Abstracting Interactions with IoT Devices Towards a Semantic Vision of Smart Spaces

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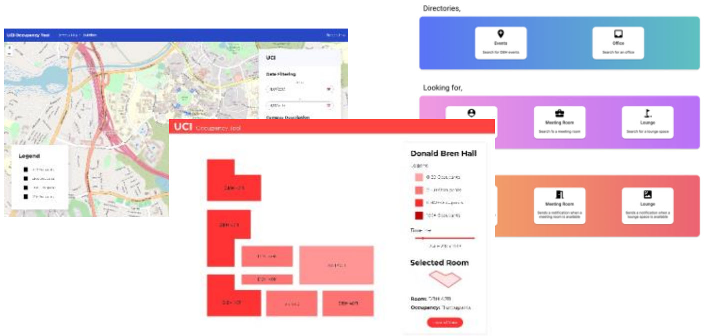
IoT Application Development

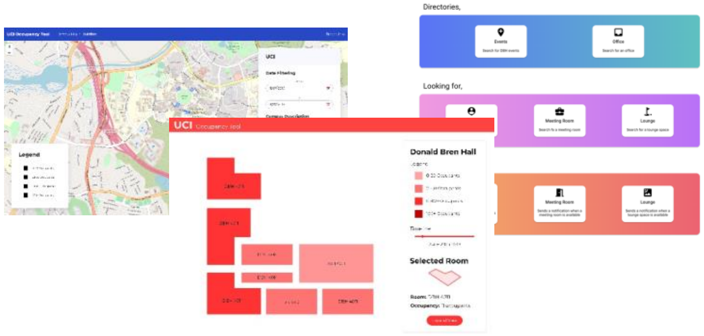
-Constrained to specific devices/protocols
-Difficult to port to other IoT spaces
-Developer needs to understand the devices in the IoT space which makes development challenging

People's world



Device's world

IoT Application Development



People's world

Device's world

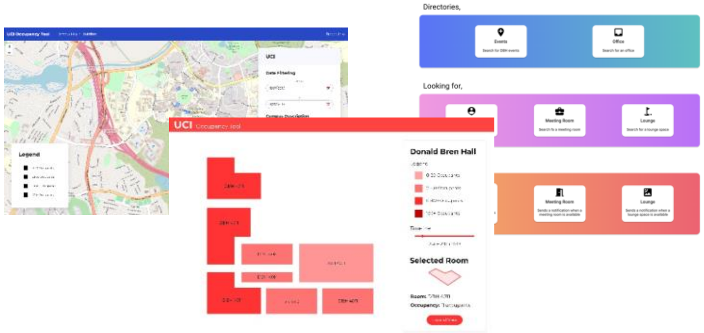
App request:

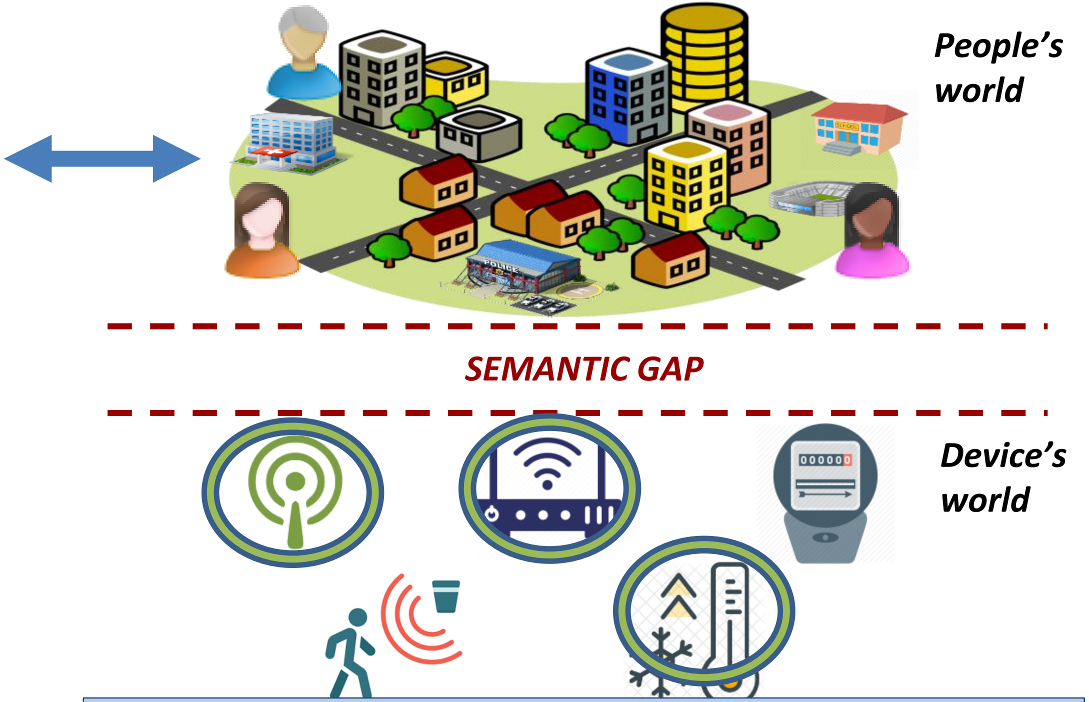
➢ *"Decrease temperature of rooms with occupancy above 50% of their capacity."*

User/Space policy:

➢ *"Do not capture the location of John and Mary when they are in their offices."*

Challenge: Semantic Gap





App request:

- ➢ *"**Decrease temperature** of **rooms** with **occupancy** above 50% of their **capacity**."*

User/Space policy:

- ➢ *"**Do not capture** the **location** of **John** and **Mary** when they are in their **offices**."*

Which sensors/actuators can we use to answer such request/policy?

Challenge: IoT Heterogeinity

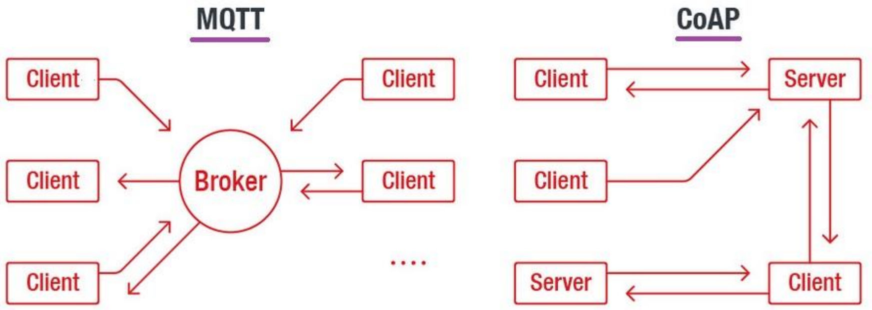
Dozens of devices in the market!

SEMANTIC GAP

https://www.postscapes.com/iot-thermostats/

Device's world

Different interaction paradigms and communication protocols



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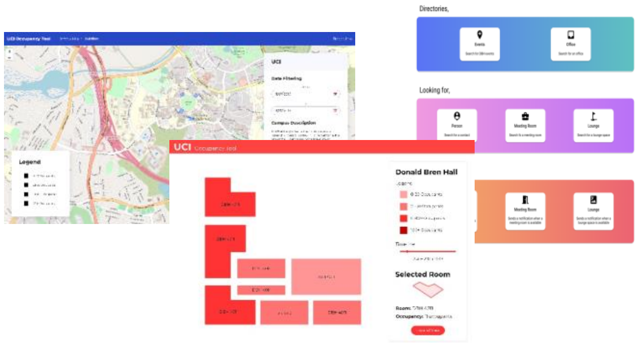
https://iotbyhvm.ooo/what-is-coap-protocol/

SemIoTic: End-to-End IoT Framework



SemIoTic

People's world

Device's world

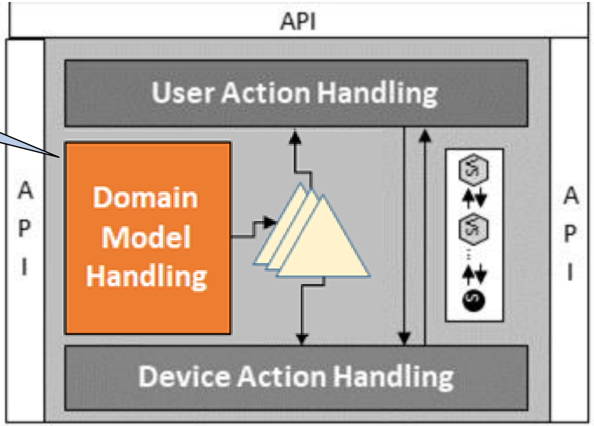
App request:

➢ *"**Decrease temperature** of **rooms** with **occupancy** above 50% of their **capacity**."*

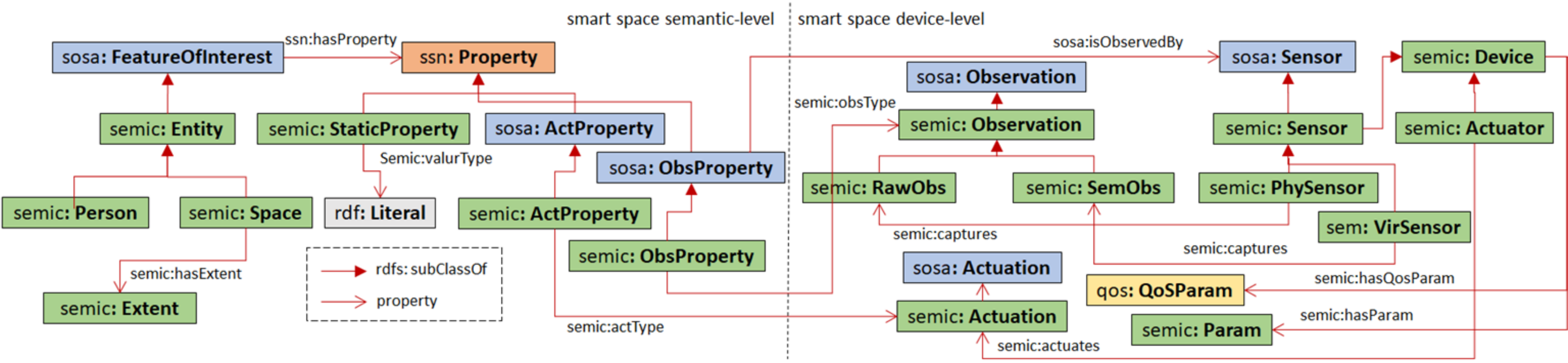
1) **Translate people's world request into device's world request**
2) **Communicate with specific devices using their protocols**

Architecture

Extensible metamodel to define IoT smart spaces



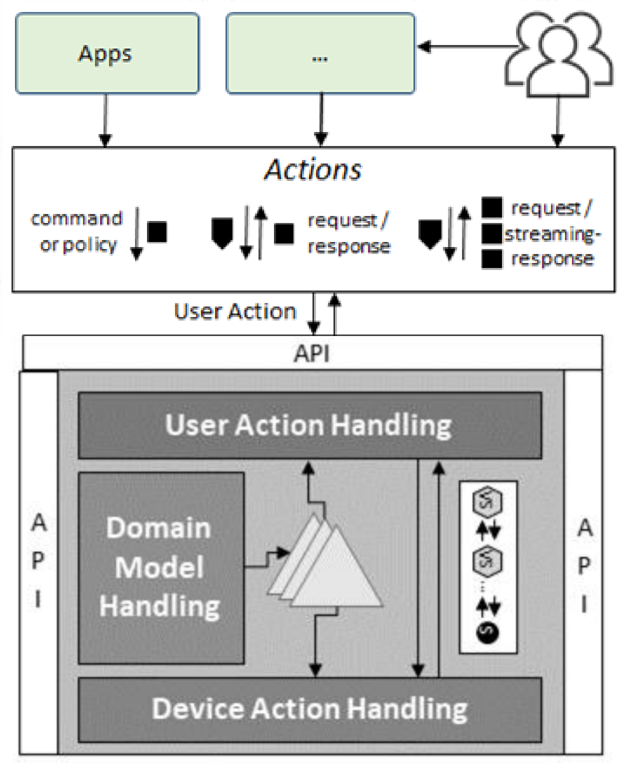
Modeling IoT Spaces



- Defining IoT spaces using an **ontology** provides **flexibility** and **extensibility**.
  - In addition, **semantic reasoning** to infer non-explicitly defined information (e.g., *if occupancy is a property of rooms, it should be also of meeting room 2065*).
- Created **OWL meta ontology (semic)** extending the popular sensor ontology (**SSN/SOSA**)
  - Focus on representing the connection between *"people's world"* and *"device's world"*.
    - Properties of people/spaces (e.g., location, occupancy, temperature) connected to sensors/actuators based on expected value types and produced value types.

Architecture

Based on domain model applications pose actions (i.e., requests, commands, or policies)



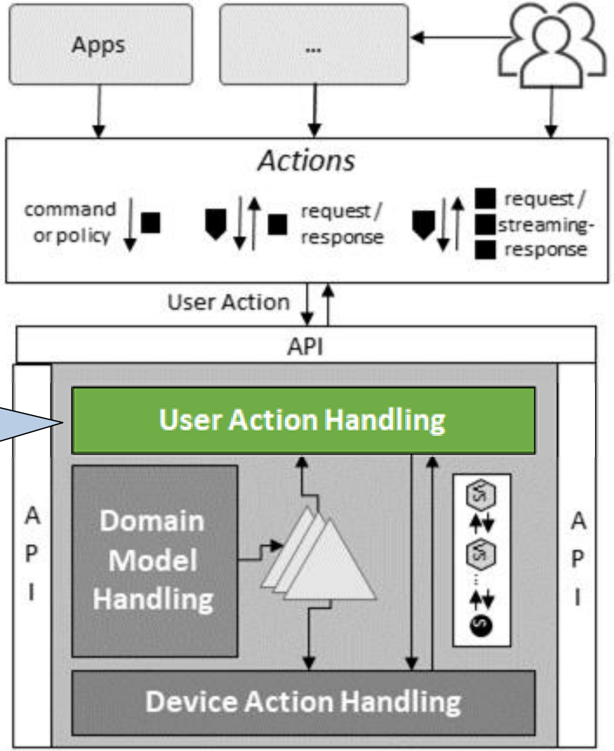
Defining User Actions

- **User Actions (UA)**, expressed at the semantic-level:
  - **Requests for data (UR)**
  - **Commands (UC)**
  - **Policies (UP)**
- Language for definition of general UAs with following elements:
  - **Entities of interest (E)** → Set of entities e_i, either entity classes ⟨e_i,*rdfs:subClassOf,semic:Entity*⟩ or entity instances ⟨e_i,*rdf:type,semic:Entity*⟩
  - **Properties of interest (P)** → Set of properties p_i ⟨p_i, *rdf:type,semic:Property*⟩.
  - **Conditions (C)** → expression containing properties that has to be satisfied to perform the actions on the entities
  - *(For UP)* **Interaction to control** (i.e., capture,store, share) and **preferred action** (i.e., accept or deny).

UR	*"retrieve the current location of John and Mary"*	⟨**<Mary, John>**, **Location**⟩
UC	*"decrease temp. of rooms with occ. above 50% of their capacity"*	⟨**Room**, **ControlTemp**, **Occupancy>0.5xCapacity**⟩
UP	*"do not capture Mary's and John's location in private spaces when the occupancy is less than 2 people"*	⟨**<Mary, John>**, **Location subClassOf PrivateSpace**, **Location.Occupancy<2**, **capture, deny**⟩

Architecture

User Actions get translated into Device-level Actions



Translating User Actions

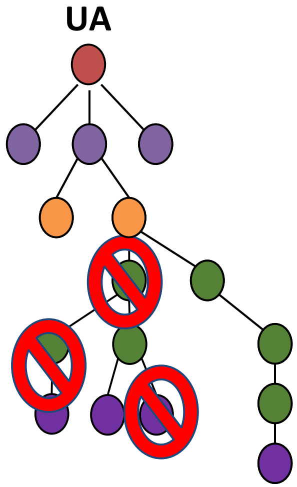
- **Goal:**
  - Create a plan involving IoT devices to process a UA.
- **Ontology-based translation algorithm that can process policies as well as requests/commands defined at a higher-level.**

Plans can be infeasible if sensors are not available (e.g., due to privacy policies)

Selection based on metrics (e.g., economical cost, latency, reliability)

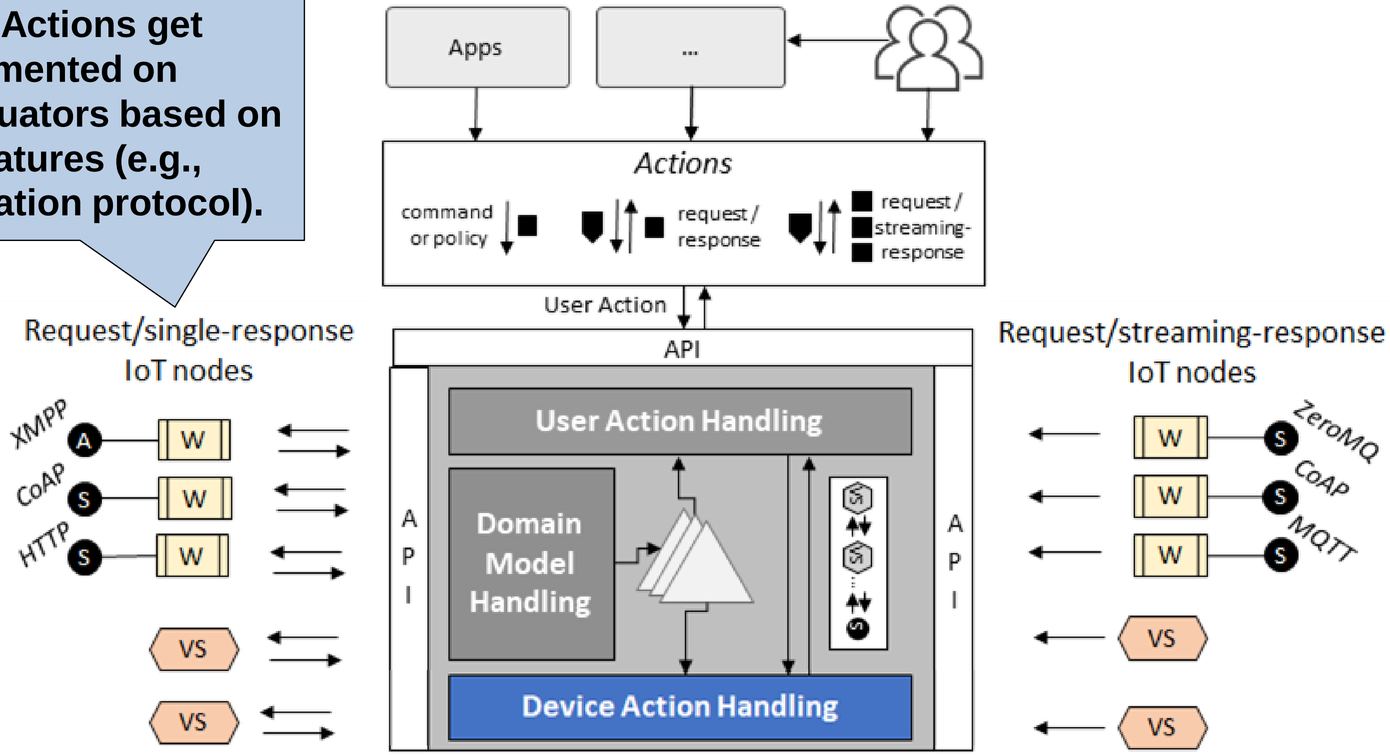
User Action Translation

1) Flattening
2) Plan Generation
3) Realizability Checking
4) Feasibility Checking
5) Plan Selection

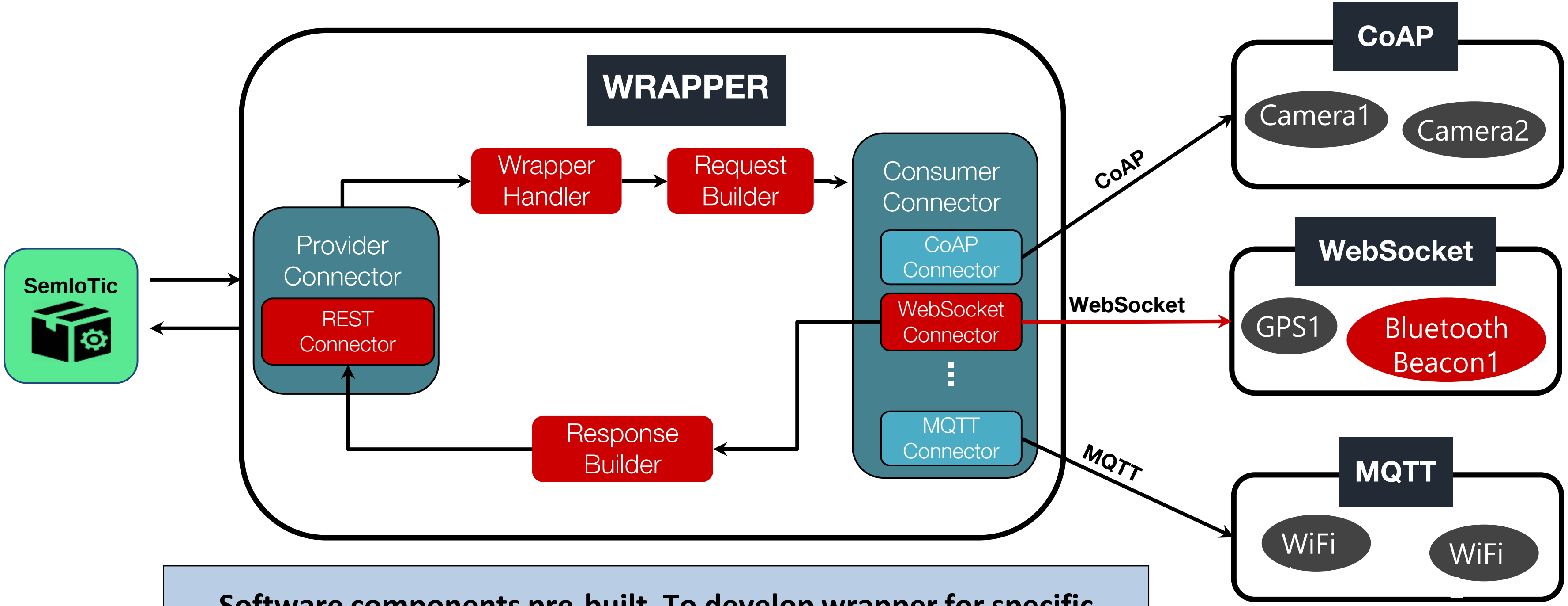


Architecture

Device-Actions get implemented on sensors/actuators based on their features (e.g., communication protocol).

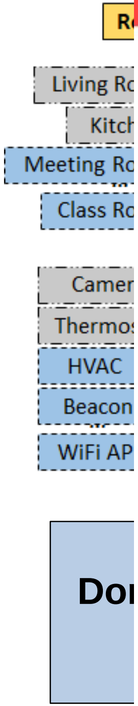


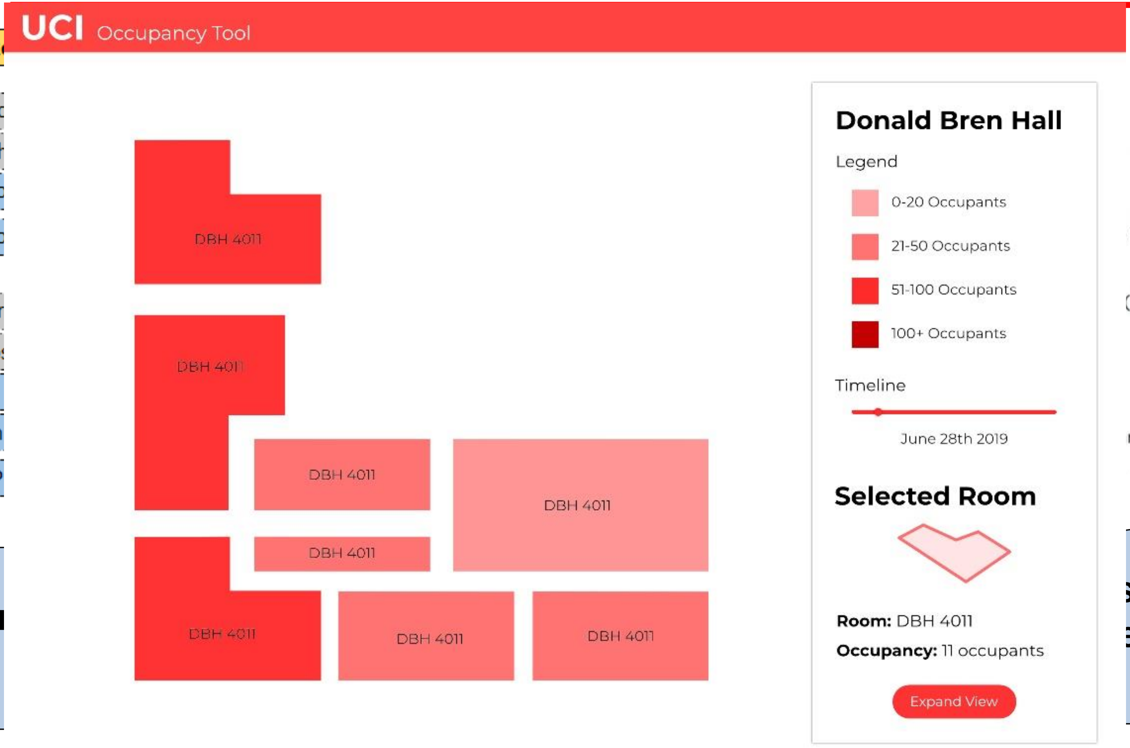
Device Action Handling



Software components pre-built. To develop wrapper for specific device, developer just includes information about: underlying protocol, parameter, data conversion.

Using SemIoTic

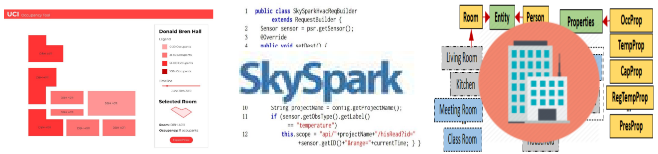




Web application to show occupancy related information of the smart space

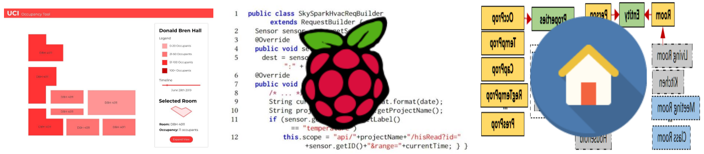
s for different sensors (e.g., erry PI camera, SkySpark HVAC)

Using SemIoTic

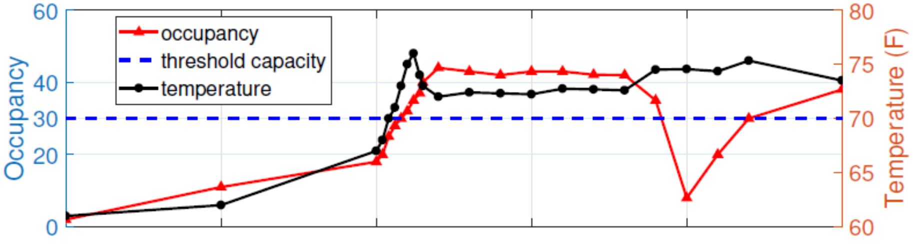


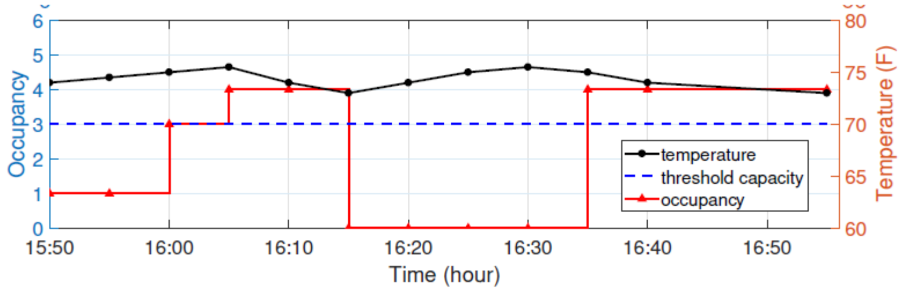
SemIoTic
(Smart Building)

SemIoTic
(Smart Home)

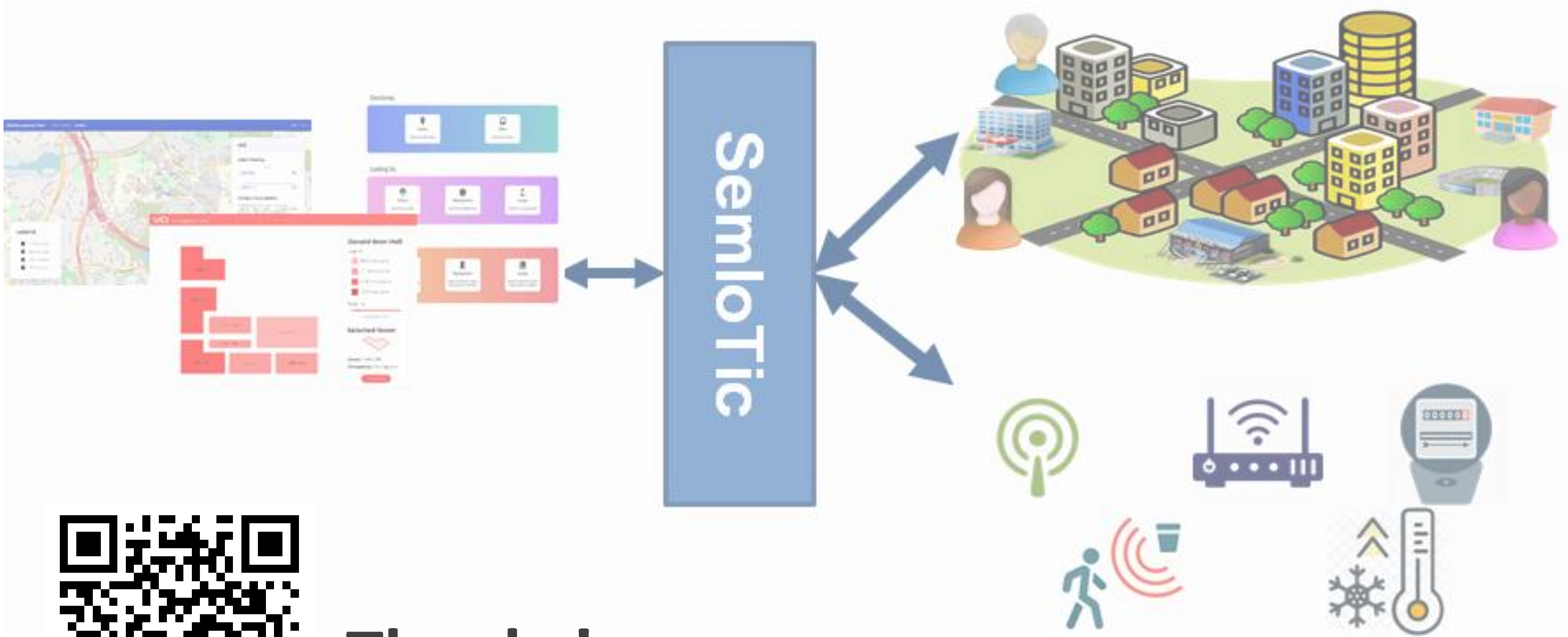


Same application and same request but different underlying sensors used by SemIoTic





Reduction of development effort (in terms of LoC) by 55% to 97%



Thanks!