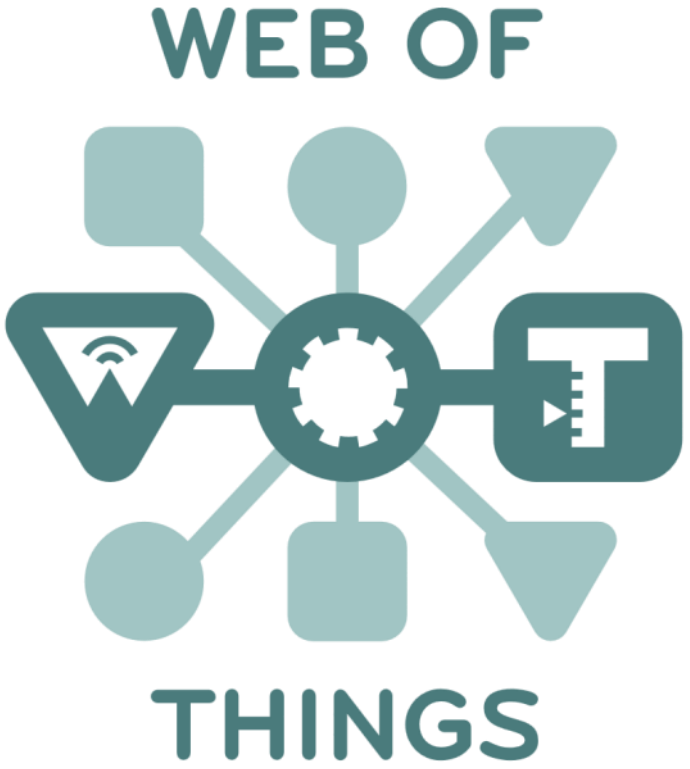


W3C WoT Face-to-Face Meeting

Bundang, Korea, July 2018

W3C Web of Things – Summary

- Counter fragmentation in the IoT
  - Web of Things (WoT) vs Internet of Things (IoT) is similar to World Wide Web vs Internet
  - Take patterns from the World Wide Web and adapt and apply them to the IoT
    - JSON, Schema, and Linked Data
    - URIs and Media Types
    - JavaScript runtime
- By Describing and Complementing
  - Not competing with existing IoT standards, as not prescribing a full-stack solution
  - W3C WoT offers building blocks to pick that enable semantic interoperability
    - WoT Thing Description (TD)
    - WoT Binding Templates
    - WoT Scripting API

W3C Web of Things – Activity

- **WoT Workshop, Berlin, 2014**
  - Identify stakeholders for W3C activity
  - Siemens took a leading role chairing the activity
- **W3C WoT Interest Group (IG)**
  - Started spring 2015
  - ~200 participants
  - Exploration and liaisons (e.g., OPC, oneM2M, OCF)
  - Continues to exists parallel to Working Group
- **W3C WoT Working Group (WG)**
  - Started end of 2016
  - ~100 participants
  - Normative work on deliverables

W3C WoT Approach – Building Blocks

WoT Thing Description (TD)

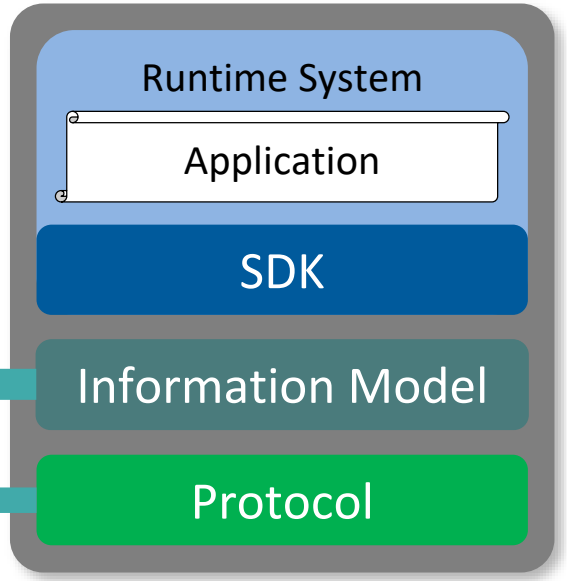
JSON-LD representation format to describe Thing *instances* with **metadata**. Uses **formal interaction model** and **domain-specific vocabularies** to uniformly describe how to use Things, which enables semantic interoperability.

The *index.html* for Things

Properties

Events

Actions



HTTP

CoAP

MQTT

…

UA Binary

Modbus

BACnet

JavaScript

WoT Scripting API

Standardized **JavaScript** object API for an IoT runtime system **similar to the Web browser**. Provides an interface between applications and Things to simplify IoT application development
and enable **portable apps** across vendors, devices, edge, and cloud.

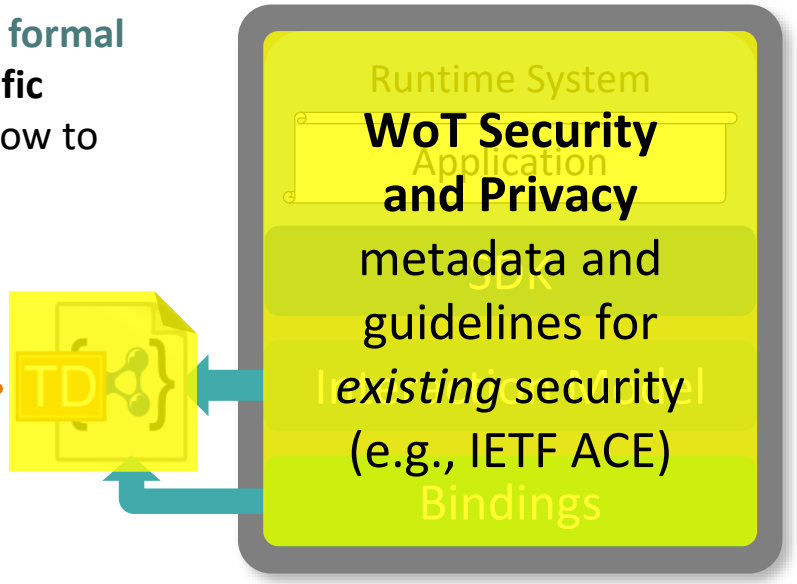
WoT Binding Templates

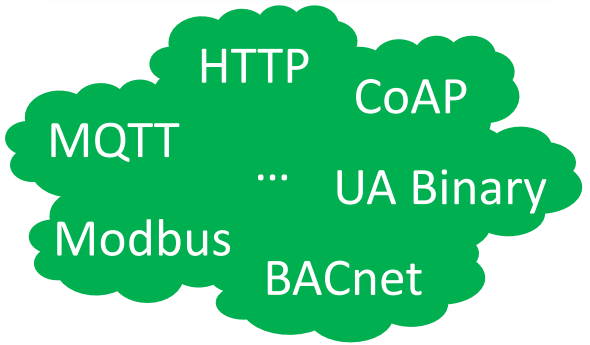
Capture how the **formal Interaction Model** is mapped to concrete protocol operations (e.g., CoAP) and platform features (e.g., OCF). These templates are re-used by concrete TDs.

W3C WoT Approach – Batteries Included

WoT Thing Description (TD)

JSON-LD representation format to describe Thing *instances* with **metadata**. Uses **formal interaction model** and **domain-specific vocabularies** to uniformly describe how to use Things, which enables semantic interoperability.





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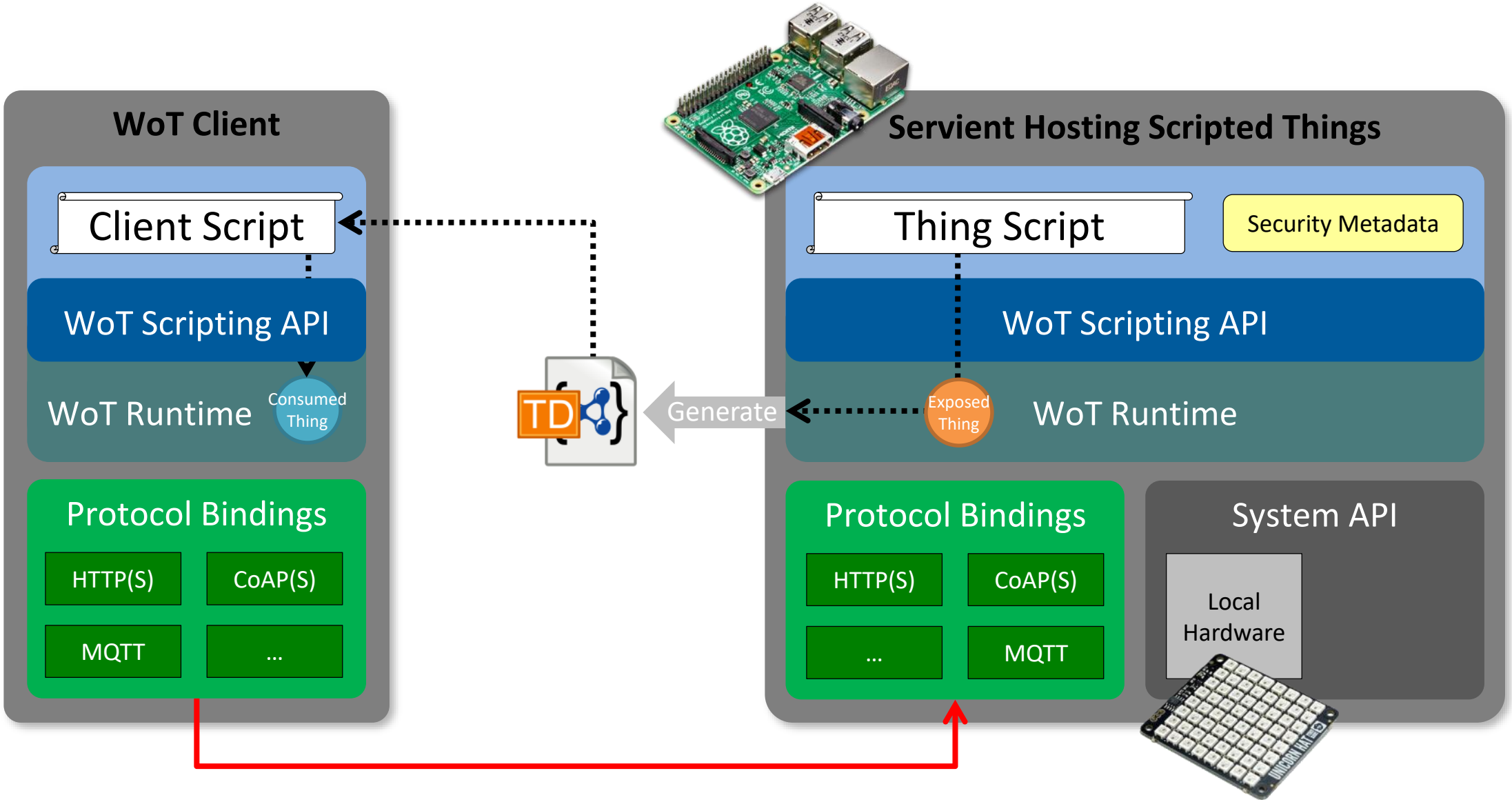
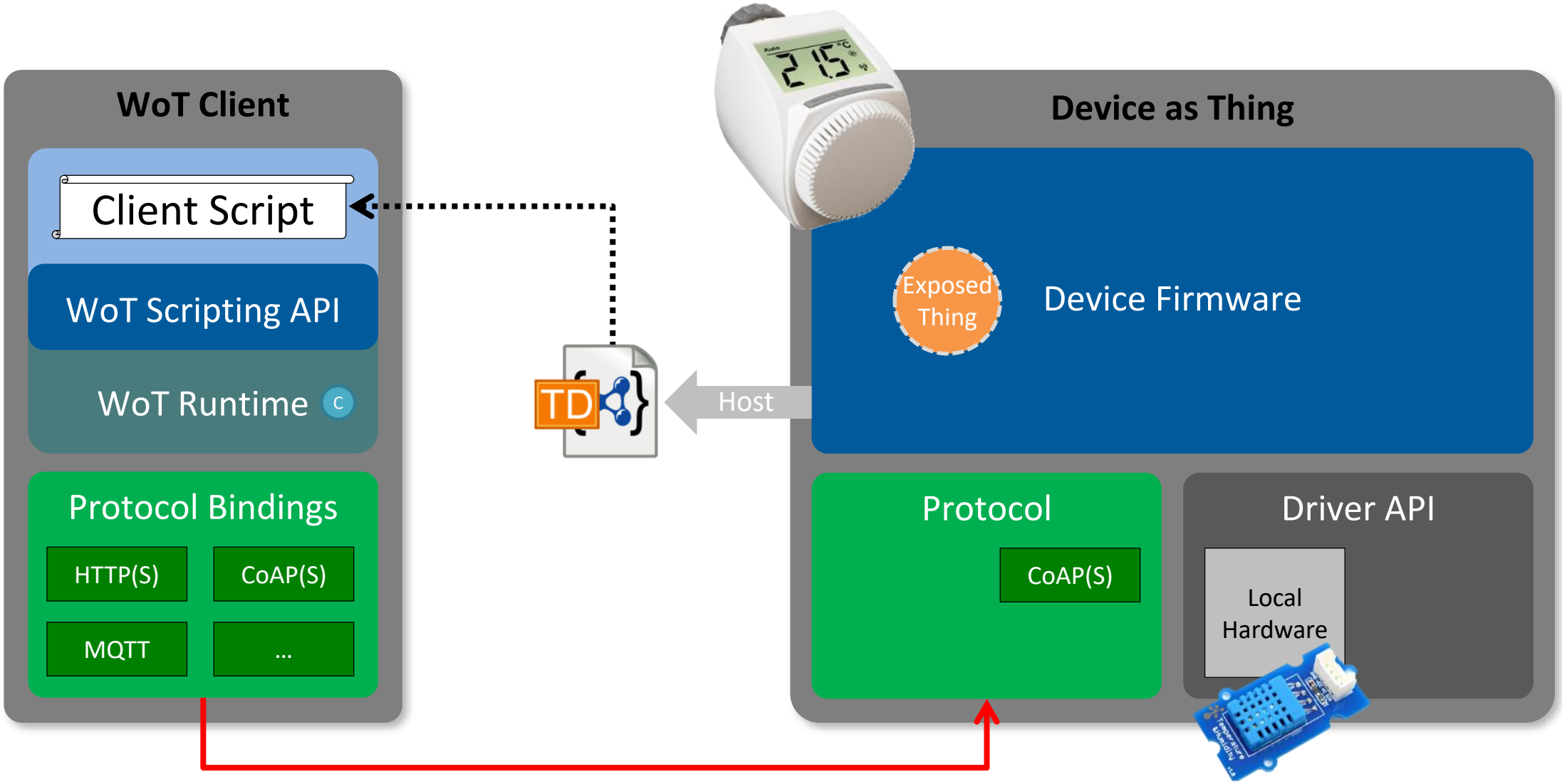
Capture how the **formal Interaction Model** is mapped to concrete protocol operations (e.g., CoAP) and platform features (e.g., OCF). These templates are re-used by concrete TDs.

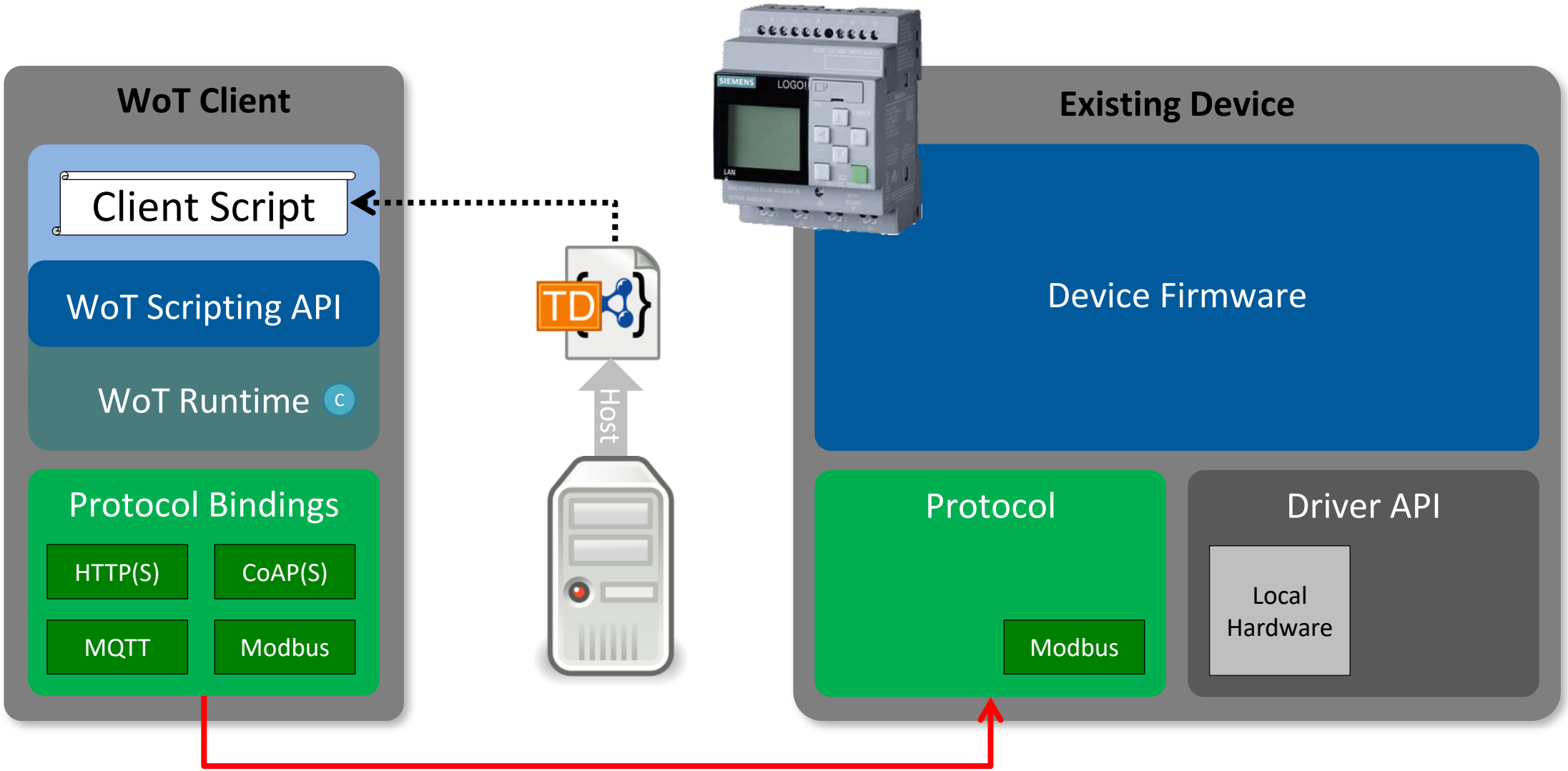
Deployment Scenarios – Full-stack Devices



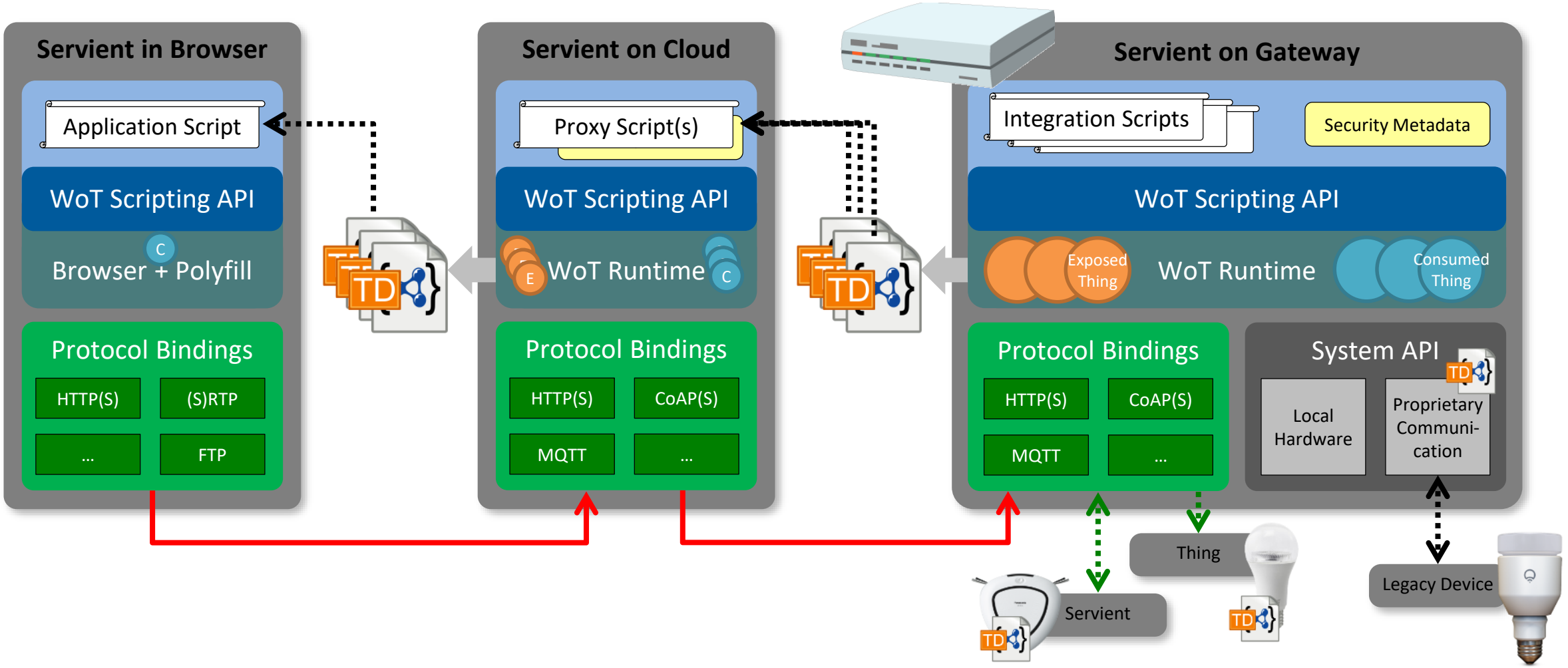
Deployment Scenarios – Constrained Devices



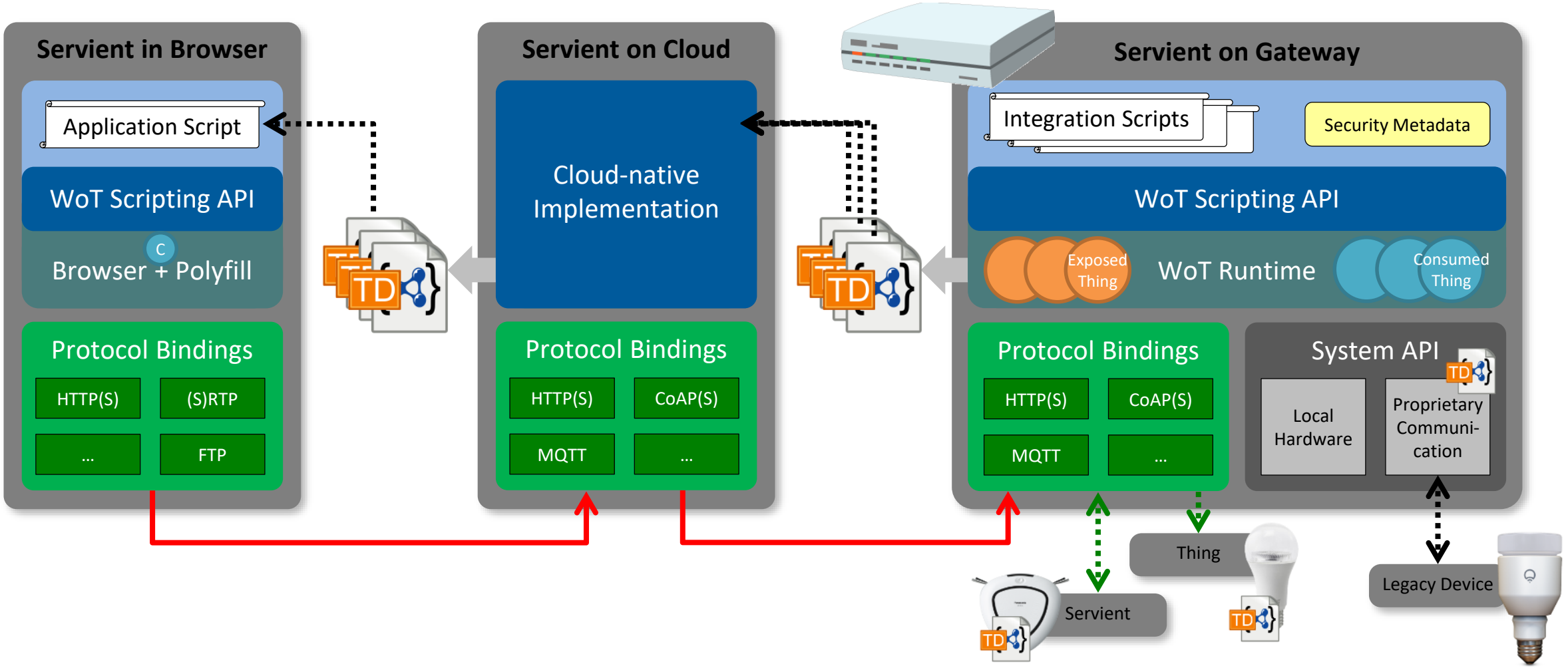
Deployment Scenarios – Retrofitting Devices



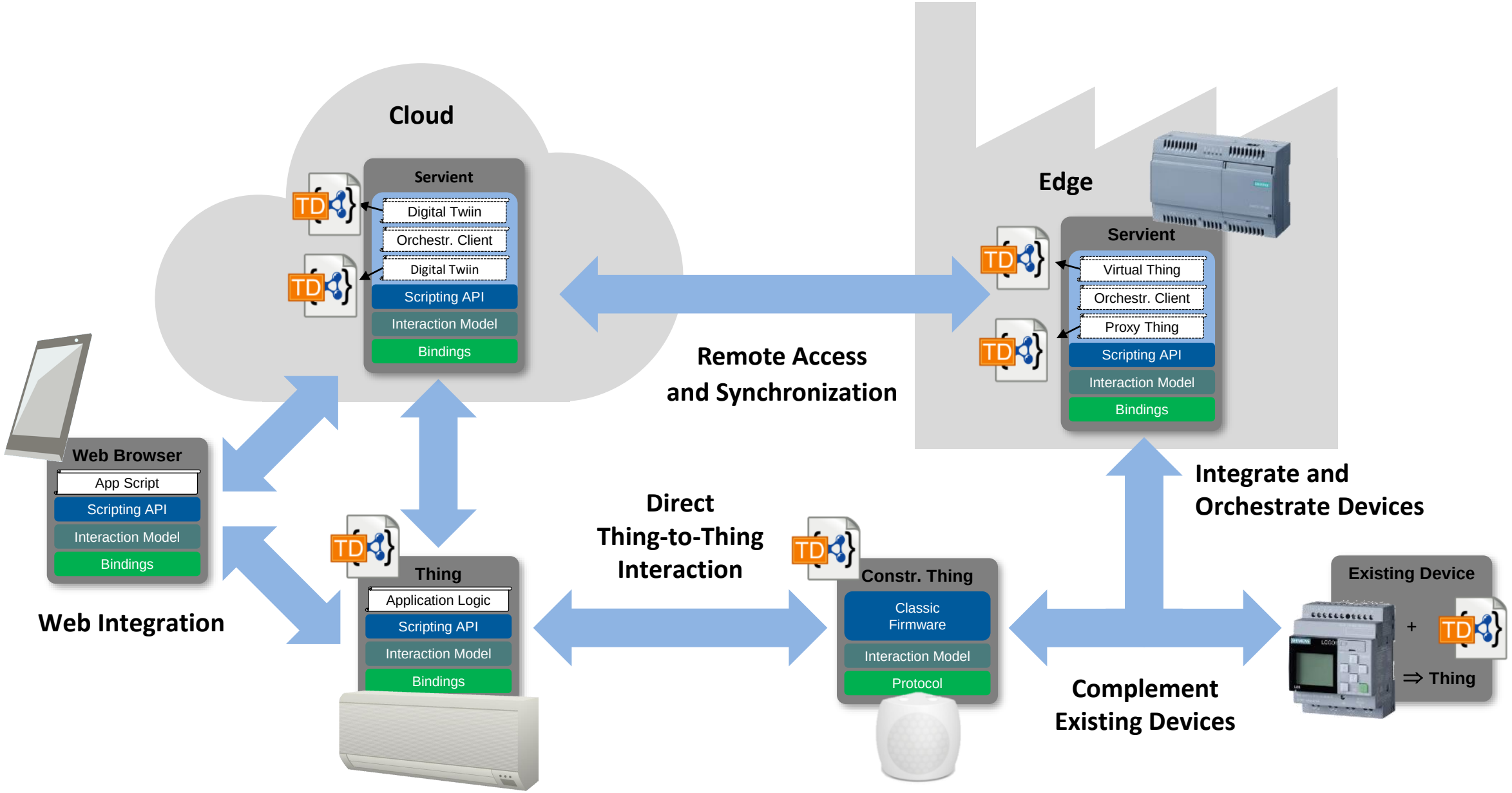
Deployment Scenarios – Web Integration



Deployment Scenarios – Web Integration



W3C WoT Integration Patterns – Things AND Cloud




WEB OF
THINGS
WoT Scripting API
WoT Runtime
System API
Web of Things Purpose and Architecture
One stop universal Platform by Web technology on IoT
Ecosystem with third party servicers
Coexist with other SDO's Standards
Maintain current services as well as new services on WoT
Current Silo Architecture
WoT Architecture
Architecture Abstract
Architecture Building Blocks
W3C
Demonstration
SIEMENS
Ingenuity for life
Demonstration
SIEMENS
Ingenuity for life

Editors‘ Draft: https://w3c.github.io/wot-thing-description/

WOT THING DESCRIPTION

WoT WG Changed to “Simplified TD” in March 2018

- JSON-LD 1.1 processing
  - Objects instead of arrays
  - Default values (e.g., `"writable": false`)
  - Framing to serialize and preprocess
- Semantic annotations optional
  - TDs can be treated as simple JSON format
  - No JSON-LD keywords or processing required
  - `properties`, `actions`, `events` on top level
  - No LD convention of terms being singular
  - New Media Type `application/td+json`
  - Context and terms known implicitly
- JSON Schema compatible
  - Data schema syntax now also identical
  - Payloads can be validated directly with JSON Schema implementations
- New terms
  - id
  - label
  - description
  - support
  - … collecting more

WG changed from the “JSON-LD 1.0 based TD” to the “Simplified TD”

DIFF FOR SIMPLIFIED TD

WoT WG Changed to “Simplified TD”

OLD

```
{
  "@context": "https://./w3c-wot-td-context.jsonld",
  "name": "Lamp",
  "@id": "urn:dev:wot:com:example:servient:lamp",
  "base": "https://servient.example.com/things/lamp/",
  "interaction": [{
    "@type": "Property",
    "name": "on",
    "schema": { "type": "boolean" },
    "writeable": false,
    "form": [{
      "href": "properties/on",
      "mediaType": "application/json"
    }]
  }, {
    "@type": "Property",
    "name": "brightness",
    "writeable": true,
    "schema": {
      "type": " integer",
      "minimum": 0,
      "maximum": 100
    },
    "form": [{
      "href": "properties/status",
      "mediaType": "application/json"
    }]
  }, {
```

NEW

```
{
  "id": "urn:dev:wot:com:example:servient:lamp",
  "label": "Lamp",
  "description": "Corner torchiere“,
  "base": "https://servient.example.com/things/lamp/",
  "properties": {
    "on": {
      "type": "boolean",
      "forms": [{
        "href": "properties/on",
        "mediaType": "application/json"
      }]
    },
    "brightness": {
      "type": "integer",
      "minimum": 0,
      "maximum": 100
      "writeable": true,
      "forms": [{
        "href": "properties/status",
        "mediaType": "application/json"
      }]
    }
  },



  "actions": {
```

WoT WG Changed to “Simplified TD”

OLD

```
}, {
  "@type": "Action",
  "name": "fade",
  "inputSchema": {
    "type": "object",
    "fields": [{
      "name": "from",
      "schema": {
        "type": "integer",
        "minimum": 0,
        "maximum": 100
      }
    }, {
      "name": "to",
      "schema": {
        "type": "integer",
        "minimum": 0,
        "maximum": 100
      }
    }, {
      "name": "duration",
      "schema": { "type": "number" }
    }]
  },
  "form": [{ "href": "actions/fade" }]
}, {
```

NEW

```
"actions": {
  "fade": {
    "input": {
      "type": "object",
      "properties": {
        "from": {
          "type": "integer",
          "minimum": 0,
          "maximum": 100
        },
        "to": {
          "type": "integer",
          "minimum": 0,
          "maximum": 100
        },
        "duration": { "type": "number" }
      }
    },
    "forms": [{
      "href": "actions/fade",
      "outputMediaType": "application/json",
      "inputMediaType": "application/json"
    }]
  }
},
"events": {
```

WoT WG Changed to “Simplified TD”

OLD

```
}, {
    "@type": "Event",
    "name": "overheated",
    "schema": {
      "type": "object",
      "fields": [{
        "name": "temperature",
        "schema": { "type": "number" }
      }]
    },
    "form": [{
      "href": "events/overheated",
      "mediaType": "application/json"
    }]
  }],
  "link": [{
    "href": "https://servient.example.com/things/pir",
    "rel": "controlledBy",
    "mediaType": "application/ld+json"
  }]
}
```

NEW

```
"events": {
    "overheated": {
      "type": "object",
      "properties": {
        "temperature": { "type": "number" }
      },
      "forms": [{
        "href": "events/overheated",
        "subProtocol": "EventSource",
        "mediaType": "application/json"
      }]
    }
  },

  "links": [{
    "href": "https://servient.example.com/things/pir",
    "rel": "controlledBy",
    "mediaType": "application/td+json"
  }]
}
```

WG changed from the “JSON-LD 1.0 based TD” to the “Simplified TD”

SIMPLIFIED TD IN DETAIL

WoT Thing Description (TD) – Minimal Form

```
{
  "id": "urn:dev:org:32473:1234567890",
  "label": "MyLEDThing",
  "description": "RGB LED torchiere",
  "security": [{
    "scheme": "Bearer",
  }],
  "properties": {
    "brightness": {
      "type": "integer",
      "minimum": 0,
      "maximum": 100,
      "writable": true,
      "forms": [ ... ]
    }
  },
  "actions": {
    "fadeIn": {
      "input": {
        "type": "object",
        "properties": {
          "target": {
            "type": "integer",
            "minimum": 0,
            "maximum": 100,
          }
```

No semantic annotations

Media Type application/td+json identifies document as TD and TD context and vocabulary apply as default

WoT Thing Description (TD) – Annotated Form

Explicit context for additional vocabularies

W3C WoT TD vocabulary

Domain-specific vocabulary

Security metadata

Semantic annotations

Protocol Bindings

Domain-specific vocabulary

```
{
  "@context": [
    "https://w3c.github.io/wot/w3c-wot-td-context.jsonld",
    { "iot": "http://iotschema.org/" }
  ],
  "id": "urn:dev:org:32473:1234567890",
  "label": "MyLEDThing",
  "description": "RGB LED torchiere",
  "@type": ["Thing", "iot:LightControl"],
  "security": [{
    "scheme": "OAuth2",
    "token": "PoP",
    "as": "https://authority-issuing.example.org"
  }],
  "properties": {
    "brightness": {
      "type": "integer",
      "minimum": 0,
      "maximum": 100,
      "@type": ["iot:CurrentDimmer"],
      "iot:Unit": "iot:Percent",
      "writable": true,
      "forms": [ ... ]
    }
  },
  "actions": {
```

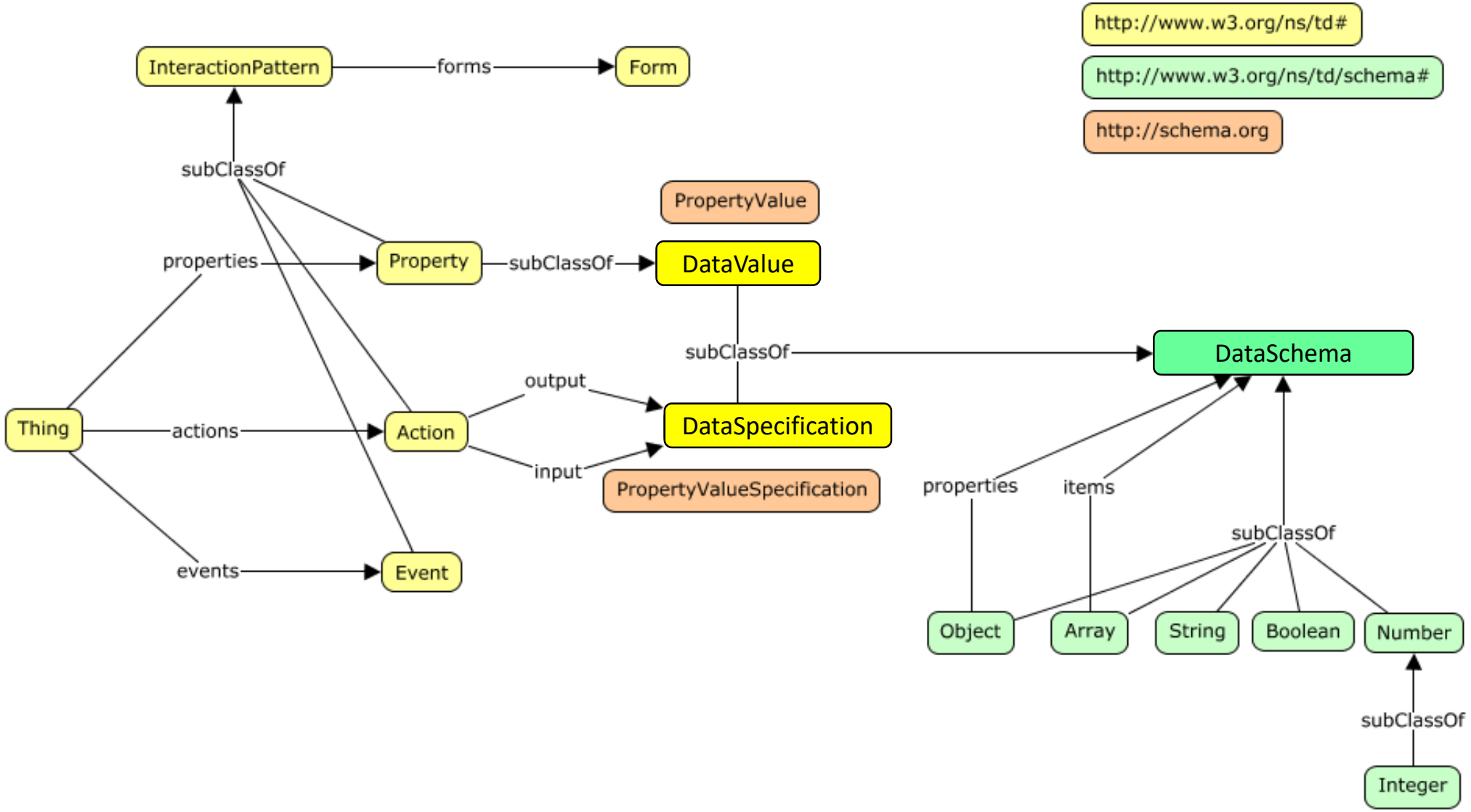
WoT Binding Templates – Instantiated in TDs

Basics to build the request

Deviation from defaults

```
...
"properties": {
  "brightness": {
    ...
    "forms": [
      {                                          // Default: GET to read, PUT to write
        "href": "https://myled.example.com:8080/pwr",
        "mediaType": "application/json"
      }
    ]
  }
},
"actions": {
  "fadeIn": {
    ...
    "forms": [
      {
        "href": "coaps://myled.example.com:5684/pwr",
        "mediaType": "application/ocf+cbor",
        "coap:methodCode": 3,                    // PUT instead of POST to invoke
        "coap:options": [ {
          "coap:optionNumber": 2053,             // OCF-Content-Format-Version
          "coap:optionValue": "1.1.0"
        } ]
      }
```

WoT Thing Description (TD) – Model



WoT Thing Description – Terms

- **@context**
- @type
- id
- name
- description
- support
- base
- security
- properties
- actions
- events
- links

- JSON-LD Context
  - Gives semantic meaning to terms used in JSON document
  - Configures semantic processing (e.g., how to handle object keys)
  - See JSON-LD spec: https://json-ld.org/spec/latest/json-ld/#the-context
- Optional
  - Default points to TD context file
    - https://w3c.github.io/wot/w3c-wot-td-context.jsonld
    - Will be changed to w3.org namespace once finished

- Used to include domain-specific vocabularies
  - Example: `{"iot": "https://iot.schema.org/"}`
    - Note: iotschema.org is the temporary work-in-progress domain
- Default TD context file always applied last
  - Protects against overrise of terms

WoT Thing Description – Terms

- `@context`
- **`@type`**
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- `events`
- `links`

- RDF Type of the Thing
  - Also see JSON-LD specification
  - https://json-ld.org/spec/latest/json-ld/#typed-values
- Optional
  - Default is "`Thing`" from TD core vocabulary

- Used for Capabilities
  - Things can offer multiple Capabilities
  - Come from domain-specific vocabularies
  - See "iot.schema.org " activity for examples
    - Note: iotschema.org is the temporary working domain
- Strict Thing types are discouraged
  - Forcing Things into strict types does not scale
  - Might be required in well-defined, closed systems
  - Strict type can be seen as a very specific "capability"

WoT Thing Description – Terms

- `@context`
- `@type`
- **`id`**
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- `events`
- `links`

- Identifier of the physical/unique Thing
- Mandatory

- Must be a URI
  - Maps to the "`@id`" of the Linked Data node (Thing)
  - Usually a URN is used, e.g., UUID or IMEI URN
  - https://tools.ietf.org/html/draft-arkko-core-dev-urn
- Same ID can occur in multiple TDs
  - Describes same physical/unique Thing (or "asset")
  - TD directly from the device
  - TD registered in a Thing Directory
  - Alternative TD serialization, e.g., different language

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- **`name`**
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- `events`
- `links`

- Human-readable name for the Thing
- Mandatory

- Used for displaying text in a UI or documentation
  - Can be language-dependent
  - One value, changed by serializing alternative TD

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- **`description`**
- `support`
- `base`
- `security`
- `properties`
- `actions`
- `events`
- `links`

- Human-readable description for the Thing
- Optional

- Used for displaying text in a UI or documentation
  - Can be language-dependent
  - One value, changed by serializing alternative TD

- **Discussion**: how to deal with language?
  - Serialize language-specific TDs (cf. Accept-Lang)?
  - Have a map with language idendifiers as key?
  - Model must be able to hold multiple languages to serialize language-specific TDs!

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- **`support`**
- `base`
- `security`
- `properties`
- `actions`
- `events`
- `links`

- Web Link (URI) to TD author or Thing vendor information
- Optional

- Used for contact/responsibility information
  - URI for Web page
  - `mailto` URI
  - Linked Data resource

- **Discussion**: make mandatory?
  - Force authors to fill out for better data quality of TDs

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- **`base`**
- `security`
- `properties`
- `actions`
- `events`
- `links`

- Base URI for optimization to enable short relative URIs in forms
- Optional

- Used for optimization
  - Usually, all Interactions have the same "`href`" prefix
  - Can use relative URIs there, which must be resolved to absolute URIs
- Only one base
  - Must use absolute URIs for alternate endpoints
  - Must use absolute URIs for alternate URI schemes
- Origin URI of the TD usually does not work
  - TDs often come from a Thing Directory, which is on different endpoint
  - TDs can be hosted externally

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- **`security`**
- `properties`
- `actions`
- `events`
- `links`

- Security metadata to interact with Thing
- Optional

- Takes TD security vocabulary
  - `scheme`, e.g., “`basic`”, “`apikey`”, “`oauth2`”
  - Scheme-specific fields, e.g., “`in`”, “`pname`”, “`flow`”

- **Discussion**: make mandatory?
  - No-security must be an explicit choice
  - Security should be used by default
- **Discussion**: vocabulary
  - Currently looked at OpenAPI and a few specific platforms (e.g., OCF)
  - Need more feedback

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- **`properties`**
- `actions`
- `events`
- `links`

- Entry point for Property Interactions
- Optional
  - Thing might not have Properties

- Expose internal state of Things for direct access
  - Always readable (don't use Property, but Action if not)
  - Optionally writable
  - Optionally observable
    (different from Events as state transfer / eventual consistency)
- Object structure with handle as key and Property as value
  - With JSON-LD 1.1 processing, keys map to @id of value node
- Property nodes have JSON Schema terms and syntax
  - https://tools.ietf.org/html/draft-handrews-json-schema-validation
  - Property description can be fed to JSON Schema validator

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- **`properties`**
- `actions`
- `events`
- `links`

- Property vocabulary
  - `label` (optional)
  - `description` (optional)
  - `@type` (optional)
  - `type` (mandatory)
    - any → const, enum
    - `object` → properties, required, dependencies, additionalProperties, …
    - `array` → items, additionalItems, maxItems, minItems, uniqueItems, contains
    - `string` → maxLength, minLength, pattern
    - `number` → minimum, maximum, multipleOf, exclusiveMinimum/-Maximum
    - `integer` → minimum, maximum, multipleOf, exclusiveMinimum/-Maximum
    - `boolean`
  - `writable` (optional – default `false`)
  - `observable` (optional – default `false`)
  - `forms` (mandatory for Interaction)
- Any domain-specific vocabulary can be added

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- **`properties`**
- `actions`
- `events`
- `links`

- Property vocabulary
  - `label` (optional)

- **Discussion**: use term "`name`"?
  - Maps to "`rdfs:label`"
  - Web Linking has term "`title`" (was for documents)
  - Has no identification purpose, so no name, but…
  - Corresponds to HTML's "`name`" (DOM's "`getElementsByName()`")

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- **`actions`**
- `events`
- `links`

- Entry point for Action Interactions
- Optional
  - Thing might not provide Actions

- Modify internal state or actuate or process data
  - State that is not exposed directly (no Property)
  - Write only, read multiple, etc.
- Deal with intended vs actual state
  - Physical processes that take time
  - State that changes over time
- Data schema for input and output of the Action
  - input/output node can be fed to JSON Schema validator

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- **`actions`**
- `events`
- `links`

- Action vocabulary
  - `label` (optional)
  - `description` (optional)
  - `@type` (optional)
  - input (optional)
    - data schema in JSON Schema syntax, see Property
  - output (optional)
    - data schema in JSON Schema syntax , see Property
  - forms (mandatory)

- Any domain-specific vocabulary can be added

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- **`events`**
- `links`

- Entry point for Event Source Interactions
- Optional
  - Thing might not emit Events

- Push messages from Things
  - May be triggered through conditions that are not exposed as state
  - Not state, but state transitions (events) are communicated
  - In practice best effort consistency applies
- Events directly have data schema in JSON Schema syntax
  - Event source description can be fed to JSON Schema validator

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- **`events`**
- `links`

- Event vocabulary
  - `label` (optional)
  - `description` (optional)
  - `@type` (optional)
  - type (mandatory, data schema in JSON Schema syntax)
  - forms (mandatory)

- **Discussion**: have input and output?
  - Some subscription mechanisms need parameters such as filters
  - "events" describe event **sources**, not data instances, hence they are similar to Actions with their data specifications!

WoT Thing Description – Terms

- `@context`
- `@type`
- `id`
- `name`
- `description`
- `support`
- `base`
- `security`
- `properties`
- `actions`
- `events`
- **`links`**

- Web Links to other Things or additional metadata
- Optional

- Resources in “links” are fetchable
  - Opposed to Linked Data predicates (e.g., domain-specific vocabulary)
  - `href` field for URI
- Provide relations to other Things
  - `rel` gives relation type, e.g., `contains`, `partOf`, `controls`
  - `mediaType` is `application/td+json`
- Provide additional metadata
  - Serves as extension point (cf. CSS for HTML)

WG changed from the “JSON-LD 1.0 based TD” to the “Simplified TD”

NEW SCRIPTING API

WoT WG Changed to “Simplified TD”

OLD

```javascript
let thing = WoT.produce({
    name: "counter"
    // no support for
    // more metadata
});

console.log("Created thing " + thing.name);

thing.addProperty(
  {
    name : "count",
    schema : '{ "type": "number"}',
    // no support for
    // custom metadata
    observable : true,
    writeable : true,
    value : 0
  });

thing.addAction({ name: "increment" });
thing.setActionHandler(
  "increment",
  () => {
    return thing.readProperty("count").then(res=>{
      thing.writeProperty("count", ++res);
    });
  });
```

NEW

```javascript
let thing = WoT.produce({
    name: "counter",
    description: "counter example Thing",
    "@context": { "iot": "http://iotschema.org/" }
  });

  console.log("Created thing " + thing.name);

  thing.addProperty(
    "count",
    {
      type: "integer",
      description: "current counter value",
      "iot:Custom": "example annotation",
      observable: true,
      writeable: true
    },
    0);

  thing.addAction("increment");
  thing.setActionHandler(
    "increment",
    () => {
      return thing.properties["count"].get().then(res=>{
        thing.properties["count"].set(++res);
      });
    });
```

WoT WG Changed to “Simplified TD”

OLD

```
WoT.fetch("http://localhost:8080/counter").then(td => {

  let thing = WoT.consume(td);

  thing.readProperty("count")
    .then(res => {
      console.info("count value is", res);
    })
    .catch(err => { console.error(err); });

  thing.invokeAction("increment");
```

NEW

```
WoT.fetch("http://localhost:8080/counter").then(td => {

  let thing = WoT.consume(td);

  thing.properties.count.get()
    .then(res => {
      console.info("count value is", res);
    })
    .catch(err => { console.error(err); });

  thing.actions.increment.run();
```

Contact

Dr. Matthias Kovatsch

Senior Research Scientist

Siemens AG

CT RDA IOT EWT-DE

matthias.kovatsch@siemens.com