

W3C Web of Things Status and Applications

Michael McCool

11 January 2023

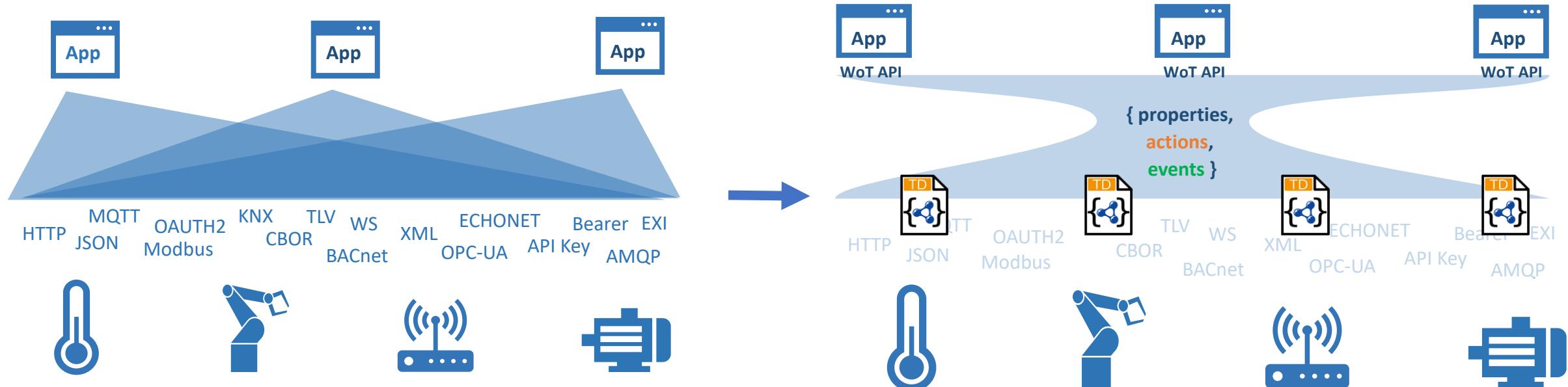
IEEE CCNC 2023 - IIWoT Workshop

Outline

- What is WoT?
 - Applying and extending web standards for IoT
 - Descriptive interoperability: Thing Descriptions
 - Finding Thing Descriptions: Discovery
 - Enhancing Interoperability: Profiles
 - Use Cases and Requirements
- Recent Activity
 - Testfest/Plugfest
 - Commercial Applications
 - Open Source Projects
 - Other Engagements
- Discussion
 - Gaps and Future Work

W3C Web of Things (WoT)

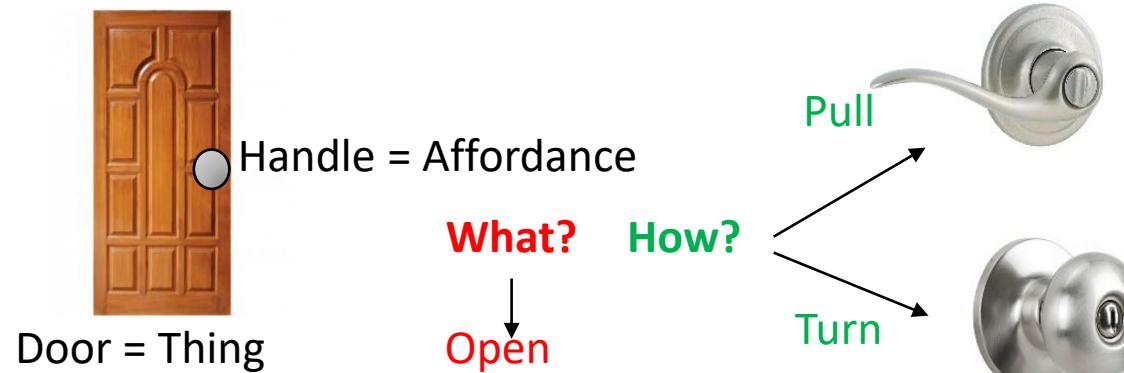
- W3C Working Group goal: Adapting web technologies to IoT
- Already published: Thing Description (TD) metadata format
 - TD describes the available interactions (network API) of a Thing
- New deliverables in progress, including Discovery and Profiles
 - How does a potential consumer obtain the TD for a Thing?
 - What constraints on TDs are appropriate for best practices and interoperability?



Descriptive Interoperability: TDs

WoT Architecture

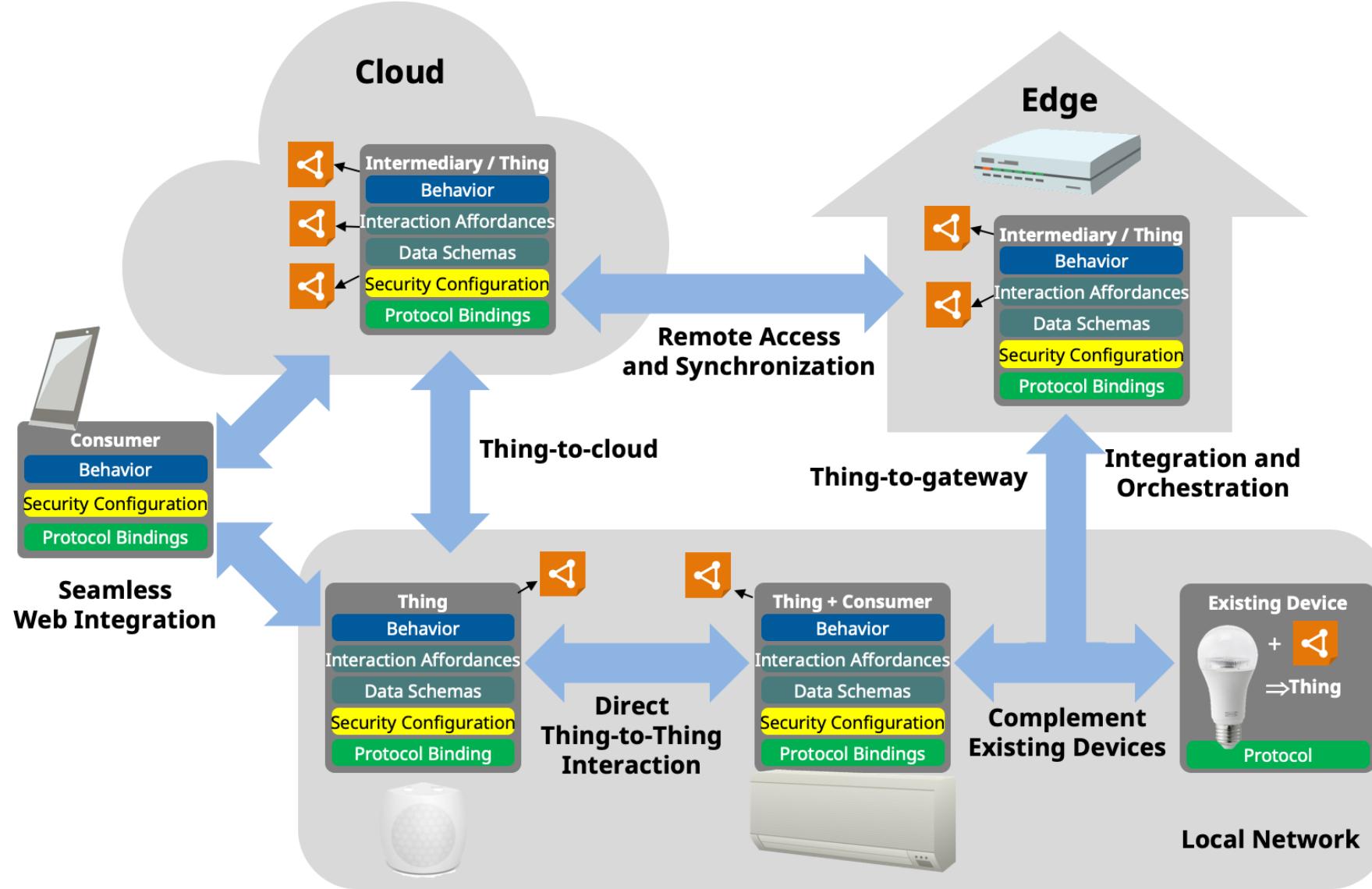
- Constraints
 - "Things" must have a TD
 - Must use URIs, IANA media types, etc.
- Thing Description Affordances
 - Describes **WHAT** the possible choices are
 - Describes **HOW** to interact with the Thing



WoT Thing Description (TD)

```
{
  "@context": [
    "https://www.w3.org/2022/wot/td/v1.1",
    { "iot": "http://iotschema.org/" }
  ],
  "id": "urn:dev:org:32473:1234567890",
  "title": "MyLEDThing",
  "description": "RGB LED torchiere",
  "@type": [ "Thing", "iot:Light" ],
  "securityDefinitions": {
    "default": { "scheme": "bearer" }
  },
  "security": [ "default" ],
  "properties": {
    "brightness": {
      "@type": [ "iot:Brightness" ],
      "type": "integer",
      "minimum": 0,
      "maximum": 100,
      "forms": [ ... ]
    }
  },
  "actions": {
    "fadeIn": {
      ...
    }
  }
}
```

Usage Patterns Overview



Deliverables

New/Updated Normative Documents:

- Architecture 1.1: <https://github.com/w3c/wot-architecture>
- Thing Description 1.1: <https://github.com/w3c/wot-thing-description>
- Discovery: <https://github.com/w3c/wot-discovery>
- Profiles: <https://github.com/w3c/wot-profile>

New/Updated Informative Documents:

- Binding Templates: <https://github.com/w3c/wot-binding-templates>
- Scripting API: <https://github.com/w3c/wot-scripting-api>
- Use Cases and Requirements: <https://github.com/w3c/wot-usecases>

Community Resources:

- Web Site: <https://www.w3.org/WoT/>

Groups

W3C Web of Things Interest Group (WoT IG)

- Exploratory and Experimental work

W3C Web of Things Working Group (WoT WG)

- Specification Development

W3C Web of Things Community Group (WoT CG)

- English-language community development

W3C Web of Things Japan Community Group (WoT-JP CG)

- Japanese-language community development

WoT Community Group

Goal: Build a community around the Web of Things specifications.

Activities:

- Increase awareness of the WoT specifications
- Collect use cases from the wider community
- Collect implementation experience and references to technologies from the wider community
- Facilitate the implementation of the specifications by providing guidelines and tutorials
- Organize community Meetups

W3C WoT CG Meetups

The Web of Things **implementers** and **enthusiasts** gather together to present their stories and ideas around the standards

- Open to the public
- Usually online, but we are also planning events in real life
- Might have a precise theme or scope
- Occasion to reach a wider community
- Gather feedback and answer questions
- Have a nice time together

WoT-JP Community Group

1. Outreach
 - To promote WoT with SDOs, Companies, Communities, etc
2. Deployment
 - To Create Libraries, Tools, Documentations for development
3. Use Cases
 - To Discover industrial Use Cases
4. Translation
 - To translate documentations from English to Japanese and from Japanese to English

WoT-JP CG

W3C WoT-JP CG

<https://www.w3.org/community/wot-jp/>

Chairs

Tomoaki Mizushima (Internet Research Institute, Inc.)

Kunihiro Toumura (Hitachi, Ltd.)

Use Cases Task Force	Outreach Task Force	Deployment Task Force	Translation Task Force
<p>Moderator: Tomoaki Mizushima (Internet Research Institute)</p> <p>Objectives:</p> <ul style="list-style-type: none"> - Discover industrial Use Cases <p>https://github.com/w3c/wot-jp-cg/tree/main/TF/Usecases</p>	<p>Moderator: Daisuke Ajitomi (Toshiba)</p> <p>Objectives:</p> <ul style="list-style-type: none"> - To promote WoT deployment with SDOs, Companies, Communities, etc. <p>https://github.com/w3c/wot-jp-cg/tree/main/TF/Outreach</p>	<p>Moderator: Kunihiro Toumura (Hitachi)</p> <p>Objectives:</p> <ul style="list-style-type: none"> - To Create Libraries, Tools, Documentations for development. <p>https://github.com/w3c/wot-jp-cg/tree/main/TF/Deployment</p>	<p>Moderator(tentative): Kazuyuki Ashimura (W3C/Keio)</p> <p>Objectives:</p> <ul style="list-style-type: none"> - English to Japanese - Japanese to English <p>https://github.com/w3c/wot-jp-cg/tree/main/TF/Translation</p>

Use Cases and Requirements

Informative Deliverable: <https://github.com/w3c/wot-usecases>

Purpose and Process:

- Identify specific use cases
- Identify application domains
 - Collect use cases from other W3C groups
 - Collect use cases from other stakeholders and SDOs
- Identify usage patterns
 - For example, hubs, proxies, automation, etc.
- Identify relevant technologies
 - For example, edge computing, digital twins, etc.

→ Extract common requirements to drive current and future work

Profiles

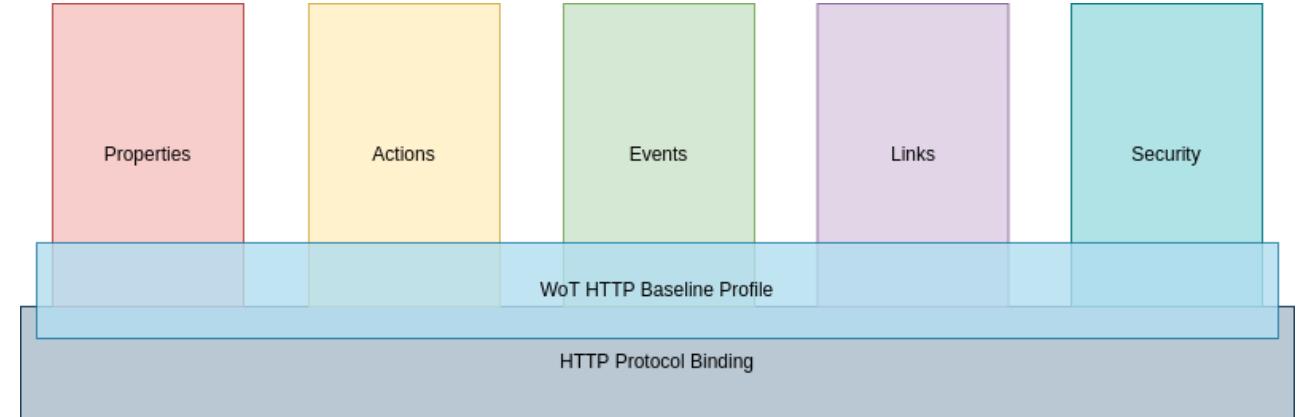
Set of constraints to:

- Improve interoperability
- Define best practices

- ***Prescriptive***

- Why:

- TDs are descriptive
 - Some devices that need to be described do not follow best practices, e.g. for security
- TDs are extensible
 - To interoperate device manufacturers need to know in advance what to expect

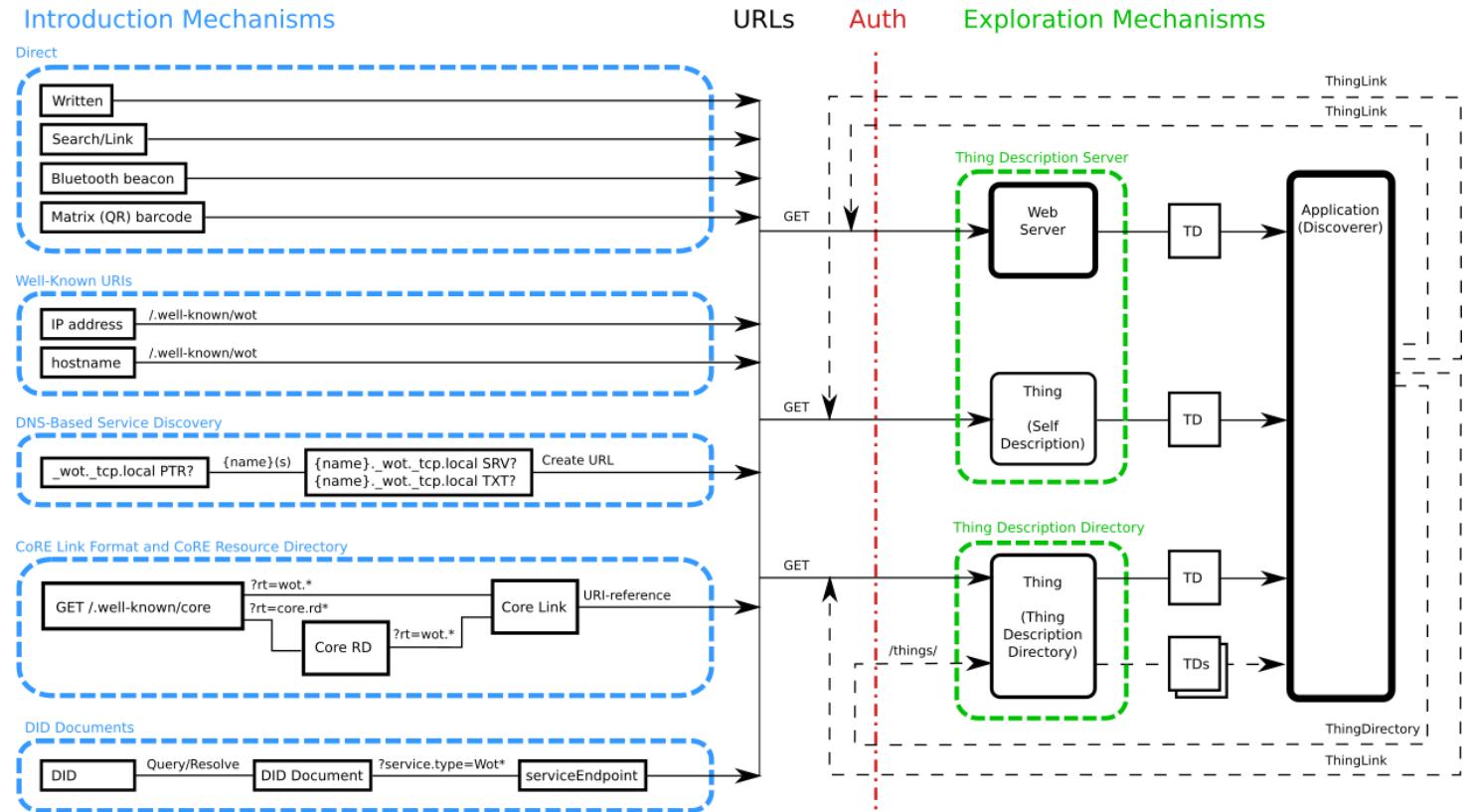


- Currently focused on HTTP Baseline Profile and two sub-profiles for SSE and WebHook Event mechanisms
- TDs satisfying profile set "profile" member and must follow constraints of profile
- Things and Consumers that implement profile also need to satisfy a set of other assertions

Discovery

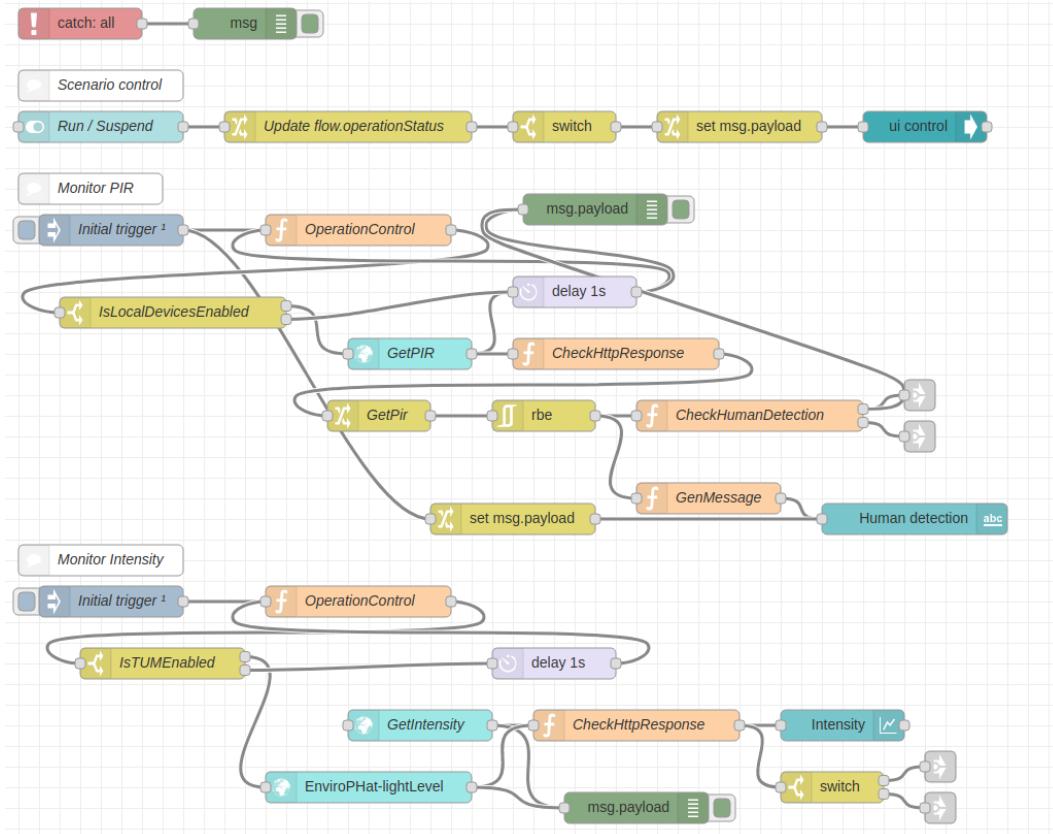
Goal: Obtain TD of interest

- Not limited to local network
- Scalable to many TDs
- Need to preserve privacy
- Phased access:
 1. Introduction: open
 2. Exploration: controlled
- Searchable via JSON Path, XPath, or SPARQL
- Future work:
 - Find "nearby" Things using geospatial data



Orchestration

Node-RED/node-gen



node-wot/Scripting API

```
WoTHelpers.fetch( "coap://localhost:5683/counter" ).then( async (td) => {  
  // using await for serial execution (note 'async' in then() of fetch())  
  try {  
    const thing = await WoT.consume(td);  
    console.info( "==== TD ===" );  
    console.info(td);  
    console.info( "=====*" );  
  }
```



```
// read property #1  
const read1 = await thing.readProperty( "count" );  
console.info( "count value is" , await read1.value());  
  
// increment property #1 (without step)  
await thing.invokeAction( "increment" );  
const inc1 = await thing.readProperty( "count" );  
console.info( "count value after increment #1 is" , await inc1.value());  
  
// increment property #2 (with step)  
await thing.invokeAction( "increment" , {step: 3});  
const inc2 = await thing.readProperty( "count" );  
console.info( "count value after increment #2 (w/ step 3) is" , await inc2.value());  
  
// decrement property  
await thing.invokeAction( "decrement" , undefined, {  
  formIndex: getFormIndexForDecrementWithCoAP(thing);  
});  
const dec1 = await thing.readProperty( "count" );  
console.info( "count value after decrement is" , await dec1.value());  
  
} catch(err) {  
  console.error( "Script error:", err);  
}  
}).catch( (err) => { console.error( "Fetch error:", err);});
```

Recent Activity

- Testing
 - <https://github.com/w3c/wot-testing/tree/main/events>
- Applications and Systems
 - Takenaka, Netzo, Siemens, Deutsch Telekom, Ditto, ...
- Discovery
 - WoT Hive, LogiLab, Fraunhofer LinkSmart, TinyIoT, Zion, Node-RED, ...
- Relationships
 - JSON Path, CoreRD, DID, COSE/JOSE, ASDF/OneDM, OPC UA, Microsoft DTDL, OGC, IEEE, ...
- Under Discussion:
 - New Charter: New Deliverables, Updates to existing specifications, Liaisons
 - Geolocation, Onboarding, Historical data: [proposals/deliverable-proposals](#)

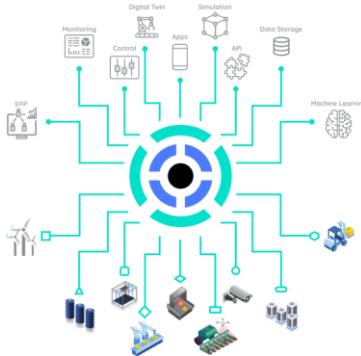
Commercial Applications



<https://www.takenaka.co.jp/news/2021/05/02/>

Takenaka Corporation

- CGLL Platform - BIM



<https://netzo.io/>

Netzo

- IoT Data Hub
- Dashboards



<https://www.nhk.or.jp/hybridcast/online/>

NHK

- Hybridcast Integration



<https://www.smarthome.de/magentazuhause-app>

Deutsche Telekom AG

- Smart Home
- App/Hub/Cloud

krelian

<https://krellian.com/>

Krellian

- Smart Building Management
- Digital Twins



<https://new.siemens.com/global/en/products/buildings/automation/designo.html>

<https://www.evosoft.com/en/digitalization-offering/saywot/>

<https://www.evosoft.com/en/application-of-the-w3c-web-of-things-standard-in-the-wunsiedel-hydrogen-generation-plant/>

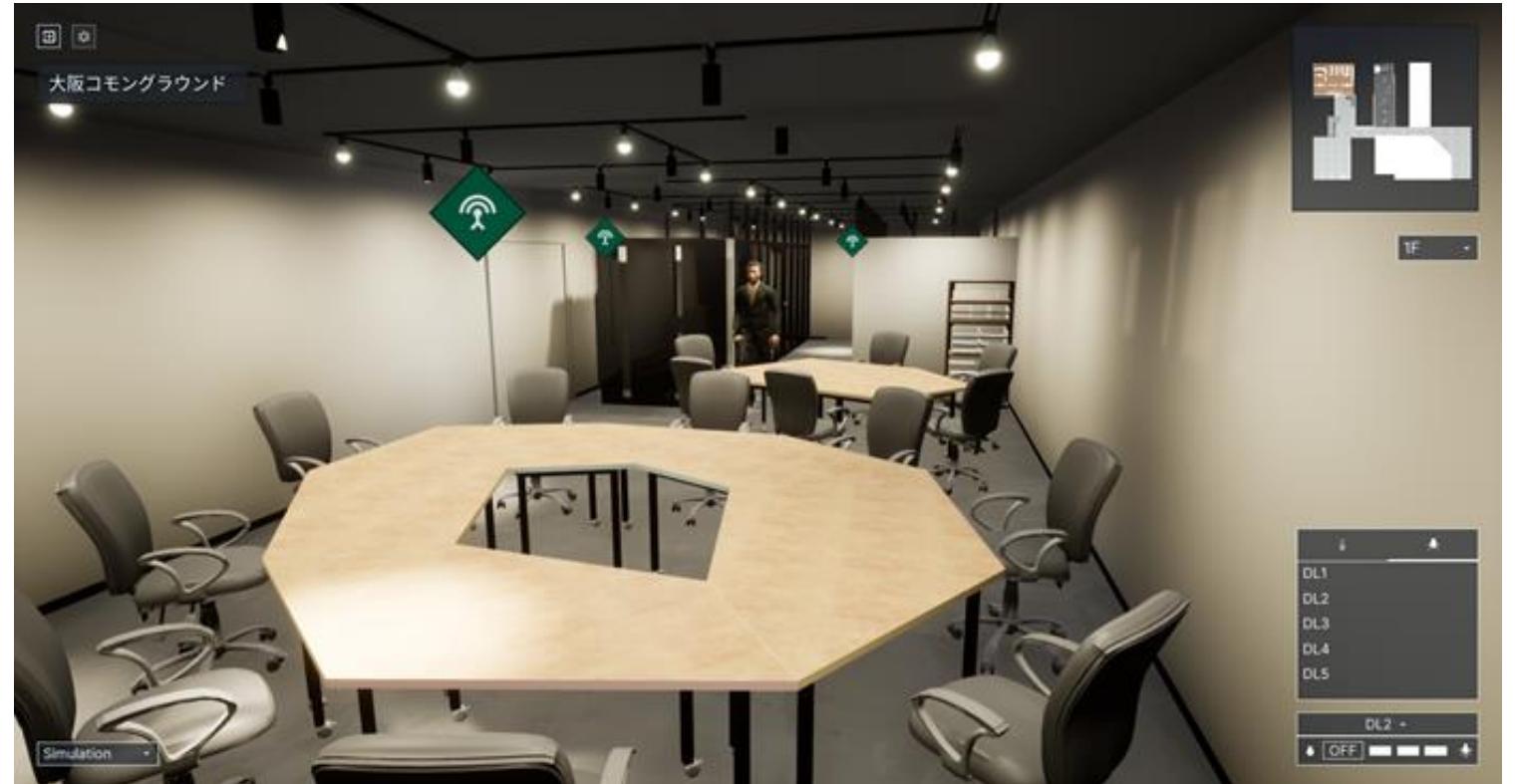
Siemens AG

- Designo CC – BIM
- Asset Performance Suite
- Say WoT! (Evosoft)
- Wunsiedel (H₂ Generation plant)

Takenaka Corporation

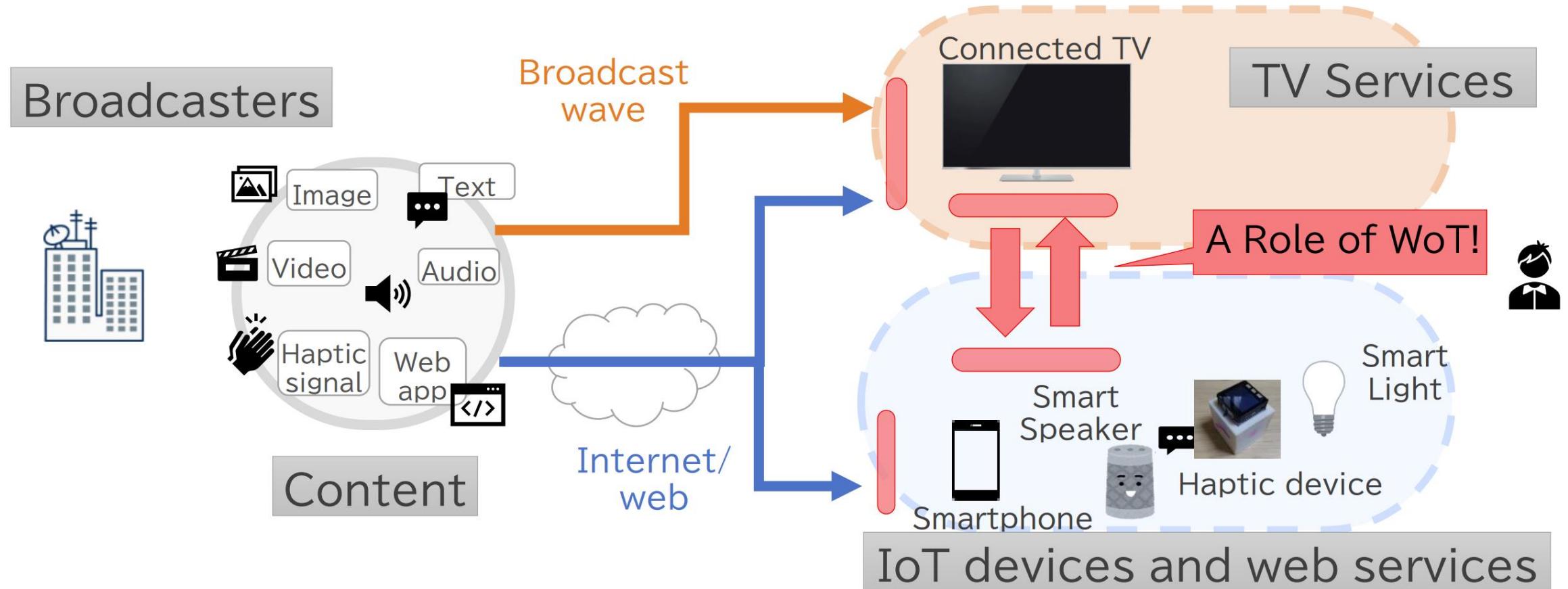
- Smart Building Management
- CGLL Platform:

<https://www.cgll.osaka/>



NHK Hybridcast

- Broadcasters will deliver content with IoT devices.
- We expect WoT to connect things across TV and Web worlds.



NHK Hybridcast



- A TV plays a soccer program.
- An air cleaner is noisy in turbo mode.
- Users want quietness in exciting scenes.
- TV can receive Event Messages related to a program via broadcasting wave.

NHK Hybridcast

Hybridcast Connect TV
(LG OLED42C2PJA)

WoT node to listen
Hybridcast Connect Event

Node-RED
App



WoT node to
control air cleaner

Node-RED
dashboard UI

Air cleaner
emulator

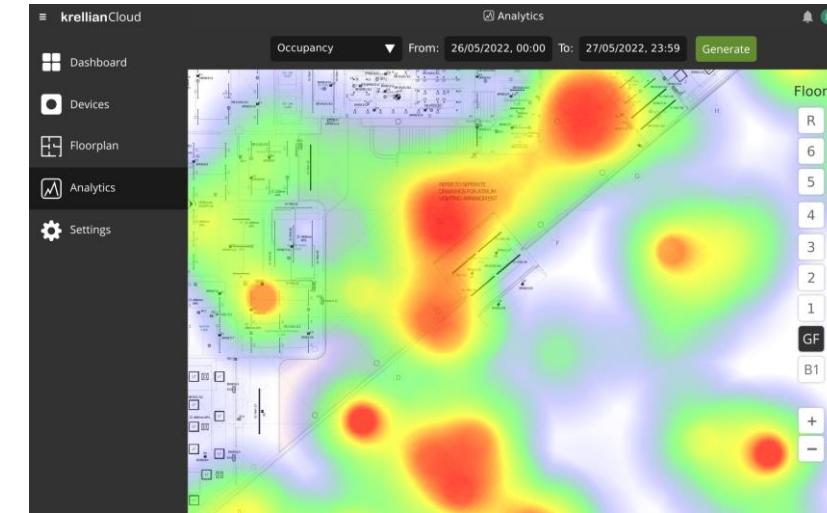
Krellian

Krellian provides a commercial smart building platform, built on the web of Things.



krellianHub

Consolidates multi-vendor building management systems into a single standardised interface.



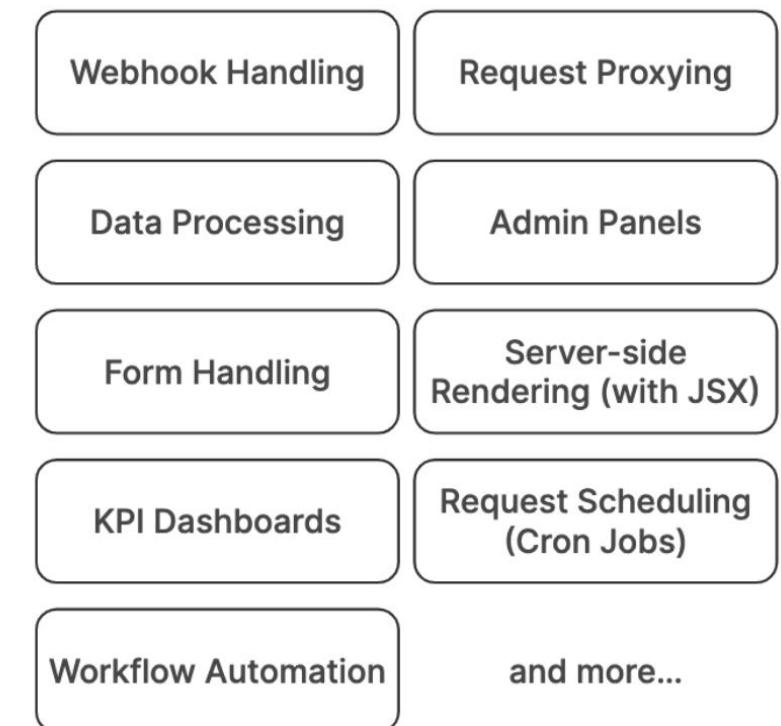
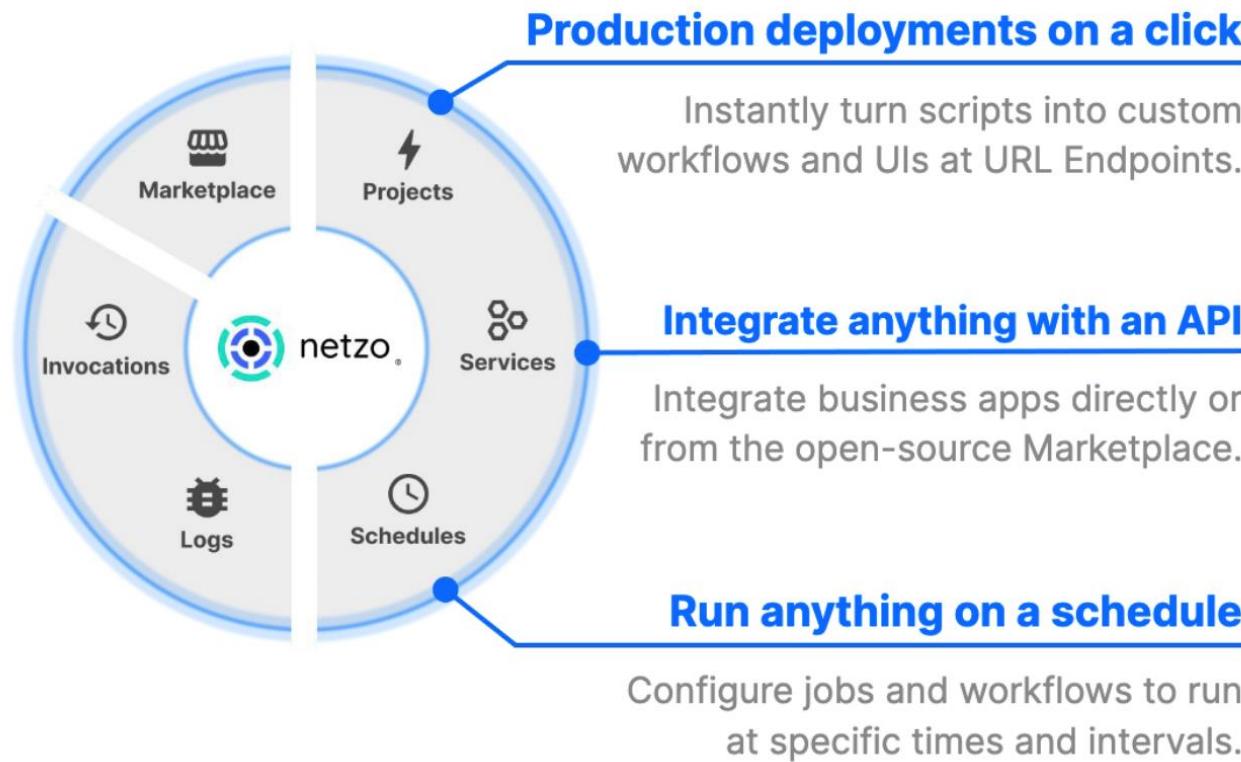
krellianCloud

Creates a digital twin of your building to model how it's being used and identify potential optimisations.

krellian.com

Netzo

Deploy JavaScript and TypeScript to URL endpoints instantly. Connect essential APIs, automate processes and build tools faster, without managing infrastructure.



Netzo

Marketplace

Marketplace items are ready-made solutions for specific use-cases. Anything you find here is public and you are free to fork into any or your Workspaces. When you fork an items, a copy is created so you can go ahead and make changes. Forked items will count normally for your Workspace usage.

TYPE

- All
- Services
- Projects

STATUS

- All
- Stable
- Beta
- Alpha
- Requested
- Deprecated

CATEGORY

- All
- Core
- Community
- Enterprise

Filter by name

Aa Request Contribute

					
ActiveCampaign <small>service</small> Service for the ActiveCampaign...	Bar Chart with Billboard <small>project</small> An HTTP server that serves a ...	Bigin <small>service</small> Service for the Bigin API	Clarifai <small>service</small> Service for the Clarifai API	Cloudflare <small>service</small> Service for the Cloudflare API	Discord <small>service</small> Service for the Discord API
<small>crm marketing</small>	<small>example chart</small>	<small>crm</small>	<small>artificial-intelligence machine-learning</small>	<small>infrastructure</small>	<small>social communications</small>
					
Enode <small>service</small> Service for the Enode API	Enphase <small>service</small> Service for the Enphase API	Ergast F1 <small>service</small> Service for the Ergast F1 API	Facturama <small>service</small> Service for the Facturama API	Fathom Analytics <small>service</small> Service for the Fathom Analyti...	FaunaDB <small>service</small> Service for the FaunaDB Graph...
<small>iot energy solar</small>	<small>iot energy solar</small>	<small>mock</small>	<small>billing</small>	<small>analytics</small>	<small>database</small>
					
Get Client IP Address <small>project</small> An HTTP server that responds ...	GitHub <small>service</small> Service for the GitHub API	Google AppSheet <small>service</small> Service for the Google AppShe...	Google Sheets <small>service</small> Service for the Google Sheets ...	Handling Form Submis... <small>project</small> An HTTP server that serves a ...	Hashnode <small>service</small> Service for the Hashnode API
<small>example json</small>	<small>infrastructure</small>	<small>productivity</small>	<small>productivity google</small>	<small>example form json</small>	<small>social blog</small>

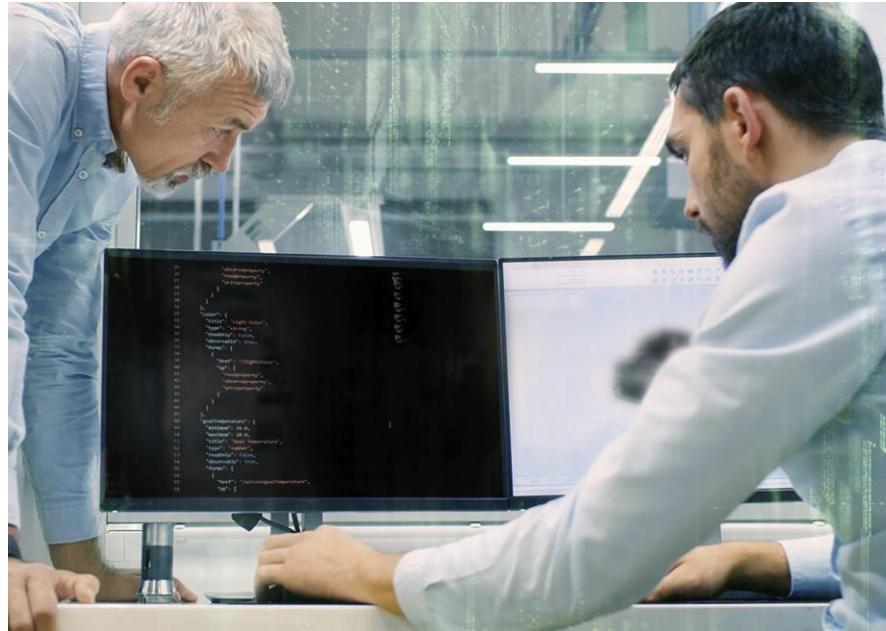
Siemens – Desigo CC

Building Information Management (BIM)

- View status in context of 3D model
- Security
- Energy Efficiency
- Maintenance management



Siemens/EvoSoft – SayWoT!



SayWoT!

<https://www.evosoftware.com/en/digitalization-offering/saywot/>

Thing Models, Thing Descriptions, Protocol adapters...



Wunsiedel H₂ Generation Plant

<https://www.evosoftware.com/en/application-of-the-w3c-web-of-things-standard-in-the-wunsiedel-hydrogen-generation-plant/>

Application of SayWoT to cloud integration

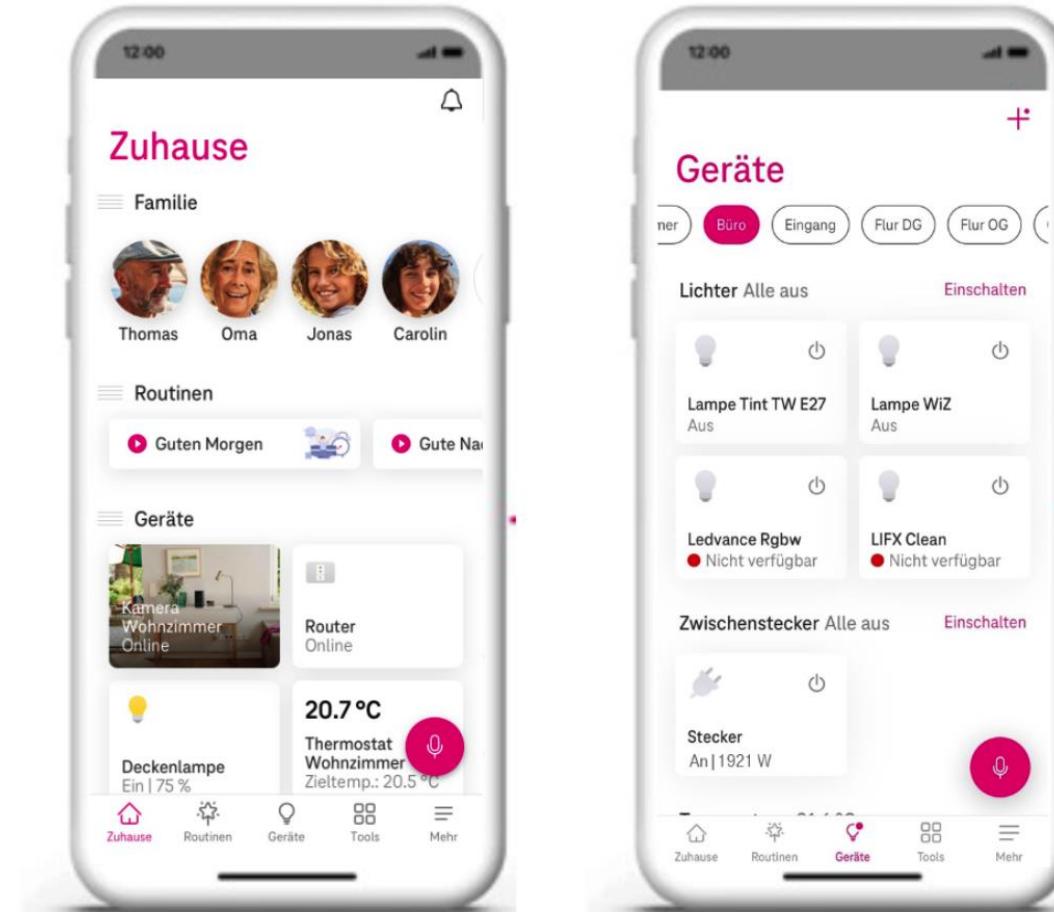
Deutsch Telekom - MagentaZuhause



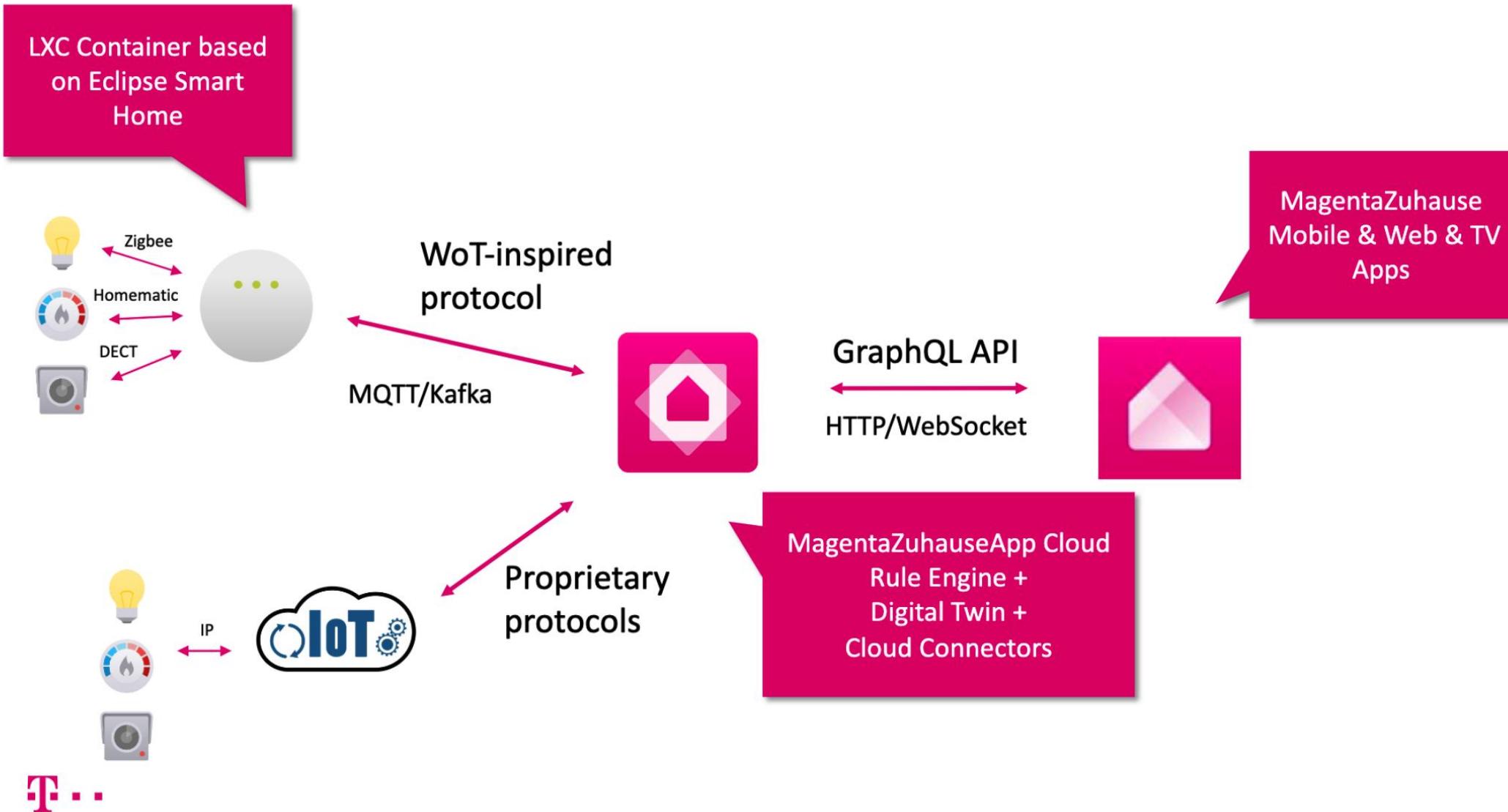
Good & safe family life
 Take care of your loved ones and manage everyday family coordination with ease.



Smarter home
 Gain security and comfort for your home.



Deutsch Telekom - MagentaZuhause



Open Source Projects



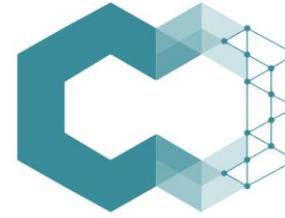
<https://webthings.io/>

- Smart Home Hub
- Reusable Software Components



<https://www.thingweb.io/>

- node-wot Scripting API
- W3C WoT Reference Implementation



<https://www.eclipse.org/ditto/2022-03-03-wot-integration.html>

- Eclipse (Bosch, Siemens, ...)
- Digital twin



<https://www.sifis-home.eu/>

- Horizon 2020 Project
- Trustworthy Connected Home

ThingWeb/node-wot

- Official reference implementation for W3C WoT interaction model
- Follows the WoT Scripting API specification
- Thing Description parser and serializer, protocol bindings, runtime system for scripting applications, based on Node.js/TypeScript
- Validation tools

```

WoTHelpers.fetch( "coap://localhost:5683/counter" ).then( async (td) => {
  // using await for serial execution (note 'async' in then() of fetch())
  try {
    const thing = await WoT.consume(td);
    console.info( "=== TD ===" );
    console.info(td);
    console.info( "===========" );

    // read property #1
    const read1 = await thing.readProperty( "count" );
    console.info( "count value is" , await read1.value());

    // increment property #1 (without step)
    await thing.invokeAction( "increment" );
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    const inc2 = await thing.readProperty( "count" );
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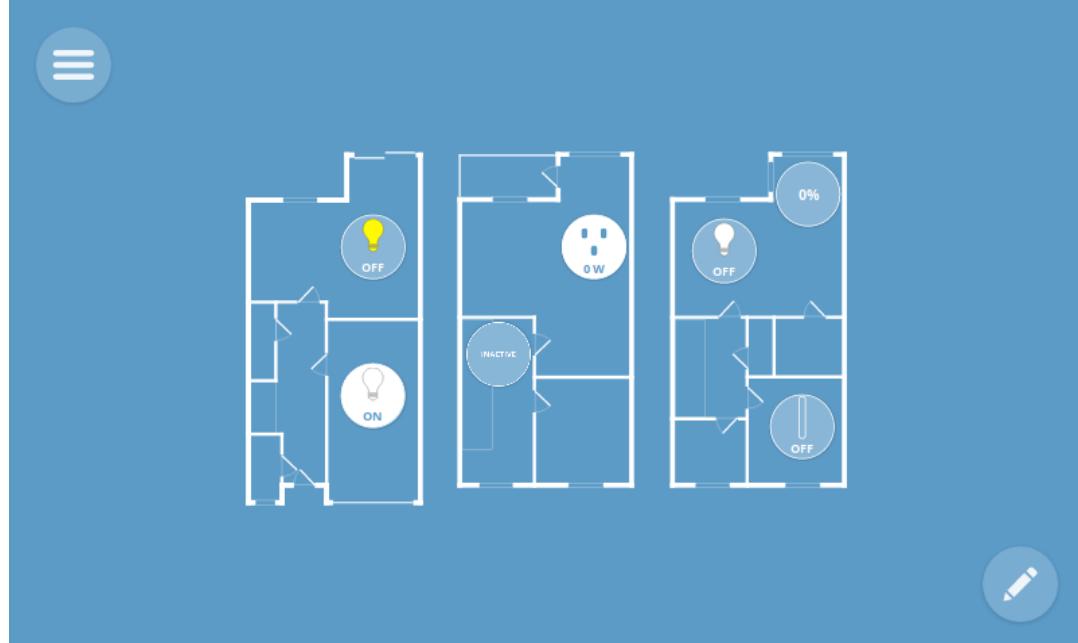
    // decrement property
    await thing.invokeAction( "decrement", undefined, {
      formIndex: getFormIndexForDecrementWithCoAP(thing);
    });
    const dec1 = await thing.readProperty( "count" );
    console.info( "count value after decrement is" , await dec1.value());

  } catch(err) {
    console.error( "Script error:", err);
  }
}).catch( (err) => { console.error( "Fetch error:", err); });

```

WebThings

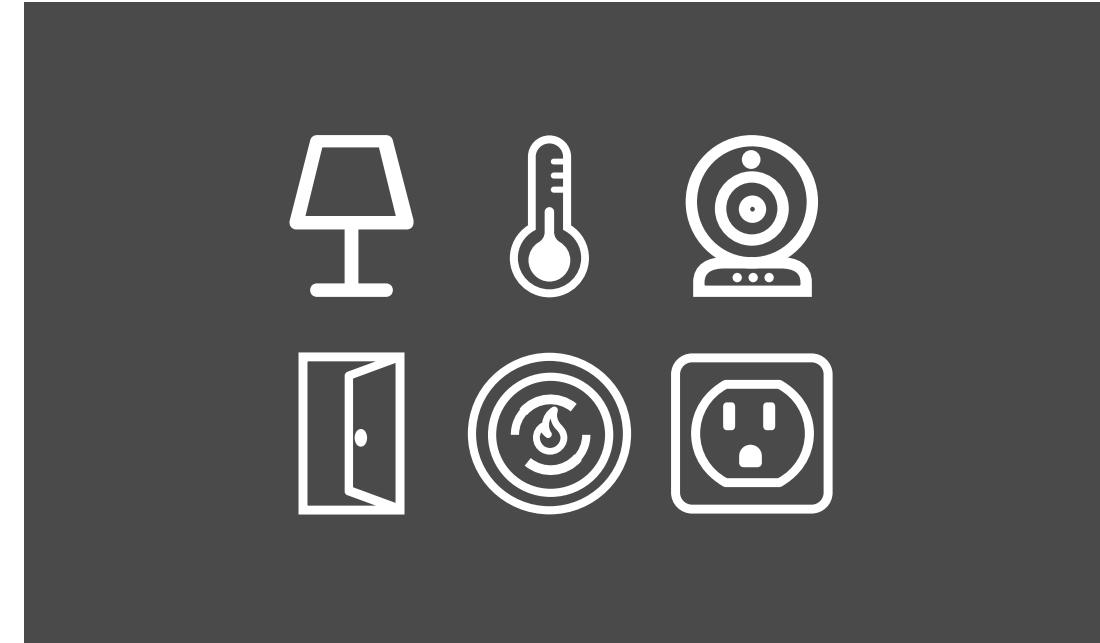
WebThings is an open platform for monitoring and controlling devices over the web.



WebThings Gateway

A software distribution for smart home hubs,
focused on privacy, security and interoperability.

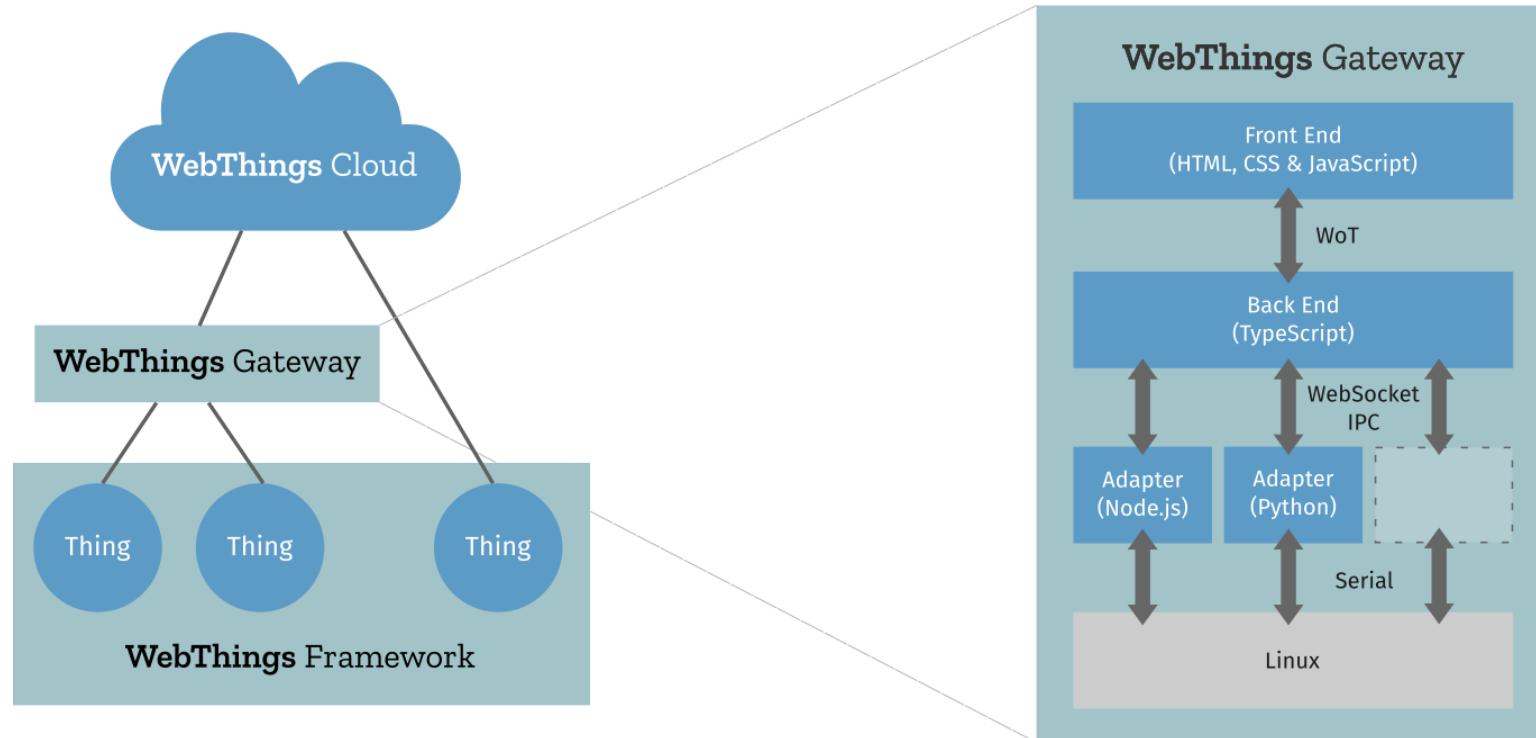
webthings.io



WebThings Framework

A collection of re-usable software components to help
developers build their own web things

WebThings



WoT Thing Description 1.1

✓ IMPLEMENTED

WoT Discovery 1.0

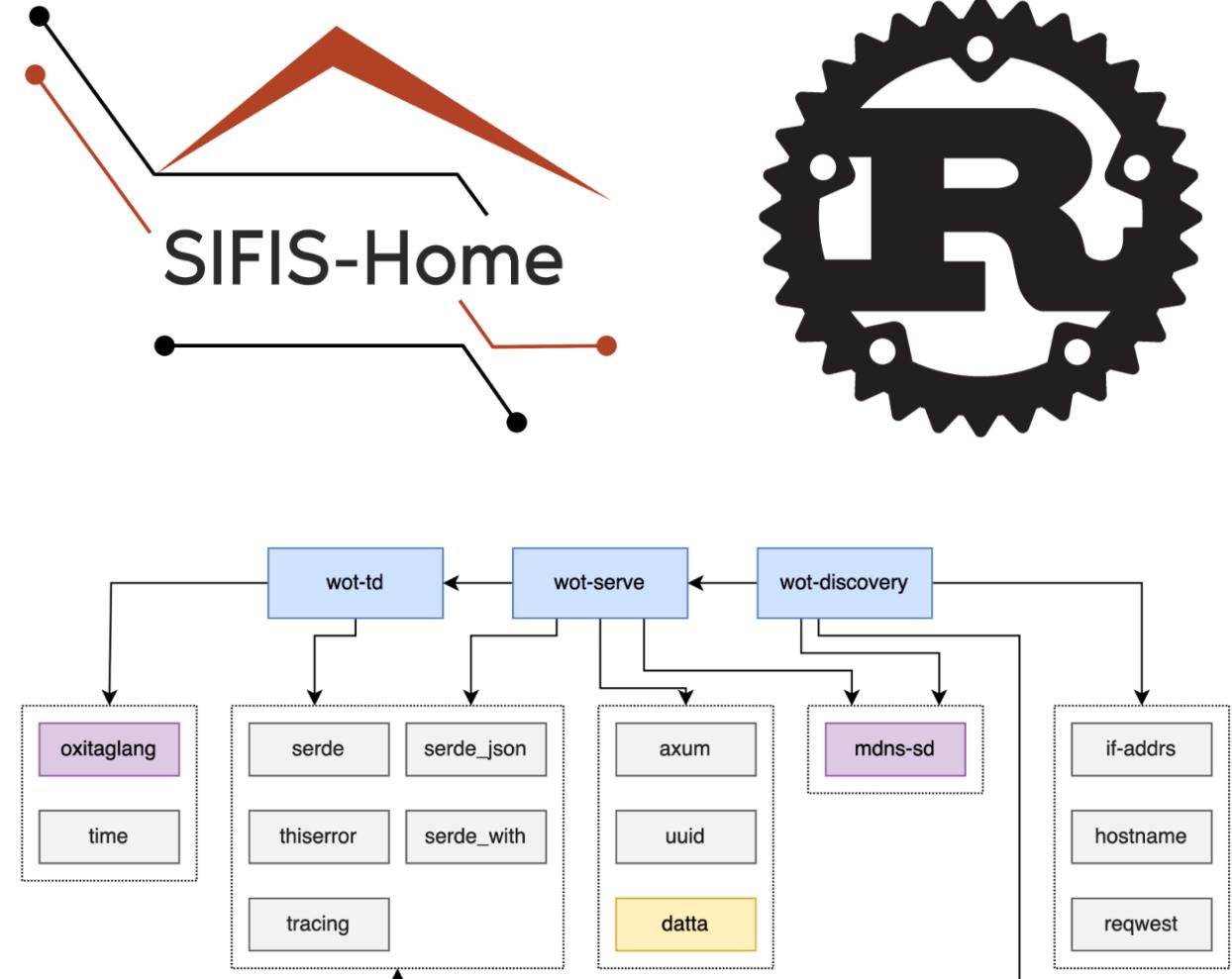
○ IN PROGRESS

WoT Profile 1.0

○ IN PROGRESS

SIFIS Home

- Horizon 2020 Project
 - <https://www.sifis-home.eu/>
- Secure and trustworthy full-stack internet of things for Smart Home
- Open Standards
- Using Rust to avoid memory bugs
- wot-rust implementation



SIFIS Home

```
.property("on", lbl {
    b.finish_extend_data_schema()
    .attype("OnOffProperty")
    .title("On/Off")
    .description("Whether the lamp is turned on")
    .form(lbl {
        b.href("/properties/on")
        .http_get(get_on_property)
        .http_put(put_on_property)
        .op(wot_td::thing::FormOperation::ReadProperty)
        .op(wot_td::thing::FormOperation::WriteProperty)
    })
    .bool()
})
.property("brightness", lbl {
    b.finish_extend_data_schema()
    .attype("BrightnessProperty")
    .title("Brightness")
    .description("The level of light from 0-100")
    .form(lbl {
        b.href("/properties/brightness")
        .http_get(get_brightness_property)
        .http_put(put_brightness_property)
        .op(wot_td::thing::FormOperation::ReadProperty)
        .op(wot_td::thing::FormOperation::WriteProperty)
    })
    .integer()
    .minimum(0)
})
```

```
"properties": {
    "brightness": {
        "@type": "BrightnessProperty",
        "description": "The level of light from 0-100",
        "forms": [
            {
                "href": "/properties/brightness",
                "op": [
                    "readproperty",
                    "writeproperty"
                ]
            }
        ],
        "maximum": 100,
        "minimum": 0,
        "readOnly": false,
        "title": "Brightness",
        "type": "integer",
        "unit": "percent",
        "writeOnly": false
    },
    "on": {
        "@type": "OnOffProperty",
        "description": "Whether the lamp is turned on",
        "forms": [
            {
                "href": "/properties/on",
                "op": [
                    "readproperty",
                    "writeproperty"
                ]
            }
        ]
    }
}
```

```
Running `target/debug/lamp`
2022-09-19T16:39:22.278330Z DEBUG mdns_sd::service_daemon: new socket bind to 0.0.0.0:5353
2022-09-19T16:39:22.278714Z DEBUG lamp: listening on 0.0.0.0:3000
2022-09-19T16:39:22.299215Z DEBUG mdns_sd::service_daemon: register service ServiceInfo { ty_domain: "_wot._tcp.local.", sub_domain: None, fullname: "mybf2faf3139540509dbecfb1207666c._wot._tcp.local.", server: "enyo.lan.local", addresses: [192.168.1.212], port: 3000, host_ttl: 120, other_ttl: 4500, priority: 0, weight: 0, properties: {"td": "/.well-known/wot", "type": "Thing"}, last_update: 1663605562278 }
2022-09-19T16:39:22.299344Z DEBUG mdns_sd::service_daemon: broadcast service mybf2faf3139540509dbecfb1207666c._wot._tcp.local.
```

```
▶ dns-sd -B _wot._tcp
Browsing for _wot._tcp
DATE: ---Mon 19 Sep 2022---
18:40:34.085 ...STARTING...
Timestamp      A/R      Flags if Domain          Service Type      Instance Name
18:40:34.086   Add       3   6 local.          _wot._tcp.
18:40:34.086   Add       2   6 local.          _wot._tcp.
mybd729b6943214caeb527e15626162967
mybf2faf3139540509dbecfb1207666c
```

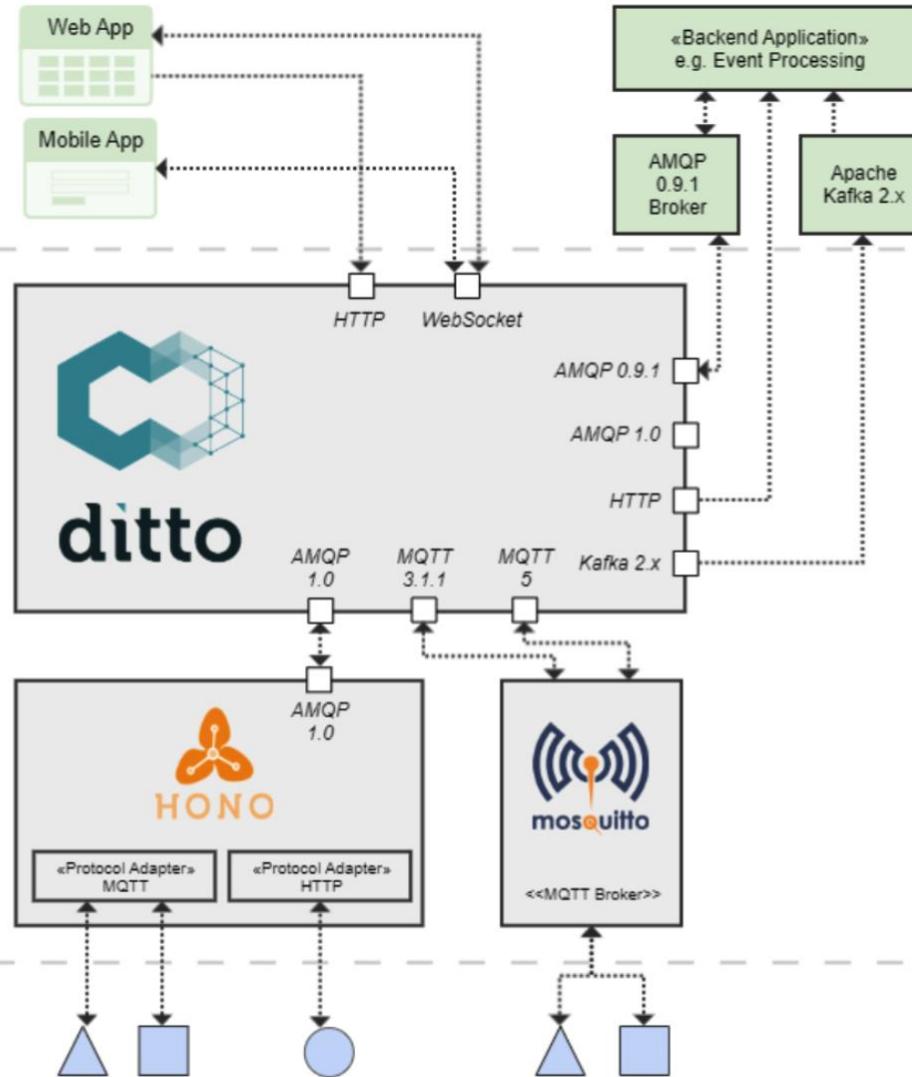
Ditto

IOT
SOLUTION

DEVICE
TWINS

DEVICE
CONNECTIVITY

IOT
DEVICES



Ditto as
Digital Twin
"middleware"

Ditto

- Ditto downloads and caches referenced TMs during runtime
- resolving extensions via `tm:extends` and imports via `tm:ref`, Thing level compositions via `tm:submodel` and TM placeholders
- Ditto generates TDs, injecting forms with HTTP API endpoints

```
curl -u ditto:ditto \
  'https://ditto.eclipseprojects.io/api/2/things/io.eclipseprojects.ditto:floor-lamp-0815' \
  -H 'Accept: application/td+json'

{
  "@context": [
    "https://www.w3.org/2022/wot/td/v1.1",
    ...
  ],
  "title": "Floor Lamp",
  "@type": "Thing",
  "id": "urn:io.eclipseprojects.ditto:floor-lamp-0815",
  "base": "https://ditto.eclipseprojects.io/api/2/things/io.eclipseprojects.ditto:floor-lamp-0815",
  "version": {
    "model": "1.0.0",
    "instance": "1.0.0"
  },
  "links": [
    {
      "rel": "type",
      "href": "https://eclipse.github.io/ditto-examples/wot/models/floor-lamp-1.0.0.tm.jsonld",
      "type": "application/tm+json"
    },
    {
      "rel": "item",
      "type": "application/td+json",
      "href": "/features/Spot1"
    },
    ...
  ],
  "security": "basic_sc",
  "securityDefinitions": {
    "basic_sc": {
      "in": "header",
      "scheme": "basic"
    }
  },
  "forms": [
    {
      "op": "readAllProperties",
      "href": "/attributes{?channel,timeout}",
      "htv:methodName": "GET",
      "contentType": "application/json"
    }
  ]
}
```

Other Engagements



<https://echonet.jp/english/>

- Smart Home / Smart City
- Echonet Lite / WoT TD Integration



<https://www.conexxus.org/>

- Convenience Stores
- Data Models and Services

Protocols:

- MQTT
- CoAP
- OCF
- OPC UA
- MODBUS

Groups

- IETF/ITRF T2TRG
- Open Geospatial Consortium
- IEC CDD/ECLASS
- OneDM
- IEEE
- ITU-T
- Microsoft DTDL

Discussion: Open Problems/Next Steps

- GIS Integration
 - Geospatial data and discovery
- Data Management
 - Digital Twins and shadows
 - Event and action modelling
 - Data management
- Security
 - Key provisioning and onboarding
 - Secure LAN access
 - Proxy services
 - Access control and ad-hoc sharing
 - MUDS
- Accessibility
 - Sensory modality mapping
 - Textual/descriptive interfaces
 - Service location
 - Mobility services
- Advanced Use Cases
 - Transportation
 - Logistics
 - Distributed energy management
 - AR visualization
 - Analytics integration e.g. for health and safety monitoring

Resources and Contacts

<https://www.w3.org/WoT>

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