests §

When an Event unsubscribe request for *name* is received by the underlying platform optionally with *options*, run the following steps:

1. If this operation is not supported, send back a NotSupportedError according to the Protocol Bindings and abort these steps.
2. If this operation is not allowed, send back a NotAllowedError according to the Protocol Bindings and abort these steps.
3. Let *interaction* be the value of *|td|*'s *events*'s *name*.
4. If an Event with the name *name* is not found, send back a NotFoundError and abort these steps.
5. If *name* has an associated *|unsubscribeHandler|* internal slot that is a function, invoke it with *options* and abort these steps.
6. Otherwise let *subscriber* be the tuple saved in *interaction*'s internal listener list.
7. Remove *subscriber* from *interaction*'s internal listener list.
8. Return **this**.

8.25 The **setEventHandler()** method §

Takes as arguments *name* and *eventHandler*. Sets the event handler function for the specified Event matched by *name*. Throws on error. Returns a reference to *this* object for supporting chaining.

The *eventHandler* callback function will implement what to do when the event is emitted. It *SHOULD* resolve with a value that represents the Event data, or reject with an error.

There *MUST* be at most one handler for any given Event, so newly added handlers *MUST* replace the previous handlers.

When the method is invoked with *name* and *eventHandler*, run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, throw a SecurityError and abort these steps.
2. Let *interaction* be the value of *|td|*'s *events*'s *name*.
3. If an Event with the name *name* is not found, throw a NotFoundError and abort these steps.
4. Set the internal slot *|eventHandler|* of *interaction* to *eventHandler*.
5. Return **this**.

8.26 Handling Events §

When an Event with name *name* is emitted with *data* either by the underlying platform or by the emitEvent() method, run the following steps:

1. Let *interaction* be the value of *|td|*'s *events*'s *name*.
2. If *data* is not defined or **null**,
 1. Let *eventHandler* be the value of the *|eventHandler|* internal slot of *interaction*.
 2. If *eventHandler* is failure, abort these steps.
 3. Let *data* be the result of awaiting to resolve the invocation of *eventHandler*. If it rejects, abort these steps.
3. For each *subscriber* in the internal listener list of *interaction*, run the following sub-steps:
 1. Create an Event notification *response* according to the Protocol Bindings from *data* and *subscriber*, including its *options*.
 2. Send *response* to the subscriber identified by *subscriber*.

8.27 The **emitEvent()** method §

Takes as arguments *name* denoting an Event name and *data*. Triggers emitting the Event with the given data. The method *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, throw a SecurityError and abort these steps.
2. Let *interaction* be the value of *|td|*'s *events*'s *name*.
3. If an Event with the name *name* is not found, throw a NotFoundError and abort these steps.
4. Make a request to the underlying platform to emit an Event with *data*, using the Protocol Bindings.

NOTE

This will trigger the handling events steps.

8.28 The **expose()** method §

Start serving external requests for the [Thing](#), so that [WoT Interactions](#) using [Properties](#), [Actions](#) and [Events](#) will be possible. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Run the [expand a TD](#) steps on the [internal slot](#) *|td|*.
4. Run the [validate a TD](#) on *|td|*. If that fails, reject *promise* with a [TypeError](#) and abort these steps.
5. For each [Property](#) definition in *|td|*'s *properties*, initialize an *|internal observer list|* [internal slot](#) in order to store observe request data needed to notify the observers on value changes.
6. For each [Event](#) definition in *|td|*'s *events*, initialize an *|internal listener list|* [internal slot](#) in order to store subscription request data needed to notify the [Event](#) listeners.
7. Set up the [WoT Interactions](#) based on introspecting *|td|* as explained in [\[WOT-TD\]](#) and [\[WOT-PROTOCOL-BINDINGS\]](#). Make a request to the underlying platform to initialize the [Protocol Bindings](#) and then start serving external requests for [WoT Interactions](#) (read, write and observe [Properties](#), invoke [Actions](#) and manage [Event](#) subscriptions), based on the [Protocol Bindings](#).
8. If there was an error during the request, reject *promise* with an [Error](#) object *error* with *error*'s *message* set to the error code seen by the [Protocol Bindings](#) and abort these steps.
9. Otherwise resolve *promise* and abort these steps.

8.29 The [destroy\(\)](#) method §

Stop serving external requests for the [Thing](#) and destroy the object. Note that eventual unregistering should be done before invoking this method. The method *MUST* run the following steps:

1. Return a [Promise](#) *promise* and execute the next steps [in parallel](#).
2. If invoking this method is not allowed for the current scripting context for security reasons, reject *promise* with a [SecurityError](#) and abort these steps.
3. Make a request to the underlying platform to stop serving external requests for [WoT Interactions](#), based on the [Protocol Bindings](#).
4. If there was an error during the request, reject *promise* with an [Error](#) object *error* with its *message* set to the error code seen by the [Protocol Bindings](#) and abort these steps.
5. Otherwise resolve *promise* and abort these steps.

8.30 ExposedThing Examples §

The next example illustrates how to create an ExposedThing based on a partial TD object constructed beforehand.

EXAMPLE 3: Create ExposedThing with a simple Property

```
try {
  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
    }
  };
  let thing1 = await WOT.produce(tdFragment);
  // initialize Properties
  await thing1.writeProperty("temperature", 0);
  // add service handlers
  thing1.setPropertyReadHandler("temperature", () => {
    return readLocalTemperatureSensor(); // Promise
  });
  // start serving requests
  await thing1.expose();
} catch (err) {
  console.log("Error creating ExposedThing: " + err);
}
```

The next example illustrates how to add or modify a [Property](#) definition on an existing [ExposedThing](#): take its *td* property, add or modify it, then create another [ExposedThing](#) with that.

EXAMPLE 4: Add an object Property

```
try {
  // create a deep copy of thing1's TD
  let instance = JSON.parse(JSON.stringify(thing1.td));
  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["name"] = "mySensor";
  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
  var thing2 = new ExposedThing(instance);
}
```

```
// TODO: add service handlers
await thing2.expose();
});
} catch (err) {
  console.log("Error creating ExposedThing: " + err);
}
```

9. The *ThingDiscovery* interface §

Discovery is a distributed application that requires provisioning and support from participating network nodes (clients, servers, directory services). This API models the client side of typical discovery schemes supported by various IoT deployments.

The *ThingDiscovery* object is constructed given a filter and provides the properties and methods controlling the discovery process.

WebIDL

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

EDITOR'S NOTE

The *ThingDiscovery* interface has a *next()* method and a *done* property, but it is not an *Iterable*. Look into [Issue 177](#) for rationale.

The *discovery results internal slot* is an internal queue for temporarily storing the found *ThingDescription* objects until they are consumed by the application using the *next()* method. Implementations *MAY* optimize the size of this queue based on e.g. the available resources and the frequency of invoking the *next()* method.

The **filter** property represents the discovery filter of type ThingFilter specified for the discovery.

The **active** property is **true** when the discovery is actively ongoing on protocol level (i.e. new TDs may still arrive) and **false** otherwise.

The **done** property is **true** if the discovery has been completed with no more results to report and discovery results is also empty.

The **error** property represents the last error that occurred during the discovery process. Typically used for critical errors that stop discovery.

9.1 Constructing ThingDiscovery §

To create ThingDiscovery with a *filter* or type ThingFilter, run the following steps:

1. If *filter* is not an object or **null**, throw a TypeError and abort these steps.
2. Let *discovery* be a new ThingDiscovery object.
3. Set the filter property to *filter*.
4. Set the active and done properties to **false**. Set the error property to **null**.
5. Return *discovery*.

The start() method sets active to **true**. The stop() method sets the active property to **false**, but done may be still **false** if there are ThingDescription objects in the discovery results not yet consumed with next().

During successive calls of next(), the active property may be **true** or **false**, but the done property is set to **false** by next() only when both the active property is **false** and discovery results is empty.

9.2 The **DiscoveryMethod** enumeration §

WebIDL

```
typedef DOMString DiscoveryMethod;
```

Represents the discovery type to be used:

- **"any"** does not provide any restriction

- **"local"** for discovering [Things](#) defined in the same device or connected to the device by wired or wireless means.
- **"directory"** for discovery based on a service provided by a [Thing Directory](#).
- **"multicast"** for discovering [Things](#) in the device's network by using a supported multicast protocol.

9.3 The **ThingFilter** dictionary §

Represents an object containing the constraints for discovering [Things](#) as key-value pairs.

WebIDL

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

The **method** property represents the discovery type that should be used in the discovery process. The possible values are defined by the [DiscoveryMethod](#) enumeration that *MAY* be extended by string values defined by solutions (with no guarantee of interoperability).

The **url** property represents additional information for the discovery method, such as the URL of the target entity serving the discovery request, for instance the URL of a [Thing Directory](#) (if **method** is **"directory"**), or otherwise the URL of a directly targeted [Thing](#).

The **query** property represents a query string accepted by the implementation, for instance a SPARQL or JSON query. Support may be implemented locally in the [WoT Runtime](#) or remotely as a service in a [Thing Directory](#).

The **fragment** property represents a template object used for matching property by property against discovered [Things](#).

9.4 The **start()** method §

Starts the discovery process. The method *MUST* run the following steps:

1. If invoking this method is not allowed for the current scripting context for security reasons, set the [error](#) property to a [SecurityError](#) and abort these steps.
2. If discovery is not supported by the implementation, set the [error](#) property to [NotSupportedError](#) and abort these steps.
3. Let *filter* denote the [filter](#) property.
4. If the *filter* is defined,
 - If *filter*'s [query](#) is defined, pass it as an opaque string to the underlying implementation to be matched against discovered items. The underlying implementation is responsible to parse it e.g. as a SPARQL or JSON query and match it against the [Thing Descriptions](#) found during the discovery process. If queries are not supported, set `|this.error|` to [NotSupportedError](#) and abort these steps.
5. Create the [discovery results internal slot](#) for storing discovered [ThingDescription](#) objects.
6. Request the underlying platform to start the discovery process, with the following parameters:
 - If `|filter|s method` is not defined or the value is ["any"](#), use the widest discovery method supported by the underlying platform.
 - Otherwise if `|filter|s method` is ["local"](#), use the local [Thing Directory](#) for discovery. Usually that defines [Things](#) deployed in the same device, or connected to the device in slave mode (e.g. sensors connected via Bluetooth or a serial connection).
 - Otherwise if `|filter|s method` is ["directory"](#), use the remote [Thing Directory](#) specified in `|filter.url|`.
 - Otherwise if `|filter|s method` is ["multicast"](#), use all the multicast discovery protocols supported by the underlying platform.
7. When the underlying platform has started the discovery process, set the [active](#) property to [true](#).
8. Whenever a new [Thing Description](#) *td* is discovered by the underlying platform, run the following sub-steps:
 1. [Fetch](#) *td* as a JSON object *json*. If that fails, set the [error](#) property to [SyntaxError](#), discard *td* and continue the discovery process.
 2. If *filter*'s [query](#) is defined, check if *json* is a match for the query. The matching algorithm is encapsulated by implementations. If that returns [false](#), discard *td* and continue the discovery process.
 3. If *filter*'s [fragment](#) is defined, for each property defined in it, check if that property exists in *json*'s properties and has the same value. If this is [false](#) in any checks, discard *td* and continue the discovery process.
 4. Otherwise add *td* to the [discovery results](#).

5. At this point implementations *MAY* control the flow of the discovery process (depending on memory constraints, for instance temporarily stop discovery if the queue is getting too large, or resume discovery when the queue is emptied sufficiently).
9. Whenever an error occurs during the discovery process,
 1. Let *error* be a new Error object. Set *error*'s *name* to "DiscoveryError".
 2. If there was an error code or message provided by the Protocol Bindings, set *error*'s *message* to that value as string.
 3. Set error property to *error*.
 4. If the error is irrecoverable and discovery has been stopped by the underlying platform, set the active property to **false**.
10. When the underlying platform reports the discovery process has completed, set the active property to **false**.

9.5 The **next()** method §

Provides the next discovered ThingDescription object. The method *MUST* run the following steps:

1. Return a Promise *promise* and execute the next steps in parallel.
2. If the active property is **true**, wait until the discovery results internal slot is not empty.
3. If discovery results is empty and the active property is **false**, set the done property to **true** and reject *promise*.
4. Remove the first ThingDescription object *td* from discovery results.
5. Resolve *promise* with *td* and abort these steps.

9.6 The **stop()** method §

Stops or suppresses the discovery process. It might not be supported by all discovery methods and endpoints, however, any further discovery results or errors will be discarded and the discovery is marked inactive. The method *MUST* run the following steps:

1. Request the underlying platform to stop the discovery process. If this returns an error, or if it is not possible, for instance when discovery is based on open ended multicast requests, the implementation *SHOULD* discard subsequent discovered items.
2. Set the active property to **false**.

9.7 Discovery Examples §

The following example finds [ThingDescription](#) objects of [Things](#) that are exposed by local hardware, regardless how many instances of [WoT Runtime](#) it is running. Note that the discovery can end (become inactive) before the internal [discovery results](#) queue is emptied, so we need to continue reading [ThingDescription](#) objects until done. This is typical with local and directory type discoveries.

EXAMPLE 5: Discover Things exposed by local hardware

```
let discovery = new ThingDiscovery({ method: "local" });
do {
  let td = await discovery.next();
  console.log("Found Thing Description for " + td.title);
  let thing = new ConsumedThing(td);
  console.log("Thing name: " + thing.getThingDescription().title);
} while (!discovery.done);
```

The next example finds [ThingDescription](#) objects of [Things](#) listed in a [Thing Directory](#) service. We set a timeout for safety.

EXAMPLE 6: Discover Things via directory

```
let discoveryFilter = {
  method: "directory",
  url: "http://directory.wotservice.org"
};
let discovery = new ThingDiscovery(discoveryFilter);
setTimeout( () => {
  discovery.stop();
  console.log("Discovery stopped after timeout.");
},
3000);
do {
  let td = await discovery.next();
  console.log("Found Thing Description for " + td.title);
  let thing = new ConsumedThing(td);
  console.log("Thing name: " + thing.getThingDescription().title);
} while (!discovery.done);
if (discovery.error) {
  console.log("Discovery stopped because of an error: " + error.message);
}
```

The next example is for an open-ended multicast discovery, which likely won't complete soon (depending on the underlying protocol), so stopping it with a timeout is a good idea. It will likely deliver results one by one.

EXAMPLE 7: Discover Things in a network

```
let discovery = new ThingDiscovery({ method: "multicast" });
setTimeout( () => {
  discovery.stop();
  console.log("Stopped open-ended discovery");
},
10000);
do {
  let td = await discovery.next();
  let thing = new ConsumedThing(td);
  console.log("Thing name: " + thing.getThingDescription().title);
} while (!discovery.done);
```

10. Security and Privacy §

A detailed discussion of security and privacy considerations for the Web of Things, including a threat model that can be adapted to various circumstances, is presented in the informative document [[WOT-SECURITY-GUIDELINES](#)]. This section discusses only security and privacy risks and possible mitigations directly relevant to the scripts and WoT Scripting API.

A suggested set of best practices to improve security for WoT devices and services has been documented in [[WOT-SECURITY-BEST-PRACTICES](#)]. That document may be updated as security measures evolve. Following these practices does not guarantee security, but it might help avoid common known vulnerabilities.

The WoT security risks and possible mitigations are concerning the following groups:

- Implementors of WoT Runtimes that do not implement a Scripting Runtime. The [[WOT-ARCHITECTURE](#)] document provides generic security guidelines for this group.
- Implementors of the WoT Scripting API in a WoT Scripting Runtime. This is the main scope and is covered in the [Scripting Runtime Security and Privacy Risks](#) sub-section that contains normative text regarding security.
- WoT script developers, covered in the [Script Security and Privacy Risks](#) sub-section that contains informative recommendations concerning security.

10.1 Scripting Runtime Security and Privacy Risks §

This section is normative and contains specific risks relevant for the WoT Scripting Runtime.

10.1.1 Corrupted Input Security and Privacy Risk §

A typical way to compromise any process is to send it a corrupted input via one of the exposed interfaces. This can be done to a script instance using WoT interface it exposes.

Mitigation:

Implementors of this API *SHOULD* perform validation on all script inputs. In addition to input validation, [fuzzing](#) should be used to verify that the input processing is done correctly. There are many tools and techniques in existence to do such validation. More details can be found in [[WOT-SECURITY-TESTING](#)].

10.1.2 Physical Device Direct Access Security and Privacy Risk §

In case a script is compromised or misbehaving, the underlying physical device (and potentially surrounded environment) can be damaged if a script can use directly exposed native device interfaces. If such interfaces lack safety checks on their inputs, they might bring the underlying physical device (or environment) to an unsafe state (i.e. device overheats and explodes).

Mitigation:

The WoT Scripting Runtime *SHOULD* avoid directly exposing the native device interfaces to the script developers. Instead, a WoT Scripting Runtime should provide a hardware abstraction layer for accessing the native device interfaces. Such hardware abstraction layer should refuse to execute commands that might put the device (or environment) to an unsafe state. Additionally, in order to reduce the damage to a physical WoT device in cases a script gets compromised, it is important to minimize the number of interfaces that are exposed or accessible to a particular script based on its functionality.

10.1.3 Provisioning and Update Security Risk §

If the WoT Scripting Runtime supports post-manufacturing provisioning or updates of scripts, WoT Scripting Runtime or any related data (including security credentials), it can be a major attack vector. An attacker can try to modify any above described element during the update or provisioning process or simply provision attacker's code and data directly.

Mitigation:

Post-manufacturing provisioning or update of scripts, WoT Scripting Runtime or any related data should be done in a secure fashion. A set of recommendations for secure update and post-manufacturing provisioning can be found in [[WOT-SECURITY-GUIDELINES](#)].

10.1.4 Security Credentials Storage Security and Privacy Risk §

Typically the WoT Scripting Runtime needs to store the security credentials that are provisioned to a WoT device to operate in WoT network. If an attacker can compromise the confidentiality or integrity of these credentials, then it can obtain access to the WoT assets, impersonate WoT things or devices or create Denial-Of-Service (DoS) attacks.

Mitigation:

The WoT Scripting Runtime should securely store the provisioned security credentials, guaranteeing their integrity and confidentiality. In case there are more than one tenant on a single WoT-enabled device, a WoT Scripting Runtime should guarantee isolation of each tenant provisioned security credentials. Additionally, in order to minimize a risk that provisioned

security credentials get compromised, the WoT Scripting Runtime should not expose any API for scripts to query the provisioned security credentials.

10.2 Script Security and Privacy Risks §

This section is non-normative.

This section describes specific risks relevant for script developers.

10.2.1 Corrupted Script Input Security and Privacy Risk §

A script instance may receive data formats defined by the TD, or data formats defined by the applications. While the WoT Scripting Runtime *SHOULD* perform validation on all input fields defined by the TD, scripts may be still exploited by input data.

Mitigation:

Script developers should perform validation on all application defined script inputs. In addition to input validation, [fuzzing](#) could be used to verify that the input processing is done correctly. There are many tools and techniques in existence to do such validation. More details can be found in [\[WOT-SECURITY-TESTING\]](#).

10.2.2 Denial Of Service Security Risk §

If a script performs a heavy functional processing on received requests before the request is authenticated, it presents a great risk for Denial-Of-Service (DOS) attacks.

Mitigation:

Scripts should avoid heavy functional processing without prior successful authentication of requestor. The set of recommended authentication mechanisms can be found in [\[WOT-SECURITY-BEST-PRACTICES\]](#).

10.2.3 Stale TD Security Risk §

During the lifetime of a WoT network, a content of a TD can change. This includes its identifier, which might not be an immutable one and might be updated periodically.

Mitigation:

Scripts should use this API to subscribe for notifications on TD changes and do not rely on TD values to remain persistent.

EDITOR'S NOTE

While stale TDs can present a potential problem for WoT network operation, it might not be a security risk.

11. Terminology and conventions §

The generic WoT terminology is defined in [WOT-ARCHITECTURE]: *Thing*, *Thing Description* (in short *TD*), *Web of Things* (in short *WoT*), *WoT Interface* (same as *WoT network interface*), *Protocol Bindings*, *WoT Runtime*, *Consuming a Thing Description*, *Thing Directory*, *WoT Interactions*, *Property*, *Action*, *Event*, *DataSchema*, *Form* etc.

JSON-LD is defined in [JSON-LD] as a JSON document that is augmented with support for Linked Data.

JSON schema is defined in [these specifications](#).

The terms *URL*, *URL scheme*, *URL host*, *URL path*, *URL record*, *parse a URL*, *absolute-URL string*, *path-absolute-URL string*, *basic URL parser* are defined in [URL].

The terms *MIME type*, *Parsing a MIME type*, *Serializing a MIME type*, *valid MIME type string*, *JSON MIME type* are defined in [MIMESNIFF].

The terms *UTF-8 encoding*, *UTF-8 decode*, *encode*, *decode* are defined in [ENCODING].

string, *parse JSON from bytes* and *serialize JSON to bytes*, are defined in [INFRA].

Promise, *Error*, *JSON*, *JSON.stringify*, *JSON.parse*, *internal method* and *internal slot* are defined in [ECMAScript].

The terms *browsing context*, *top-level browsing context*, *global object*, *current settings object*, executing algorithms *in parallel* are defined in [HTML5] and are used in the context of browser implementations.

The term *secure context* is defined in [WEBAPPSEC].

IANA media types (formerly known as MIME types) are defined in [RFC2046](#).

The terms *hyperlink reference* and *relation type* are defined in [\[HTML5\]](#) and [RFC8288](#).

A. API design rationale §

API rationale usually belongs to a separate document, but in the WoT case the complexity of the context justifies including basic rationale here.

A.1 Approaches to WoT application development §

The WoT Interest Group and Working Group have explored different approaches to application development for WoT that have been all implemented and tested.

A.1.1 No Scripting API §

It is possible to develop WoT applications that only use the [WoT network interface](#), typically exposed by a WoT gateway that presents a REST-ful API towards clients and implements IoT protocol plugins that communicate with supported IoT deployments. One such implementation is the [Mozilla WebThings](#) platform.

A.1.2 Simple Scripting API §

WoT [Things](#) show good synergy with software objects, so a [Thing](#) can be represented as a software object, with [Properties](#) represented as object properties, [Actions](#) as methods, and [Events](#) as events. In addition, metadata is stored in special properties. Consuming and exposing is done with factory methods that produce a software object that directly represents a remote [Thing](#) and its interactions. One such implementation is the [Arena Web Hub](#) project.

In the next example, a [Thing](#) that represents interactions with a lock would look like the following: the *status* property and the `open()` method are directly exposed on the object.

EXAMPLE 8: Open a lock with a simple API

```
let lock = await WoT.consume('https://td.my.com/lock-00123');
console.log(lock.status);
lock.open('withThisKey');
```


A.1.3 This API, aligned with [\[WOT-TD\]](#) §

Since the direct mapping of [Things](#) to software objects have had some challenges, this specification takes another approach that exposes software objects to represent the [Thing](#) metadata as data property and the WoT interactions as methods. One implementation is [node-wot](#) in the the [Eclipse ThingWeb](#) project, which is the current reference implementation of the API specified in this document.

The same example now would look like the following: the *status* property and the `open()` method are represented indirectly.

[EXAMPLE 9](#): Open a lock

```
let res = await fetch('https://td.my.com/lock-00123');
let td = await res.json();
let lock = new ConsumedThing(td);
console.log(lock.readProperty('status'));
lock.invokeAction('open', 'withThisKey');
```

In conclusion, the WoT WG decided to explore the third option that closely follows the [\[WOT-TD\]](#) specification. Based on this, a simple API can also be implemented. Since Scripting is an optional module in WoT, this leaves room for applications that only use the WoT network interface. Therefore all three approaches above are supported by [\[WOT-TD\]](#).

Moreover, the WoT network interface can be implemented in many languages and runtimes. Consider this API an example for what needs to be taken into consideration when designing a Scripting API for WoT.

A.2 Fetching and validating a TD §

The `fetch(url)` method has been part of this API in earlier versions. However, now fetching a [TD](#) given a URL should be done with an external method, such as the [Fetch API](#) or a HTTP client library, which offer already standardized options on specifying fetch details. The reason is that while simple fetch operations (covering most use cases) could be done in this API, when various fetch options were needed, there was no point in duplicating existing work to re-expose those options in this API.

Since fetching a [TD](#) has been scoped out, and [TD](#) validation is defined externally in [\[WOT-TD\]](#), that is scoped out, too. This specification expects a [TD](#) as [parsed JSON object](#) that has been validated according to the [\[WOT-TD\]](#) specification.

A.3 Factory vs constructors §

The factory methods for consuming and exposing [Things](#) are asynchronous and fully validate the input [TD](#). In addition, one can also construct [ConsumedThing](#) and [ExposedThing](#) by providing a parsed and validated [TD](#). Platform initialization is then done when needed during the WoT interactions. So applications that prefer validating a [TD](#) themselves, may use the constructors, whereas applications that leave validation to implementations and prefer interactions initialized up front *SHOULD* use the factory methods on the [WoT API object](#).

A.4 Observers §

Earlier drafts used the [Observer](#) construct, but since it has not become standard, a new design was needed that was light enough for embedded implementations. Therefore observing [Property](#) changes and handling WoT [Events](#) is done with callback registrations.

A.5 Using Events §

This API ended up not using software events at all, for the following reasons:

- Subscription to WoT [Events](#) may be different from handling software events (subscription might need parameters, might involve security tokens etc).
- Most implementations are for Node.js and browser implementations will likely be libraries (because possible dependency management issues in native implementations), using Events has been challenging.
- Observing [Property](#) changes and handling WoT [Events](#) is done with the solution above.

A.6 Polymorphic functions §

The reason to use function names like [readProperty\(\)](#), [readMultipleProperties\(\)](#) etc. instead of a generic polymorphic [read\(\)](#) function is that the current names map exactly to the "op" vocabulary from the [Form](#) definition in [\[WOT-TD\]](#).

B. Changes §

The following is a list of major changes to the document. Major versions of this specification are the following:

- First Public Working Draft [September 2017](#).
- Working Draft [April 2018](#).
- Working Draft [November 2018](#).
- This version, introducing the following major changes:
 - Remove `fetch()` for fetching a [TD](#) (delegated to external API).
 - Remove `Observer` and use [W3C TAG recommended design patterns](#).
 - Align the discovery API to other similar APIs (such as [W3C Generic Sensor API](#)).
 - Remove the large data definition API for constructing [TDs](#) and leverage using [ThingDescription](#) instead.
 - Add missing algorithms and rework most existing ones.
 - Allow constructors for [ConsumedThing](#) and [ExposedThing](#).
 - Add API rationale as an appendix to this document.

For a complete list of changes, see the [github change log](#). You can also view the [recently closed issues](#).

C. Open issues §

The following problems are being discussed and need most attention:

- Script management and runtime related issues (<https://github.com/w3c/wot-scripting-api/issues/>)
- An explicit API for adding and removing [Property](#), [Action](#) and [Event](#) definitions on [ExposedThing](#) (it was present in earlier versions, but removed for complexity and a simpler way to do it).

D. Full Web IDL §

WebIDL

```
typedef object ThingDescription;

[SecureContext, Exposed=(Window,Worker)]
interface WOT {
    // methods defined in UA conformance classes
};
```

```

partial interface WOT {
    Promise<ConsumedThing> consume(ThingDescription td);
};

partial interface WOT {
    Promise<ExposedThing> produce(ThingDescription td);
};

partial interface WOT {
    ThingDiscovery discover(optional ThingFilter filter = null);
};

typedef any DataSchemaValue;
typedef (ReadableStream or DataSchemaValue) InteractionInput;

[SecureContext, Exposed=(Window,Worker)]
interface InteractionOutput {
    readonly attribute ReadableStream? data;
    readonly attribute boolean dataUsed;
    readonly attribute Form? form;
    readonly attribute DataSchema? schema;
    Promise<ArrayBuffer> arrayBuffer();
    Promise<any> value();
};

[SecureContext, Exposed=(Window,Worker)]
interface ConsumedThing {
    constructor(ThingDescription td);
    Promise<InteractionOutput> readProperty(DOMString propertyName,
                                          optional InteractionOptions options =
null);
    Promise<PropertyMap> readAllProperties(optional InteractionOptions
options = null);
    Promise<PropertyMap> readMultipleProperties(
                                          sequence<DOMString> propertyNames,
                                          optional InteractionOptions options =
null);
    Promise<void> writeProperty(DOMString propertyName,
                               InteractionInput value,
                               optional InteractionOptions options =
null);
    Promise<void> writeMultipleProperties(PropertyMap valueMap,
                                          optional InteractionOptions options =
null);
};

```

```

    Promise<InteractionOutput> invokeAction(DOMString actionName,
                                           optional InteractionInput params = null,
                                           optional InteractionOptions options =
null);
    Promise<void> observeProperty(DOMString name,
                                WotListener listener,
                                optional InteractionOptions options =
null);
    Promise<void> unobserveProperty(DOMString name,
                                   optional InteractionOptions options =
null);
    Promise<void> subscribeEvent(DOMString name,
                                WotListener listener,
                                optional InteractionOptions options =
null);
    Promise<void> unsubscribeEvent(DOMString name,
                                   optional InteractionOptions options =
null);
    ThingDescription getThingDescription();
};

dictionary InteractionOptions {
    unsigned long formIndex;
    object uriVariables;
    any data;
};

typedef object PropertyMap;

callback WotListener = void(InteractionOutput data);

[SecureContext, Exposed=(Window,Worker)]
interface ExposedThing: ConsumedThing {
    ExposedThing setPropertyReadHandler(DOMString name,
                                       PropertyReadHandler handler);
    ExposedThing setPropertyWriteHandler(DOMString name,
                                       PropertyWriteHandler handler);
    ExposedThing setPropertyObserveHandler(DOMString name,
                                       PropertyReadHandler handler);
    ExposedThing setPropertyUnobserveHandler(DOMString name,
                                       PropertyReadHandler handler);

    ExposedThing setActionHandler(DOMString name, ActionHandler action);

```

```

    ExposedThing setEventSubscribeHandler(DOMString name,
        EventSubscriptionHandler handler);
    ExposedThing setEventUnsubscribeHandler(DOMString name,
        EventSubscriptionHandler handler);
    ExposedThing setEventHandler(DOMString name,
        EventListenerHandler eventHandler);
    void emitEvent(DOMString name, InteractionInput data);

    Promise<void> expose();
    Promise<void> destroy();
};

callback PropertyReadHandler = Promise<any>(
    optional InteractionOptions options = null);

callback PropertyWriteHandler = Promise<void>(
    InteractionOutput value,
    optional InteractionOptions options = null);

callback ActionHandler = Promise<InteractionInput>(
    InteractionOutput params,
    optional InteractionOptions options = null);

callback EventSubscriptionHandler = Promise<void>(
    optional InteractionOptions options = null);

callback EventListenerHandler = Promise<InteractionInput>();

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

typedef DOMString DiscoveryMethod;

dictionary ThingFilter {
    (DiscoveryMethod or DOMString) method = "any";

```

```
USVString? url;  
USVString? query;  
object? fragment;  
};
```

E. Acknowledgements §

Special thanks to former editor Johannes Hund (until August 2017, when at Siemens AG) and Kazuaki Nimura (until December 2018) for developing this specification. Also, the editors would like to thank Dave Raggett, Matthias Kovatsch, Michael Koster, Elena Reshetova, Michael McCool as well as the other WoT WG members for their comments, contributions and guidance.

F. References §

F.1 Normative references §

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[fetch]

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[HTML]

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