SemBeacon: A Semantic Proximity Beacon Solution for Discovering and Detecting the Position of Physical Things

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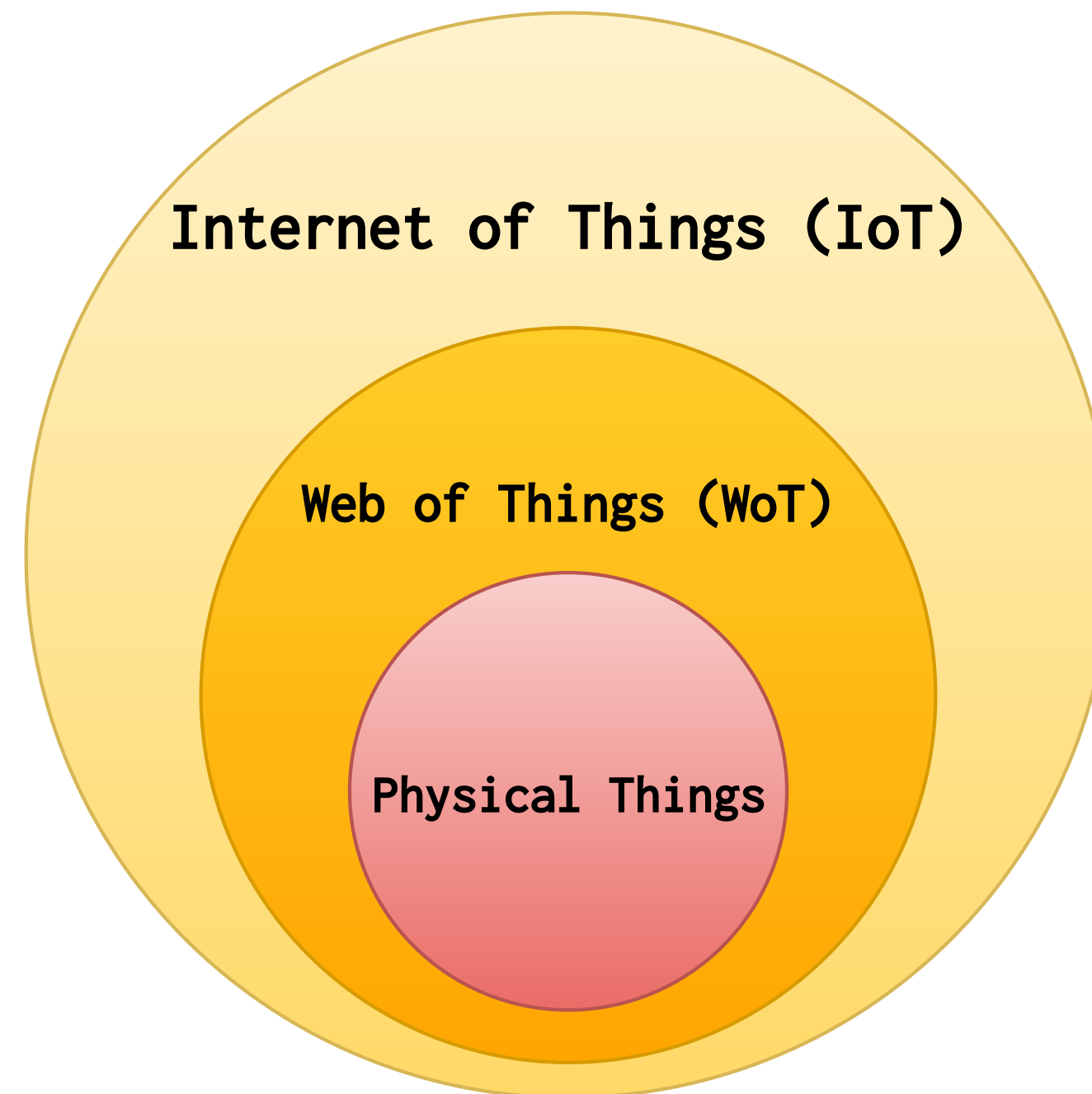*Vrije Universiteit Brussel*

Overview

*"A Physical Thing is an abstraction of a **physical** entity that provides **interactions** to and participates in the Web of Things"*

- W3C Web of Things (WoT) Thing Description 1.1

Problem Statement

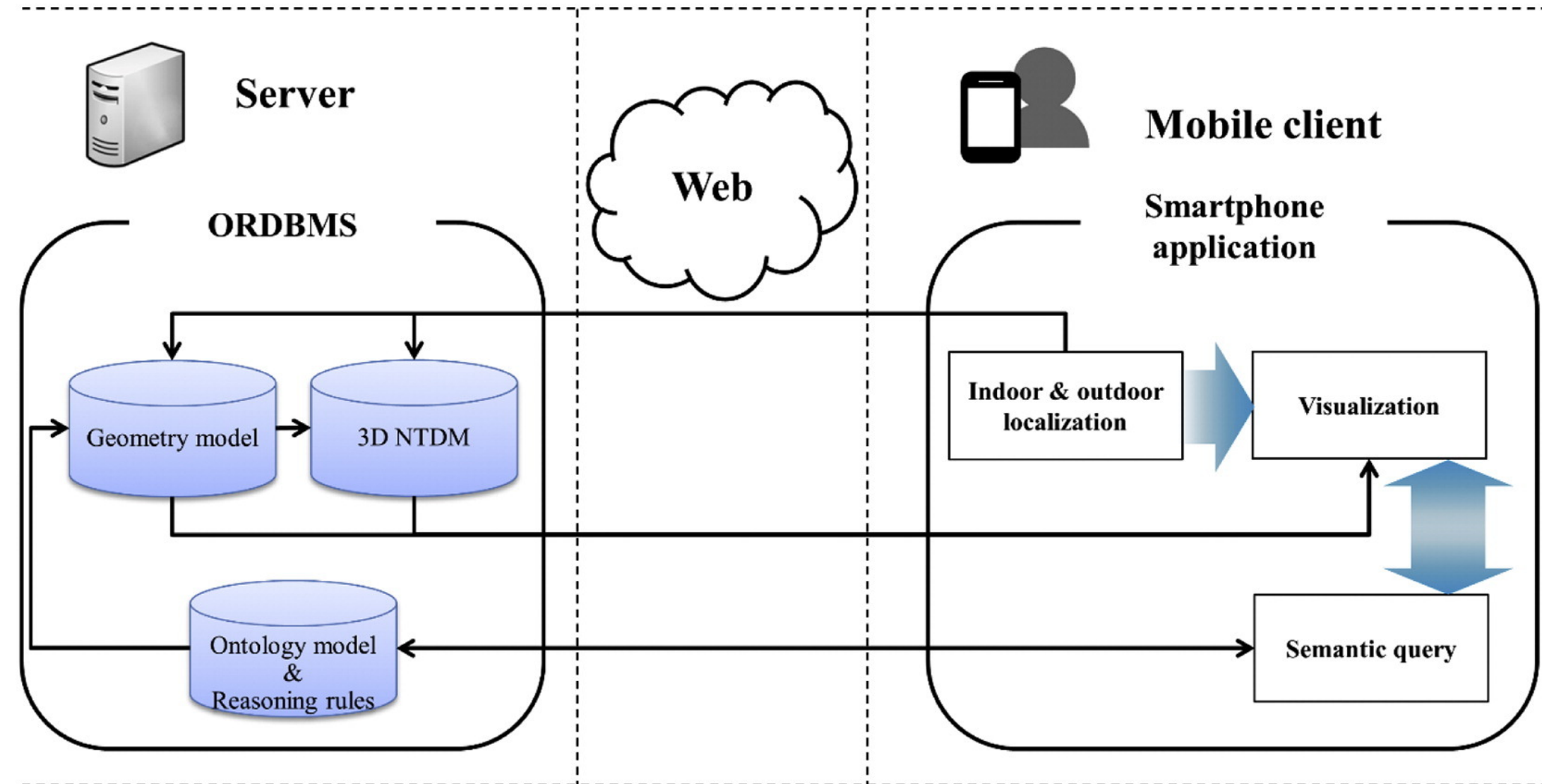*"How to discover and track Physical Things indoors?"*

"How to provide context to Physical Things?"

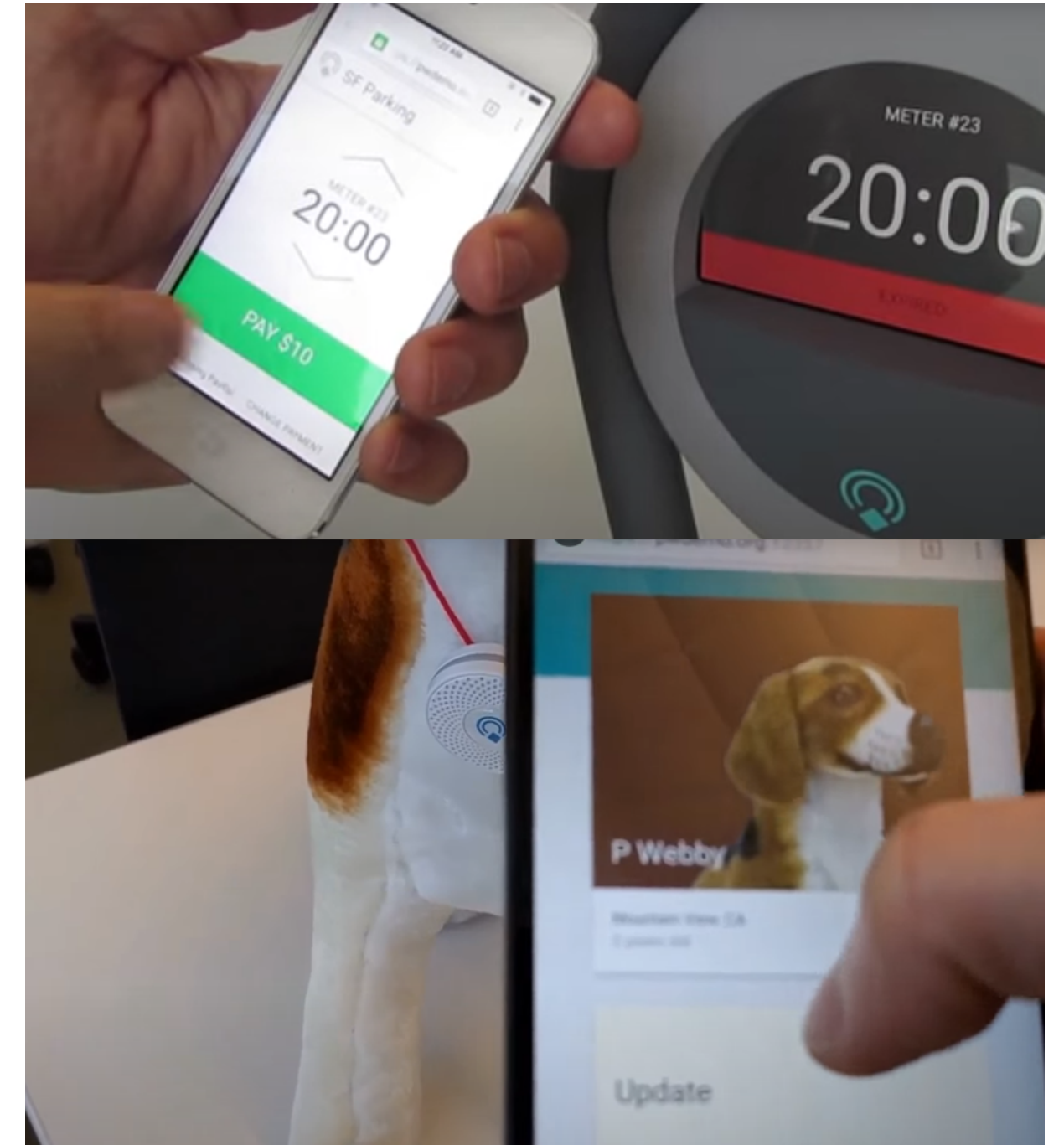*"How to get this context to the user?"*
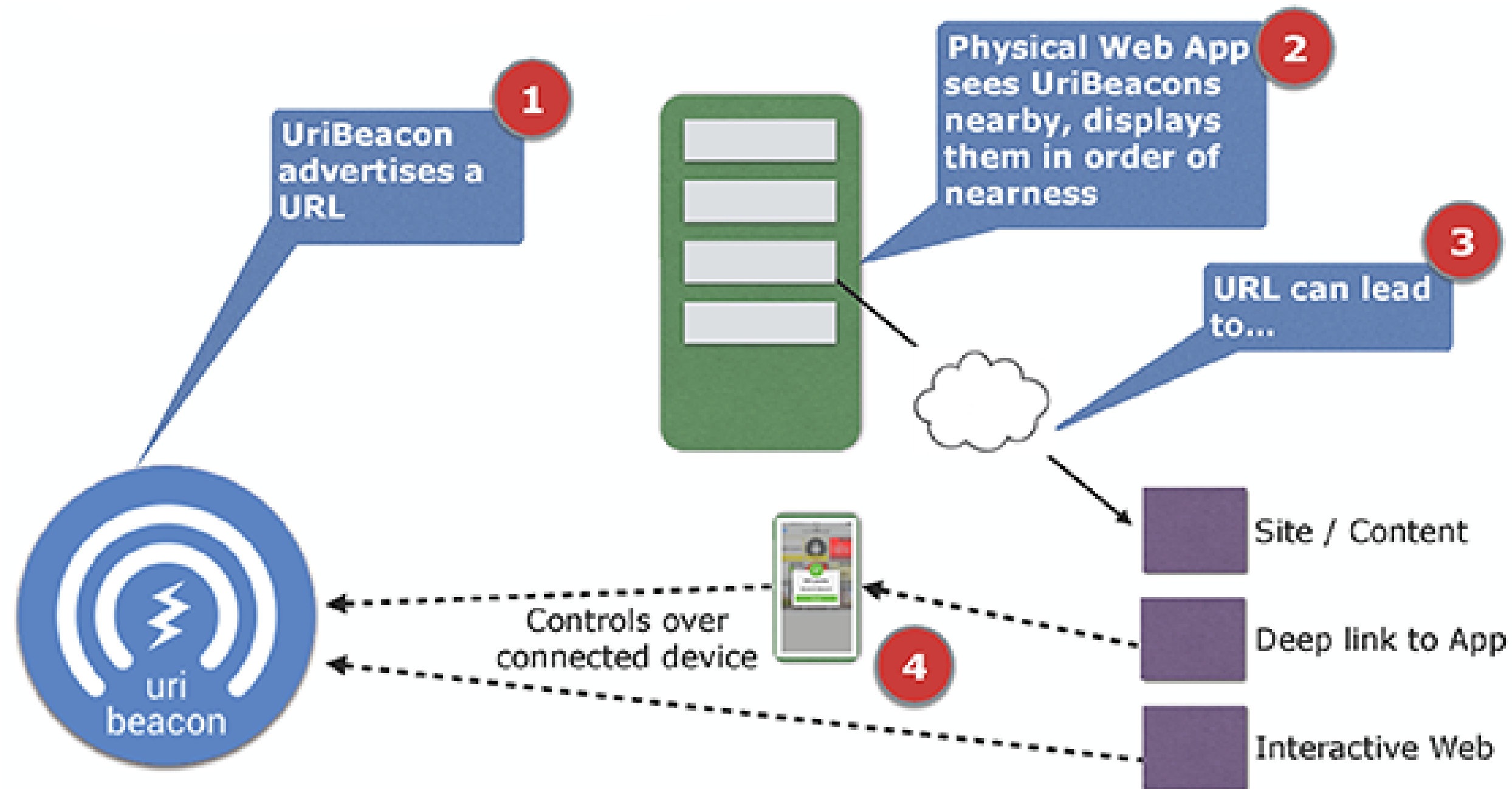
Related Work

- HP CoolTown Beacon (2000) [26]

- Location-based service using ontology-based semantic queries (2017) [18]
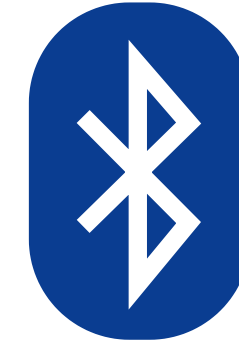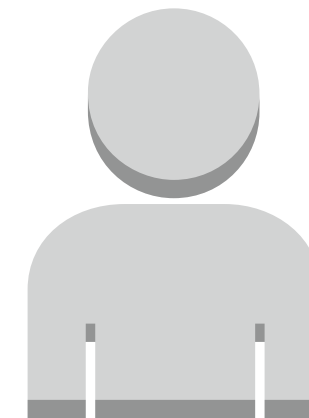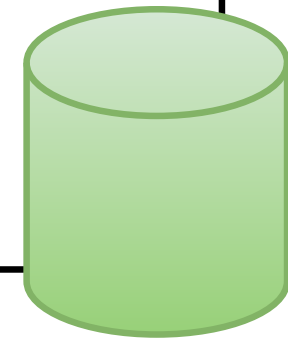
Related Work > Physical Web

- Manfred Sneps-Sneppe, Dmitry Namiot, "On Physical Web models" (2016)

Bluetooth Low Energy (BLE) > Positioning

Database (local/cloud)	
__ID__	__Location__
1	X=2, Y=3
...	...
3	X=4, Y=3

I am ID=1

I am ID=2
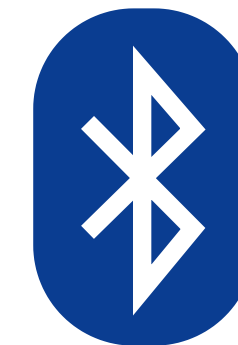
I am ID=3

Adv Flags 3B	Service List 4B	Len 1B	Type 1B	UUID 2B	Eddystone Frame 2B - 20B
-	0x0303,0xFEAA	0x??	0x16	0xFEAA	...

Len 1B	Type 1B	UUID 2B
0x03	0x03	0xFEAA

UID

Frame Type 1B	TX @ 0m 1B	Namespace ID 10B	Instance ID 6B	Reserved 2B
0x00	int8	uint8[]	uint8[]	0x0000

URL

Frame Type 1B	TX @ 0m 1B	URL Prefix 1B	Encoded URL 0B - 17B
0x10	int8	uint8	uint8[]

BLE Specifications > iBeacon & AltBeacon

iBeacon Advertisement Data (30 bytes)

Adv Flags 3B	Len 1B	Type 1B	Company ID 2B	Beacon Type 1B	Beacon Len 1B	Proximity UUID 16B	Major 2B	Minor 2B	TX @ 1m 1B	
-	0x1A	0xFF	0x4C00	0x02	0x15	uint8[]	uint16	uint16	int8	

AltBeacon Advertisement Data (31 bytes)

Adv Flags 3B	Len 1B	Type 1B	Company ID 2B	Beacon Code 2B	Beacon ID 20B	TX @ 1m 1B	Unused 1B
-	0x1B	0xFF	uint16	0xBEAC	uint8[]	int8	-

SemBeacon
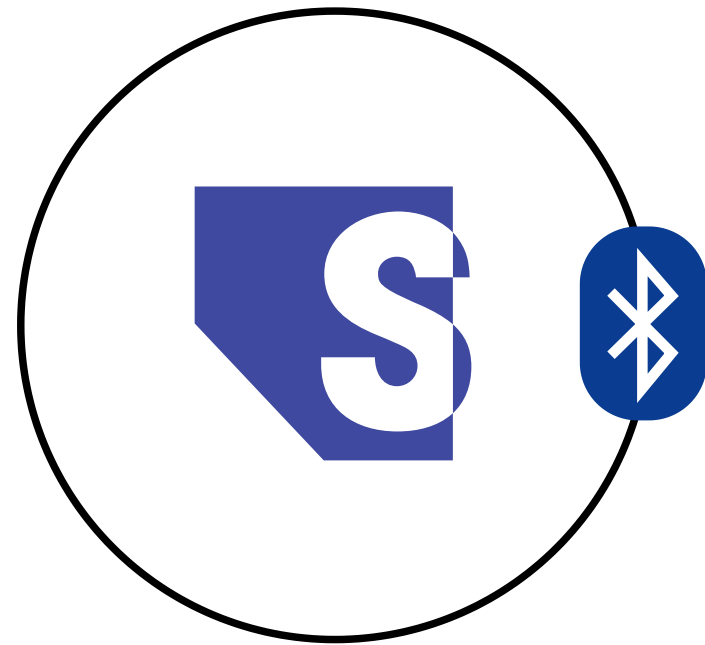
Hey I am a 0xBEAC with
\<namespace\> \<instance\> !

I do not know your namespace

Check https://bit.ly/3JsEnF9

HTTP GET (Accept: text/turtle,
application/rdf+xml)

Linked data response

RDF

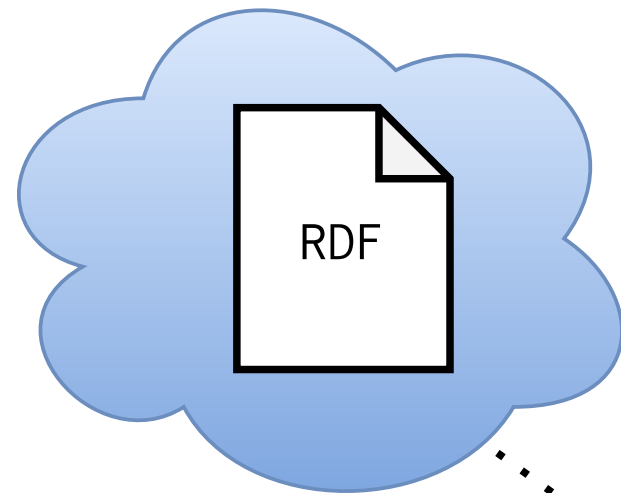Check cache

Cache \<namespace\>
and all beacons
within response

Beacon Map

BEACON_01
Last seen: 1s ago
RSSI: -59 dBm
Distance: 1.41 m

Open
Geospatial
Consortium
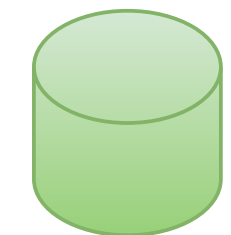
SemBeacon > Bluetooth Specification

BLE 4.X

SemBeacon Advertisement Data (31 bytes) — 4.0

Adv Flags 3B	Len 1B	Type 1B	Company ID 2B	Beacon Code 2B	Namespace ID 16B	Instance ID 4B	TX @ 1m 1B	Flags 1B
-	0x1B	0xFF	*uint16*	0xBEAC	*128-bit UUID*	*32-bit UUID*	*int8*	-

SemBeacon Scan Response Data (max 24 bytes) — 4.0

Len 1B	Type 1B	UUID 2B	Frame 1B	TX @ 0m 1B	URI Prefix 1B	Encoded Short Resource URI 0B - 17B
0x??	0x16	0xFEAA	0x10	*int8*	*uint8*	*uint8[]*

Eddystone-URL compatible service

```
0x00 'http://www.'
0x01 'https://www.'
0x02 'http://'
0x03 'https://'
0x04 'urn:uuid:'
```

US-ASCII URL

```
0x00 '.com/'     0x06 '.com'
0x01 '.org/'     0x07 '.org'
0x02 '.edu/'     0x08 '.edu'
0x03 '.info/'    0x09 '.info'
0x04 '.biz/'     0x0A '.biz'
0x05 '.gov/'     0x0B '.gov'
```

Flags

Based on UriBeacon, Bluetooth IPS and Eddystone frames

Bit (MSB)	Description	Example
0	Indicates if the beacon has a position.	0 = Unsure, 1 = Yes
1	Indicates if the beacon is private.	0 = Public, 1 = Private
2	Indicates if the beacon is attached to a moving object.	0 = No, 1 = Yes
3	Indicates if the beacon has a positioning system.	0 = No, 1 = Yes
4	Indicates if the beacon has telemetry data.	0 = No, 1 = Yes
5 - 7	*Reserved for future use.*	

SemBeacon > Bluetooth Specification

BLE 5.X (Work in Progress)

SemBeacon Extended Advertisement Data (max 156 bytes)   *5.0*

SemBeacon Service 4B	Namespace ID 16B	Instance ID 4B	TX @ 1m 1B	Version 1B	Flags 1B	URI Prefix 1B	Encoded Resource URI 0B - 128B
-	*128-bit UUID*	*32-bit UUID*	*int8*	0x10	-	*uint8*	*uint8[]*

Len 1B	Type 1B	UUID 4B
0x??	0x20	0x00BEAC00

Major 4b	Minor 4b
0001	0000

```
...
0x05 'urn:'
0x06 'tag:'
0x06 'http://purl.org/'
0x07 'https://purl.org/'
0x08 'http://w3id.org/'
0x09 'https://w3id.org/'
```

```
...
0x0C '.rdf#'
0x0D '.ttl#'
0x0E '.rdf'
0x0F '.ttl'
0x10 '.jsonld'
```
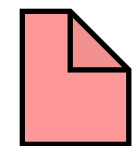
SemBeacon > Namespace and Instance

http://example.org/beacons.ttl#

MD5("http://example.org/beacons.ttl#") = 24d72e569889db5328be761d8488688d

http://other.org/beacons.ttl#

MD5("http://other.org/beacons.ttl#") = 08483bc99d448c83bff6cb9d5bccd40d

---

Namespace ID: 0x24d72e569889db5328be761d8488688d
Instance ID: 0x00000001
Resource URI: http://example.org/beacons.ttl#b1
Short Resource URI: https://tinyurl.com/3u9tpt7k

Namespace ID: 0x08483bc99d448c83bff6cb9d5bccd40d
Instance ID: 0x00000001
Resource URI: http://other.org/beacons.ttl#b1
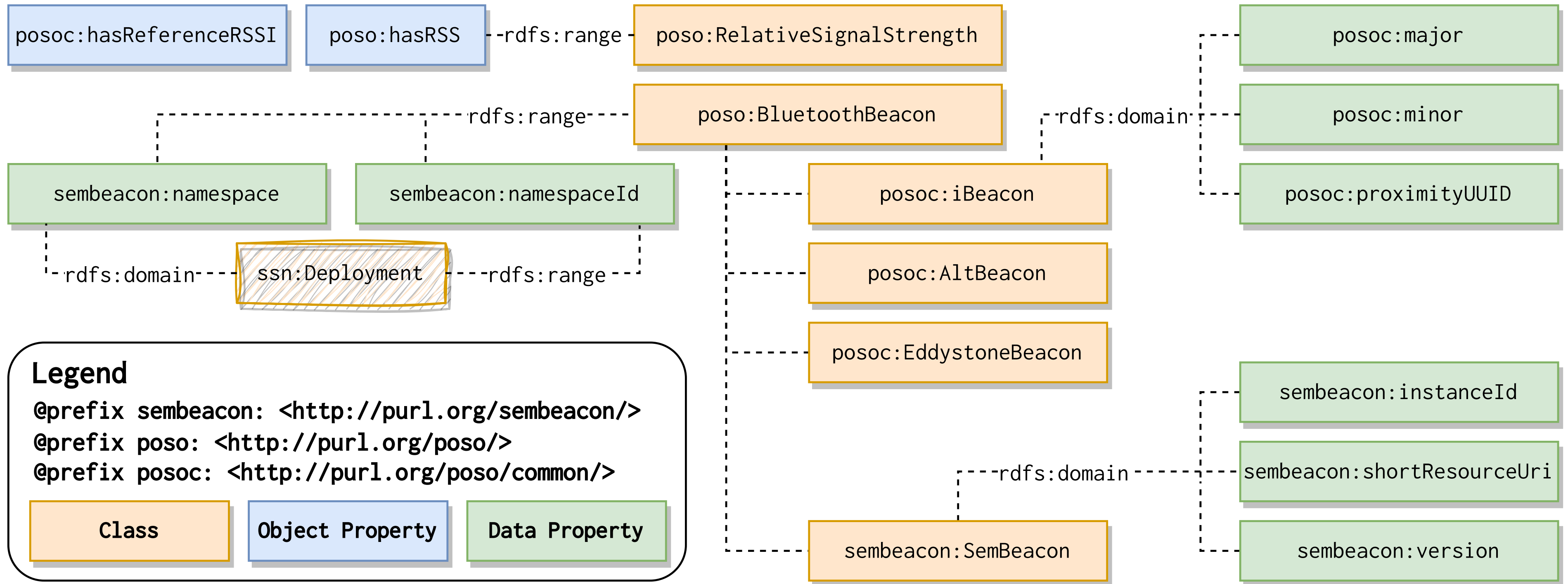**Short Resource URI:** https://tinyurl.com/bdmbu7jb

---

Type: iBeacon
UUID: 0x24d72e569889db5328be761d8488688d
Major: 0x0000   **Minor:** 0x0003

Type: AltBeacon
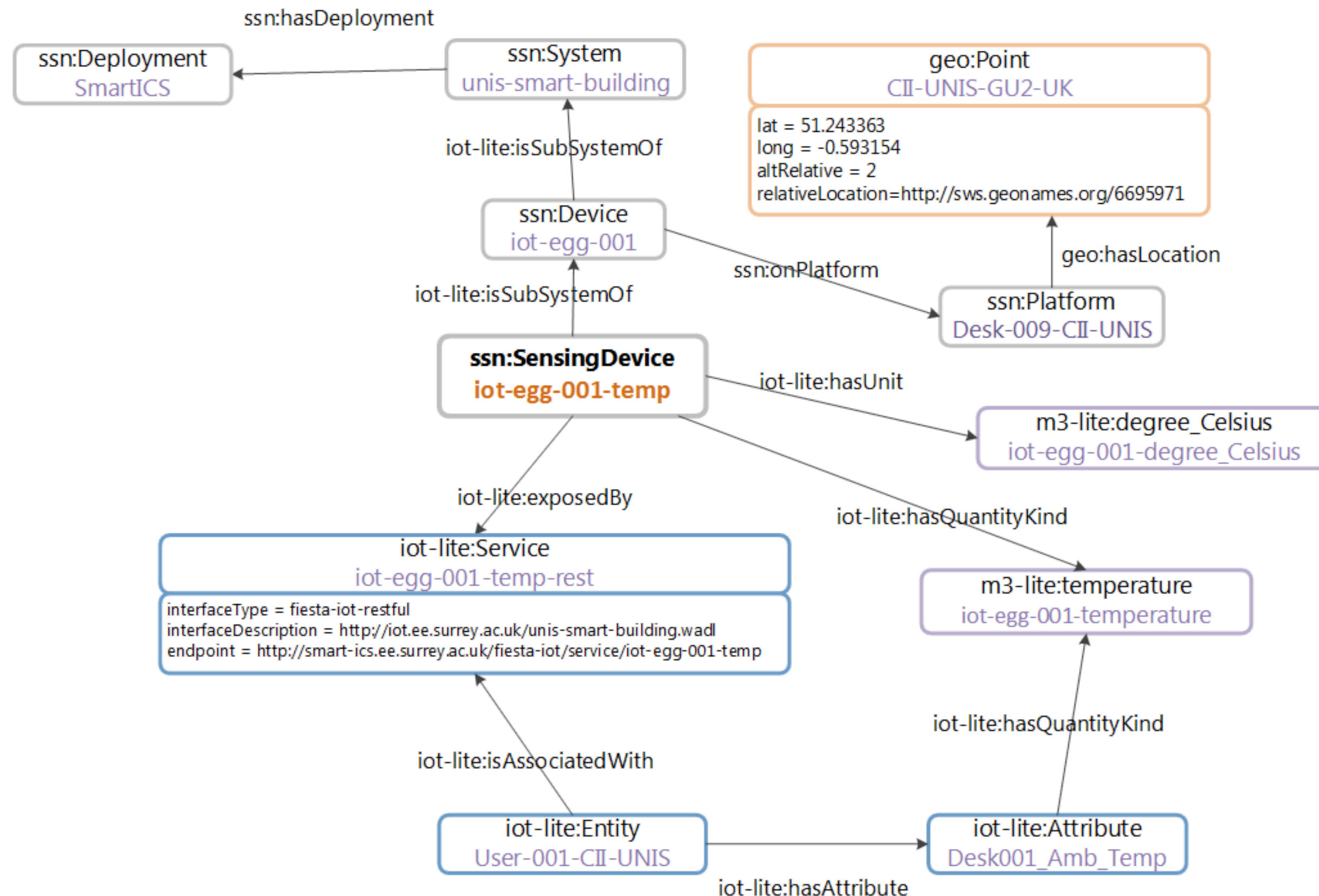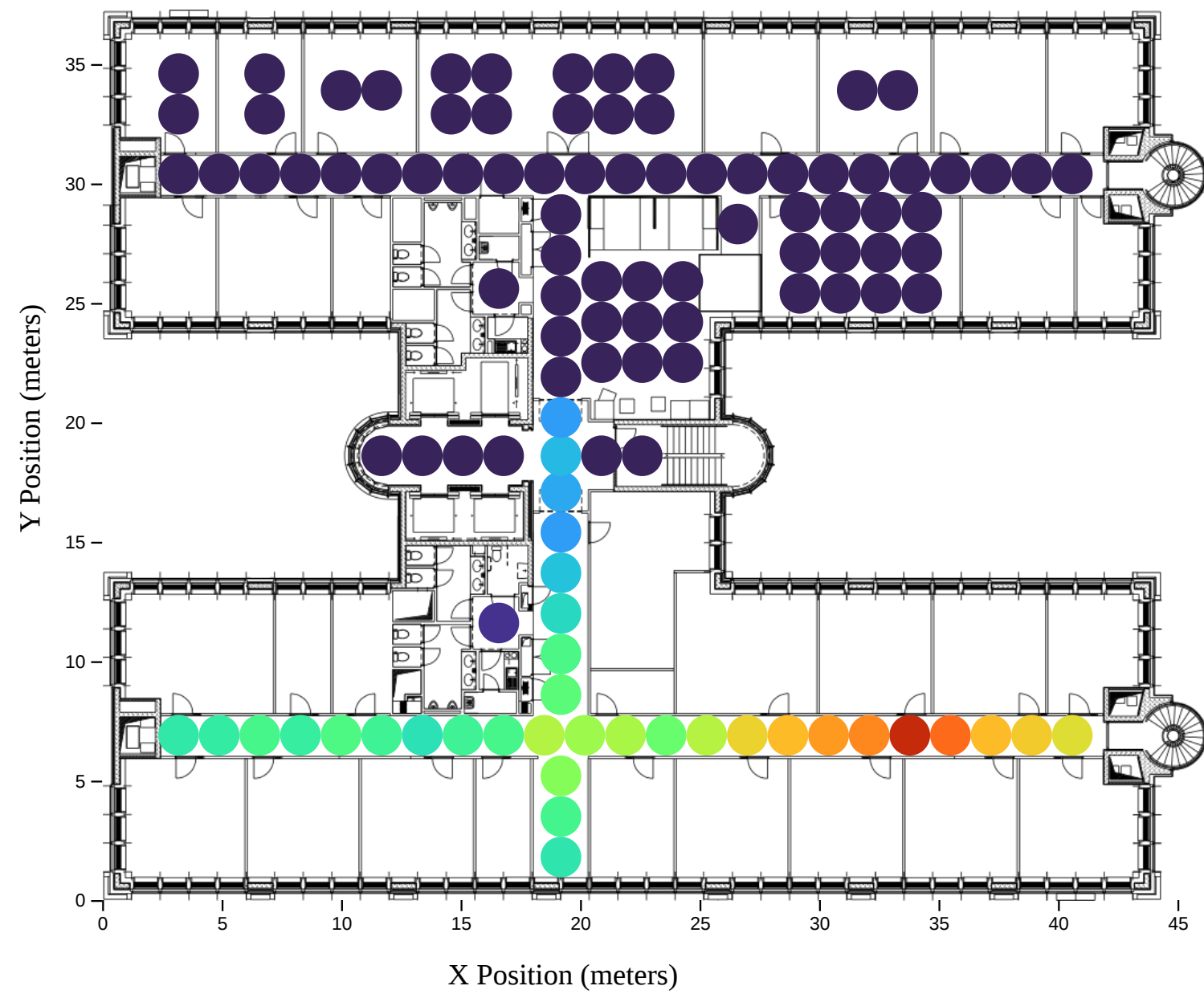**ID:** 0x08483bc99d448c83bff6cb9d5bccd40d00000003

SemBeacon > POSO Extension

posoc:hasReferenceRSSI

poso:hasRSS ─rdfs:range─ poso:RelativeSignalStrength

posoc:major

posoc:minor

poso:BluetoothBeacon ──rdfs:range── ··· rdfs:domain ··· posoc:proximityUUID

sembeacon:namespace   sembeacon:namespaceId

posoc:iBeacon

rdfs:domain ─ ssn:Deployment ─ rdfs:range

posoc:AltBeacon

posoc:EddystoneBeacon

Legend
@prefix sembeacon: <http://purl.org/sembeacon/>
@prefix poso: <http://purl.org/poso/>
@prefix posoc: <http://purl.org/poso/common/>

| Class | Object Property | Data Property |

sembeacon:instanceId

sembeacon:shortResourceUri

··· rdfs:domain ···

sembeacon:SemBeacon

sembeacon:version

SemBeacon > Device Interactions

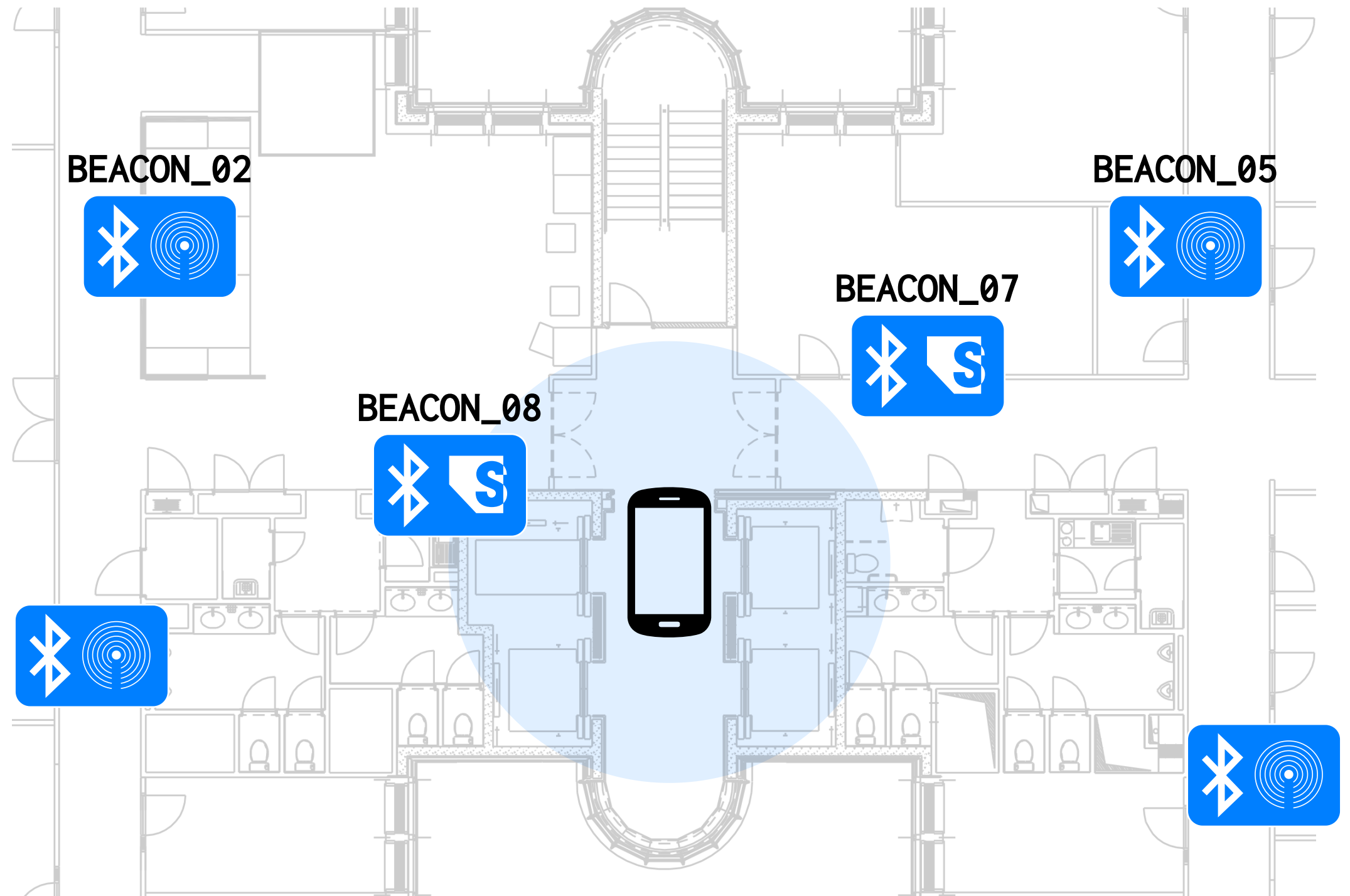## M. Bermudez-Edo, T. Elsaleh et al. "IoT-Lite Ontology", November 2015

- M. Van de Wynckel & B. Signer, OpenHPS Single Floor Dataset (2021)

BEACON_02

BEACON_05

BEACON_07

BEACON_08

Demonstrator > Transformation

https://sembeacon.org/examples/openhps2021/beacons.ttl

```
:BEACON_08 a sosa:FeatureOfInterest, ogc:SpatialObject, poso:RFLandmark,
        poso:BluetoothBeacon, sembeacon:SemBeacon;
    rdfs:label "BEACON_08";
    poso:hasPosition [ a geo:Point, poso:AbsolutePosition;
        ogc:asWKT "POINT Z(4.392253994600526 50.82057562786381 93.5999999962747)"^^ogc:wktLiteral
        ogc:coordinateDimension 3; ogc:spatialDimension 3; ogc:dimension 3;
        schema:latitude "50.82057562786"^^xsd:double; schema:longitude "4.392253994600"^^xsd:doub
        schema:elevation "93.5999999962"^^xsd:double ];
    posoc:hasReferenceRSSI [
        poso:hasRSS [ a qudt:QuantityValue;
                qudt:unit unit:DeciB_M;
                qudt:numericValue -56 ];
        poso:hasRelativeDistance [ a qudt:QuantityValue;
            qudt:unit unit:M;
            qudt:numericValue 1 ]];
    hardware:macAddress "f7:5c:38:a4:45:ec";
    ogc:sfWithin :pl9_3_corridor;
    sembeacon:namespace :pl9_3;
    sembeacon:shortResourceURI "https://bit.ly/3JsEnF9"^^xsd:anyURI;
    sembeacon:instanceId "c187d748"^^xsd:hexBinary.
```

https://sembeacon.org/examples/openhps2021/beacons.ttl

```
:pl9_3 a ssn:Deployment, sosa:FeatureOfInterest, ogc:SpatialObject, schema:Accommodation, seas:F
    ogc:hasGeometry [ a ogc:Geometry;
        ogc:asWKT "POLYGON Z((4.3926809491 50.82056 92, 4.3925189891 50.820491195 92,
            4.3924384904 50.820566477 92, 4.3923227711 50.820517092 92, 4.3924032699 50.8204418100
            4.3922413107 50.820372691 92, 4.3918880594 50.820703046 92, 4.3920500197 50.8207721659
                ...
            4.3921796702 50.820650918 95, 4.3922953899 50.820700303 95, 4.3921657397 50.82082155(
            4.3923277009 50.820890669 95, 4.3926809491 50.820560314 92))"^^ogc:wktLiteral;
        ogc:coordinateDimension 3; ogc:spatialDimension 3; ogc:dimension 3 ];
    rdfs:label "PL9.3";
    sembeacon:namespaceId "77f340dbac0d20e8aa3af656a29f236c"^^xsd:hexBinary .
:pl9_3_lobby_1 a schema:Place, ssn:Deployment, sosa:FeatureOfInterest, ogc:SpatialObject;
    ogc:hasGeometry [ a ogc:Geometry;
        ogc:asWKT "POLYGON Z((4.392281317197596 50.82061024217639 92,
            4.39223788808538 50.82065085654958 92, 4.392153959019106 50.82061503844629 92,
            4.392197388204323 50.8205744240731 92, 4.392281317197596 50.820610242176386 94,
            4.39223788808538 50.82065085654958 95, 4.392153959019106 50.82061503844629 95,
            4.392197388204322 50.8205744240731 94,
            4.392281317197596 50.82061024217639 92))"^^ogc:wktLiteral;
        ogc:coordinateDimension 3; ogc:spatialDimension 3; ogc:dimension 3 ];
    rdfs:label "Lobby #1" .
```

Demonstrator > Mobile Application

▸ **Scans** and **Simulates** SemBeacon, iBeacon, AltBeacon and Eddystone

▸ **Extracts** and visualises SemBeacon encoded information

▸ Implements HTTP **caching** and namespace mapping to environments
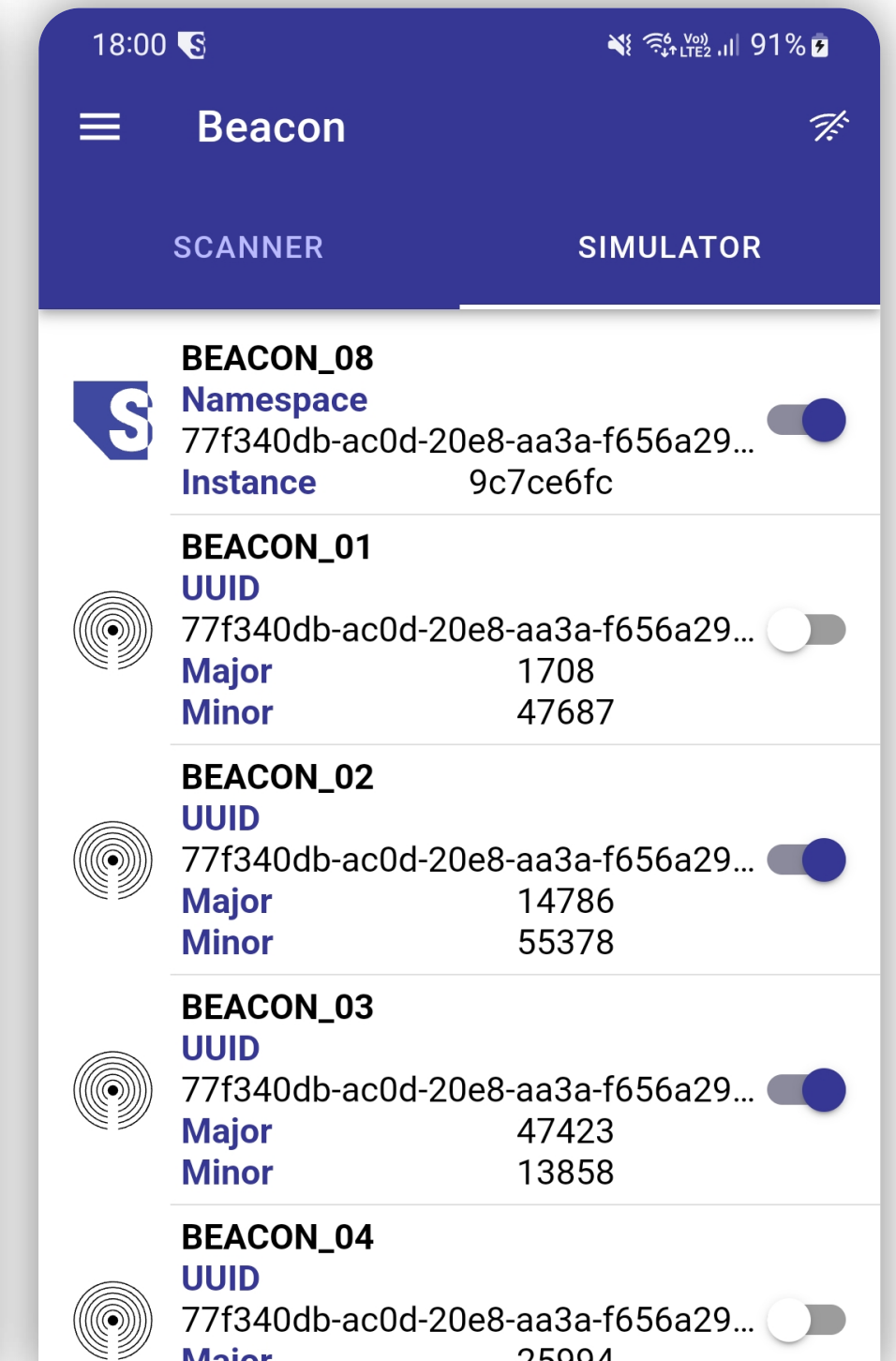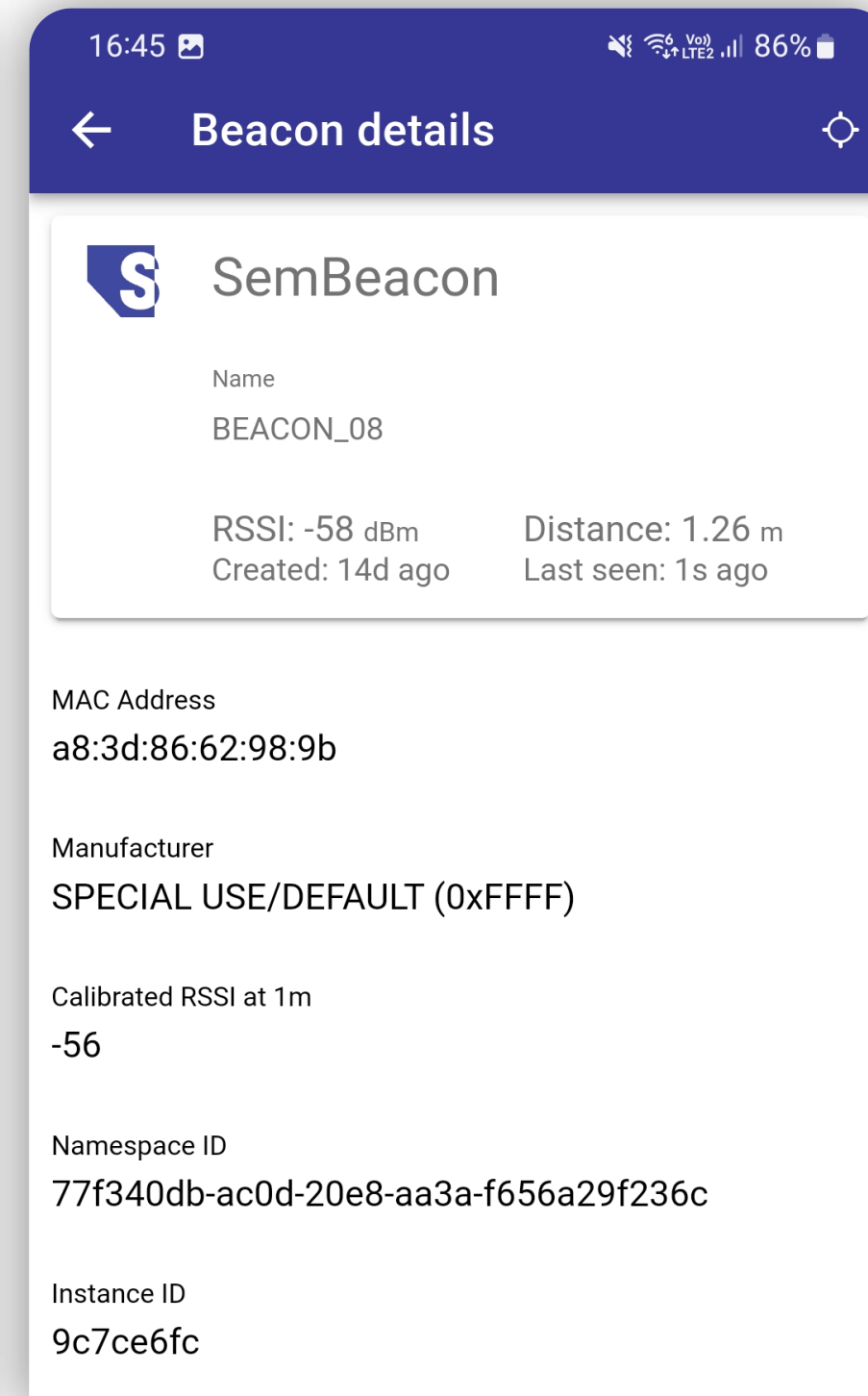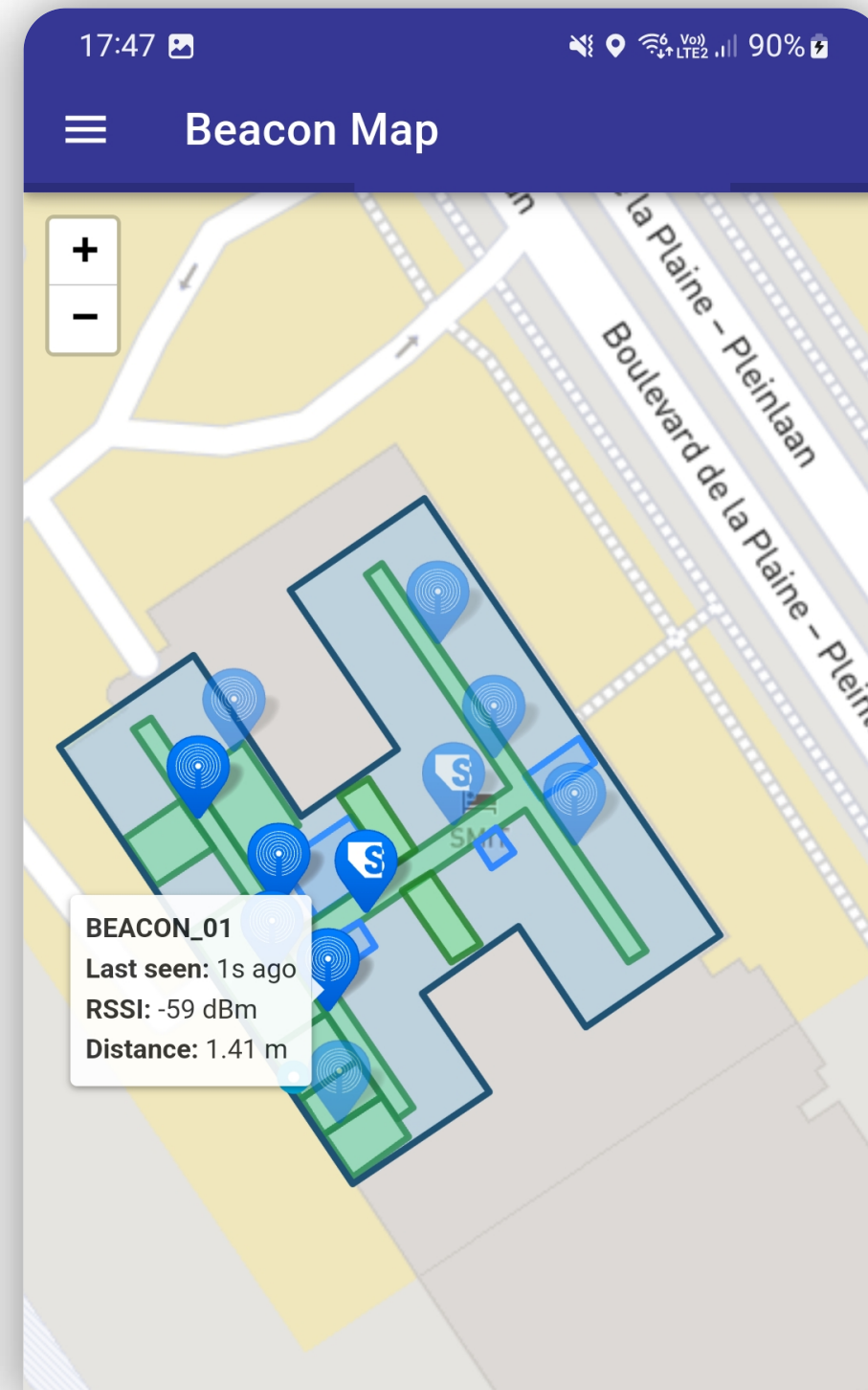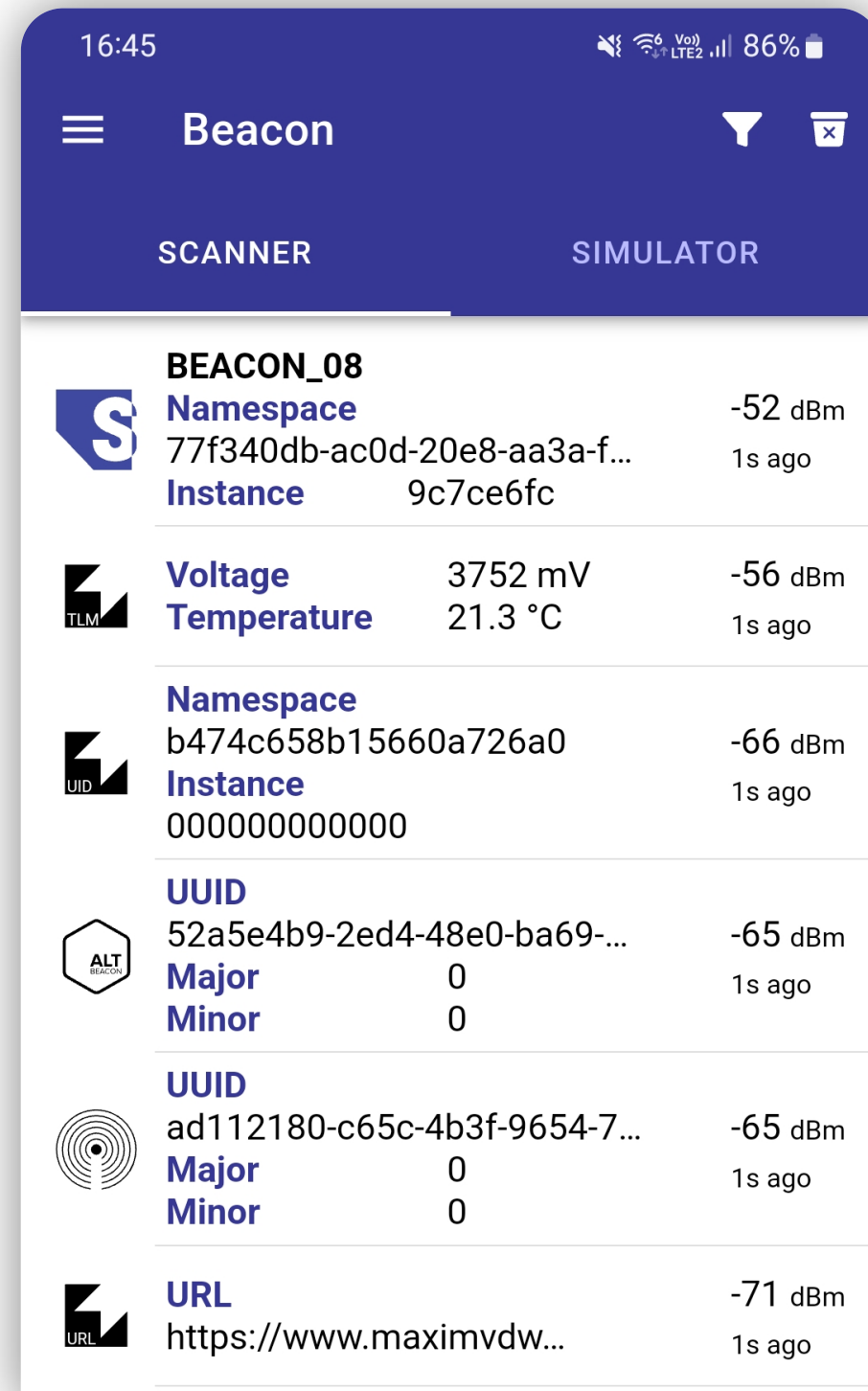
Supplemental Material

▸ Android Application to scan and broadcast SemBeacons

    Created using Ionic Capacitor and @sembeacon/openhps

▸ Arduino ESP32 Library to advertise SemBeacon

    Available in the Arduino IDE as "ESP32_SemBeacon"

▸ Android library extension to identify SemBeacons

    Using the AltBeacon Beacon Library

▸ TypeScript library to create and detect SemBeacons

    Using the OpenHPS framework (@sembeacon/openhps)

Conclusion and Future Work

▸ Semantic beacon solution called SemBeacon
▸ Describes beacons, environments and all devices within
▸ Backwards compatible, offline identification, scalable
▸ Expanding the vocabulary to facilitate device interactions
▸ Expanding to Solid Pods to enable the advertising of digital twins

https://github.com/SemBeacon/
https://sembeacon.org/
Android App on Google Play Store
Slides can be found on the website