

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

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*Vrije Universiteit Brussel*



WEB & INFORMATION  
SYSTEMS ENGINEERING

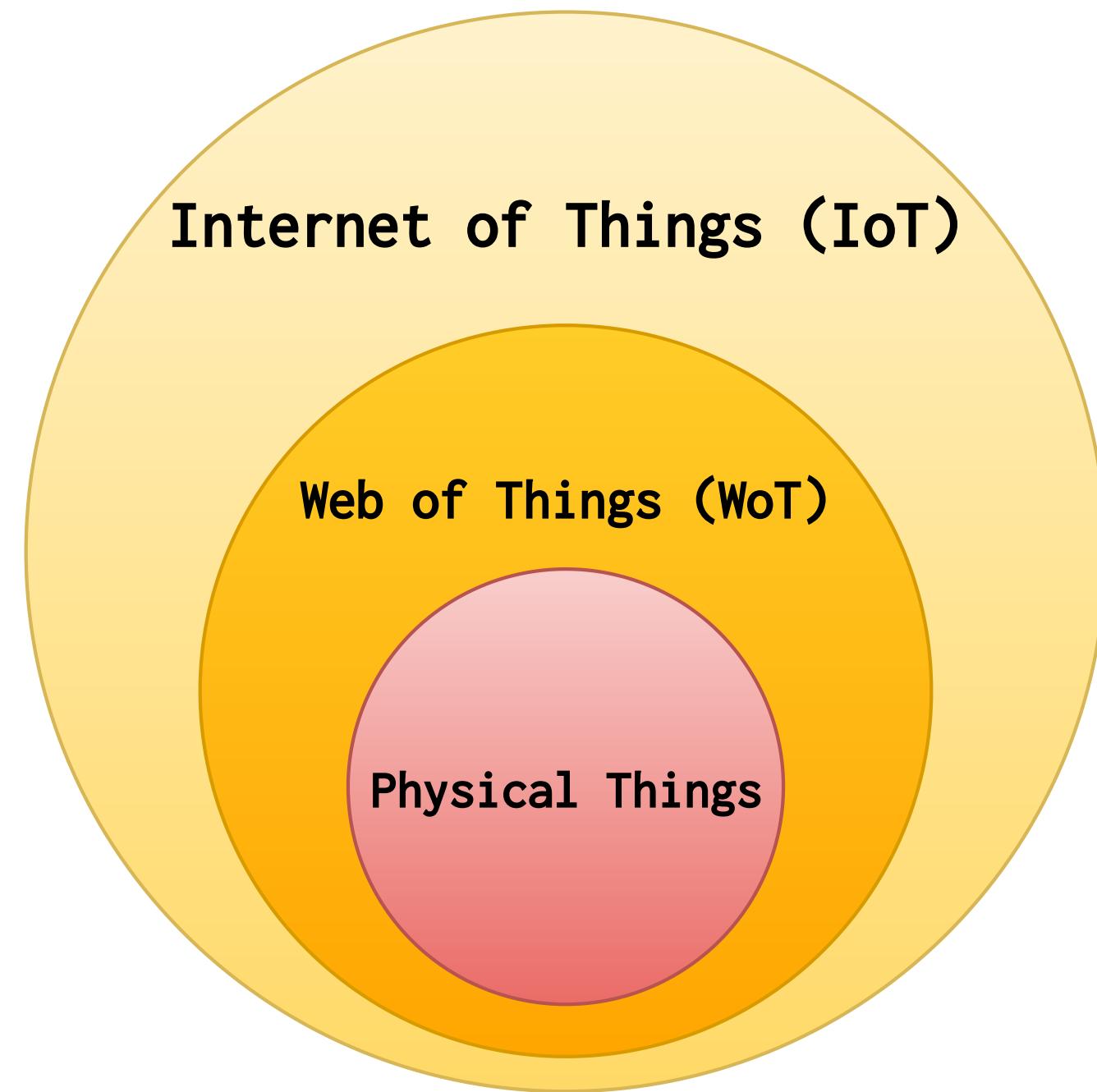


# Overview

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*"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?"*

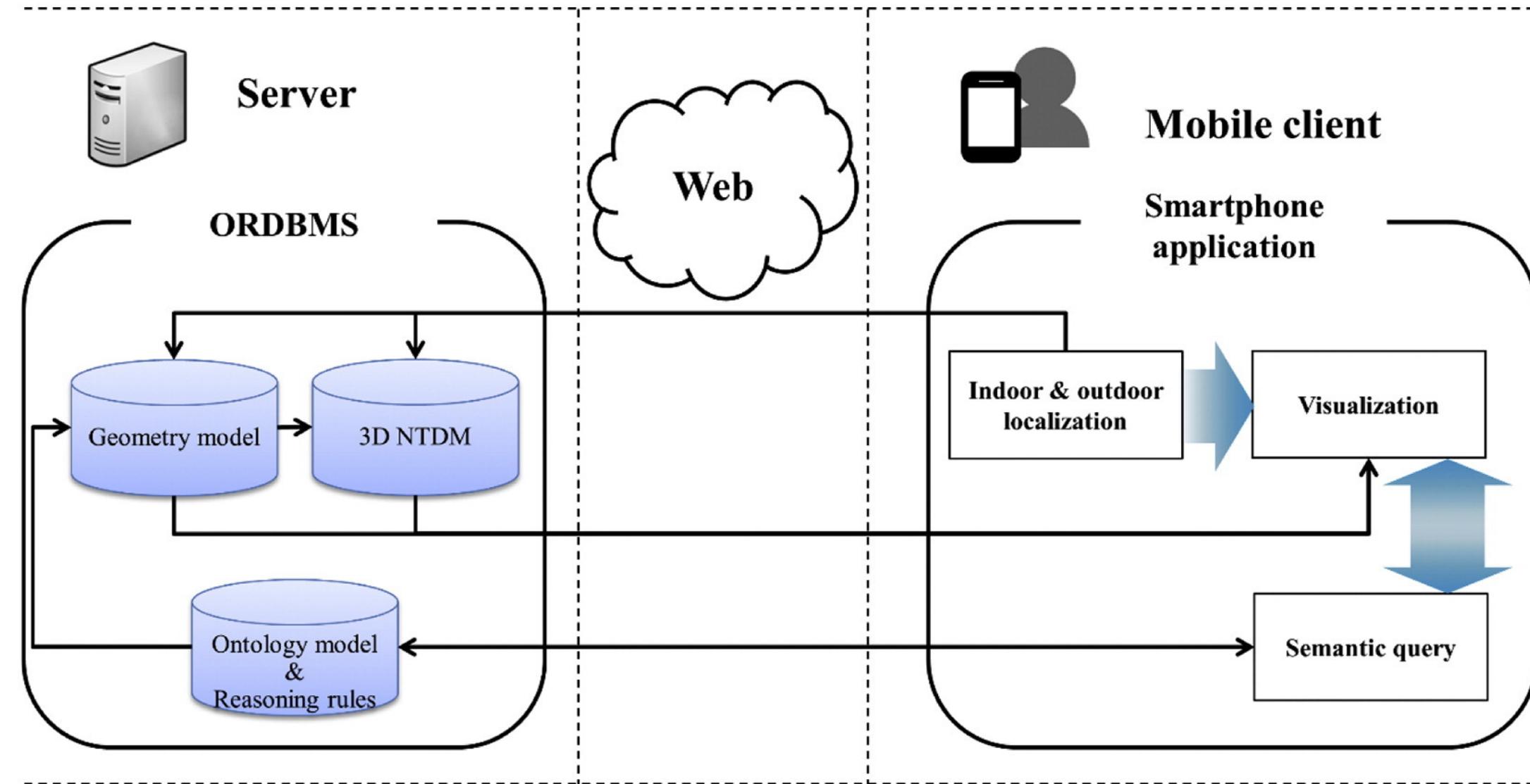
*"How to provide context to Physical Things?"*

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

# Related Work



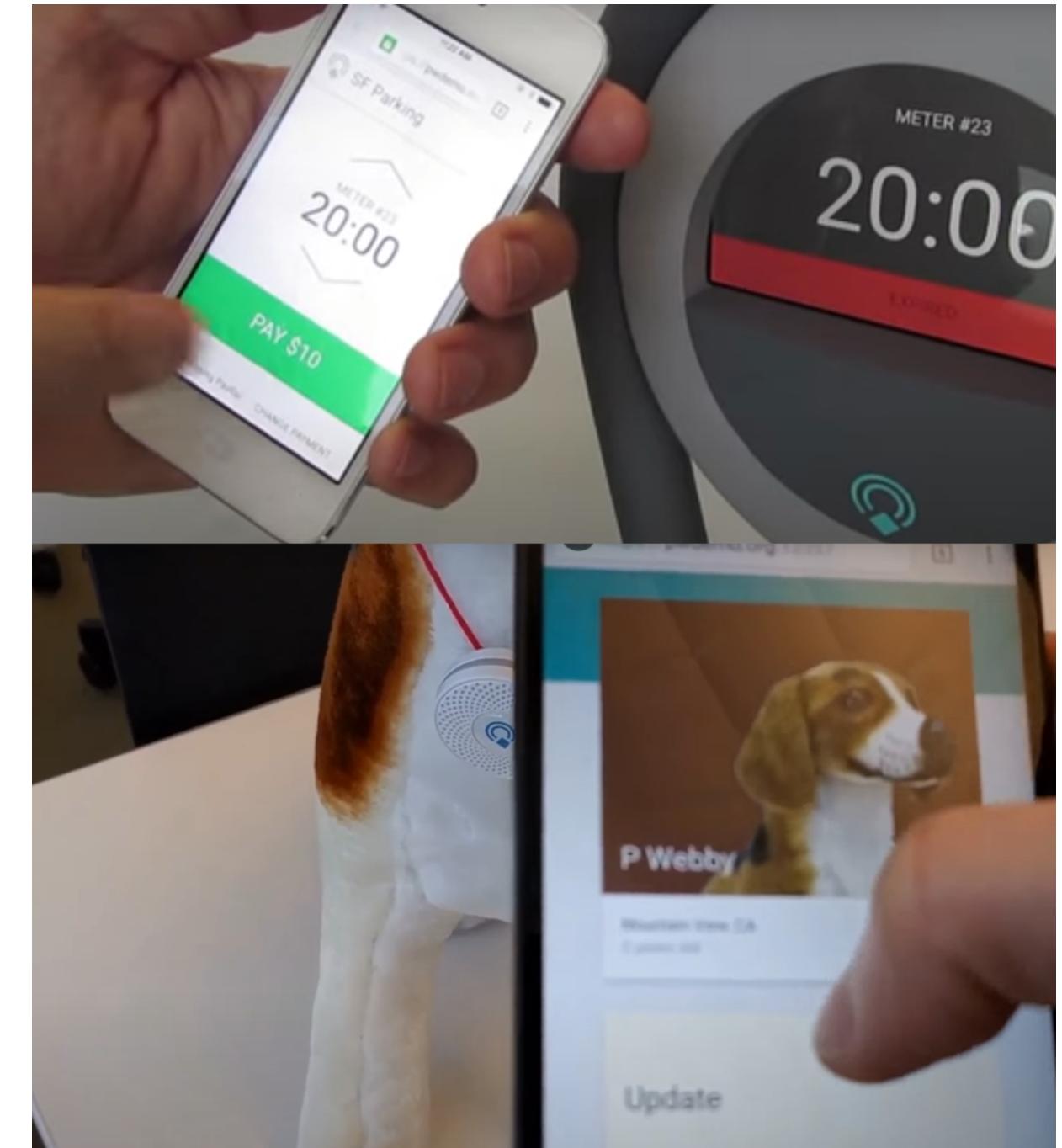
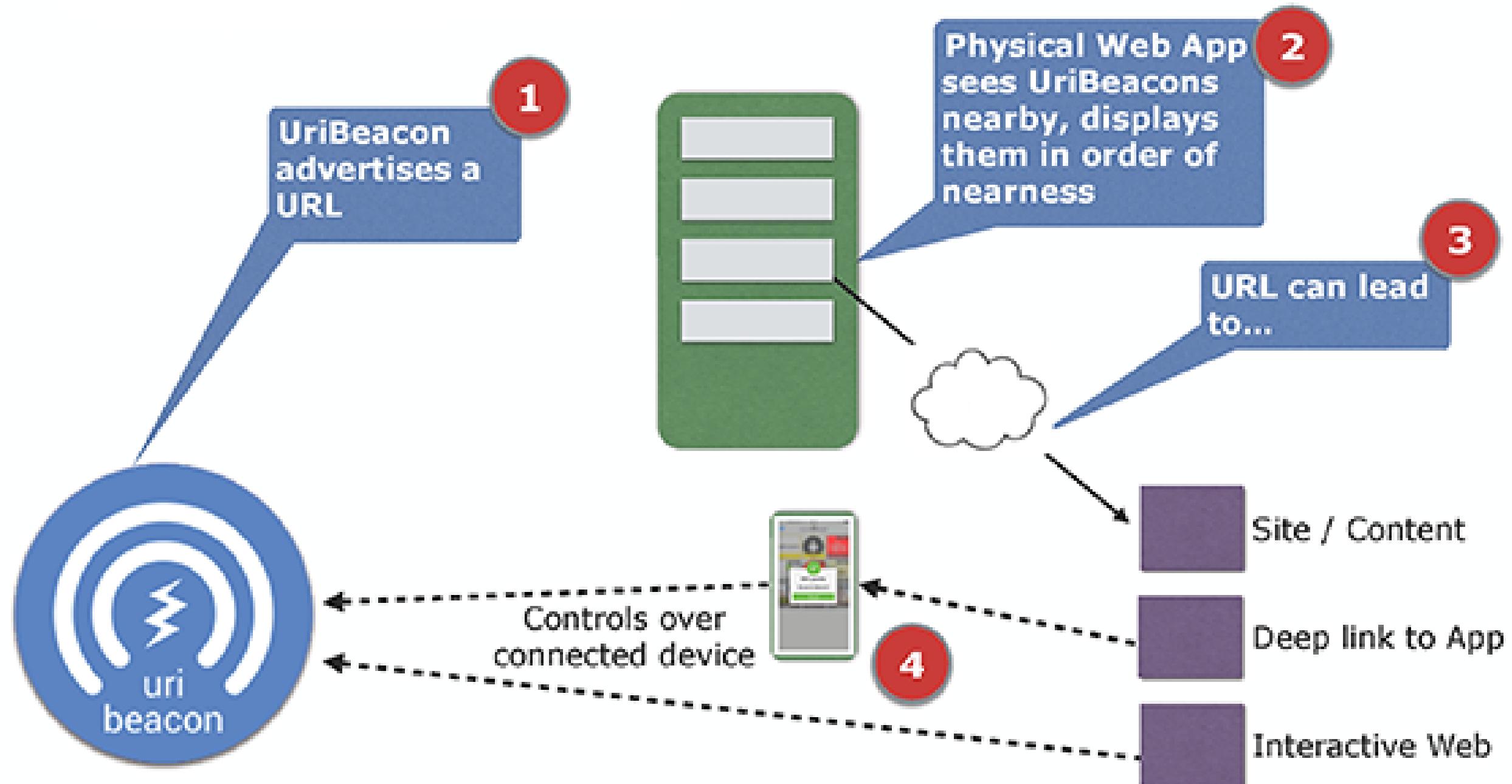
- HP CoolTown Beacon (2000) [26]



- Location-based service using ontology-based semantic queries (2017) [18]

# Related Work > Physical Web

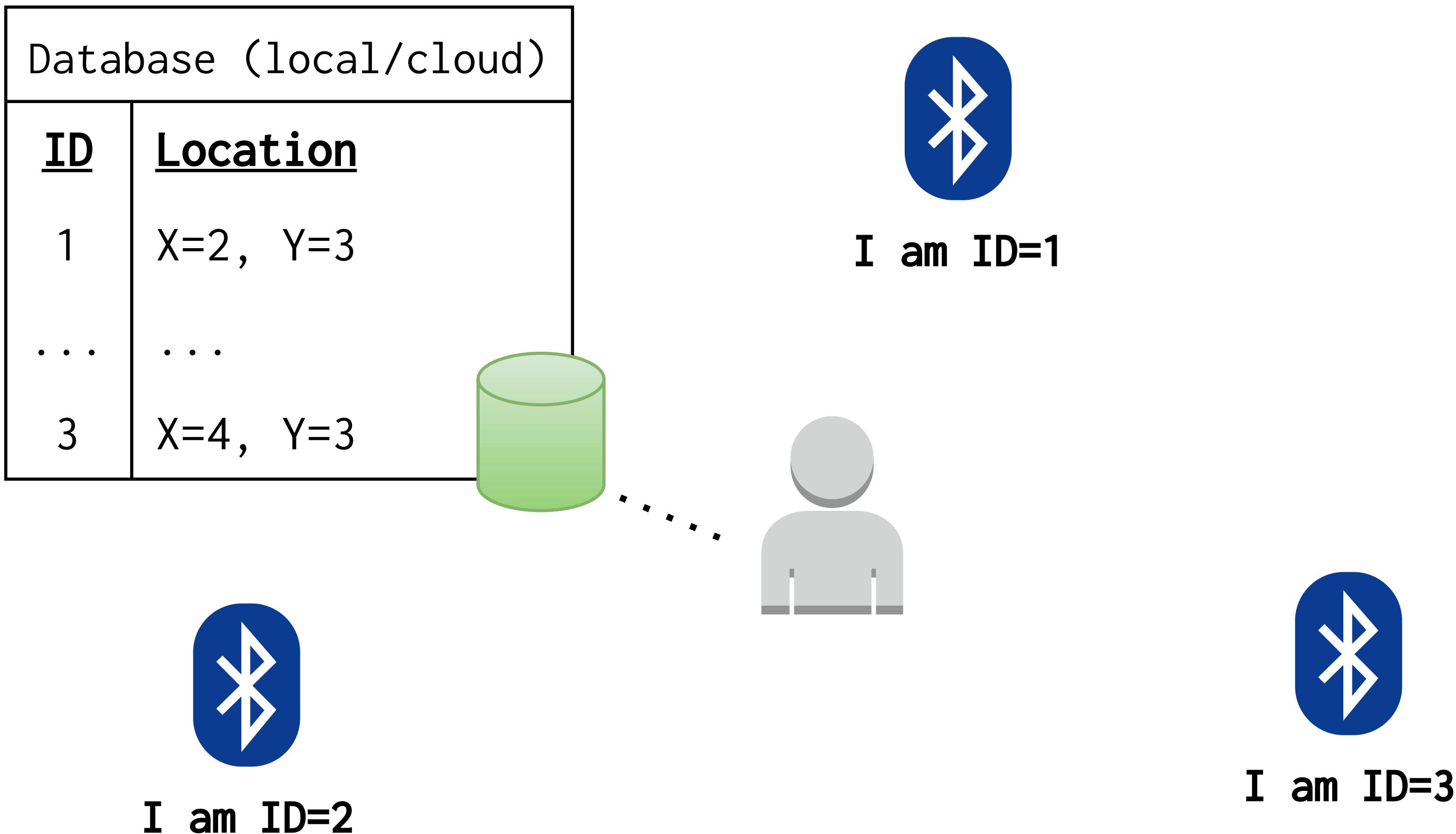
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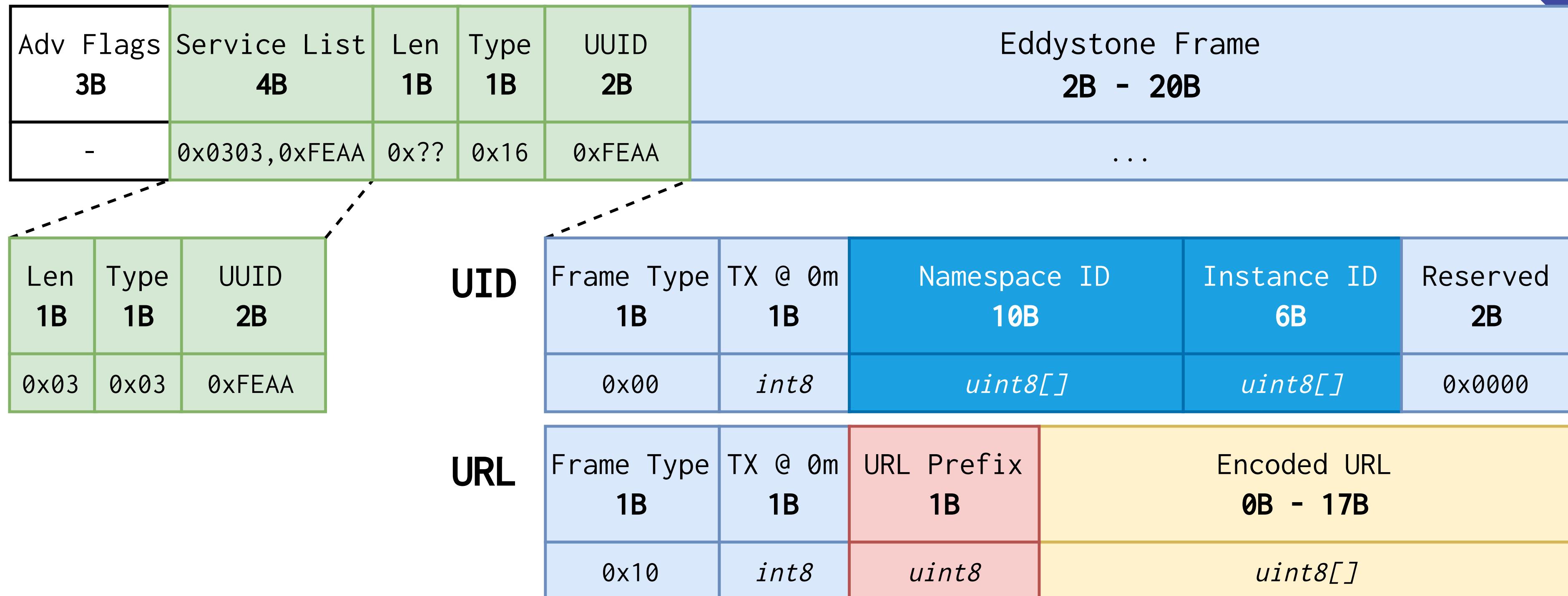
- Manfred Sneps-Sneppe, Dmitry Namiot, "On Physical Web models" (2016)

# Bluetooth Low Energy (BLE) > Positioning

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# BLE Specifications > Eddystone



# BLE Specifications > iBeacon & AltBeacon

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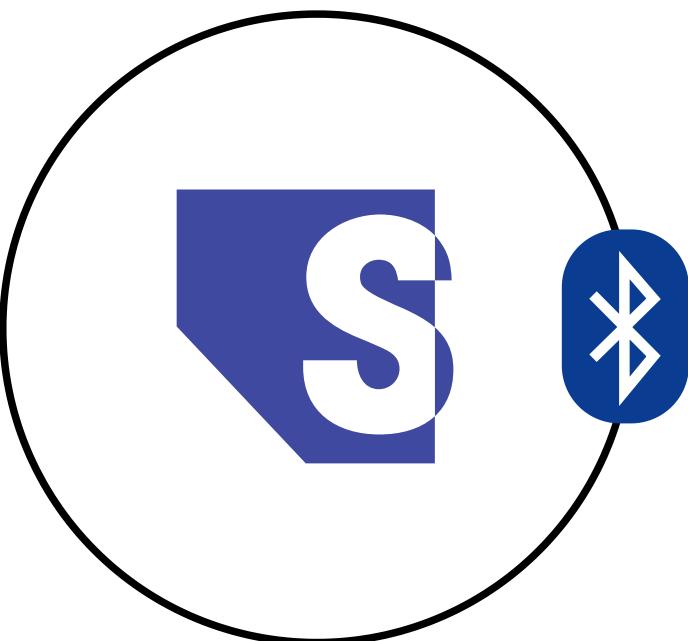
## iBeacon Advertisement Data (30 bytes)

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	<i>uint8[]</i>	<i>uint16</i>	<i>uint16</i>	<i>int8</i>	

## 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	<i>uint16</i>	0xBEAC	<i>uint8[]</i>	<i>int8</i>	-

# SemBeacon



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

I do not know your namespace

Check <https://bit.ly/3JsEnF9>



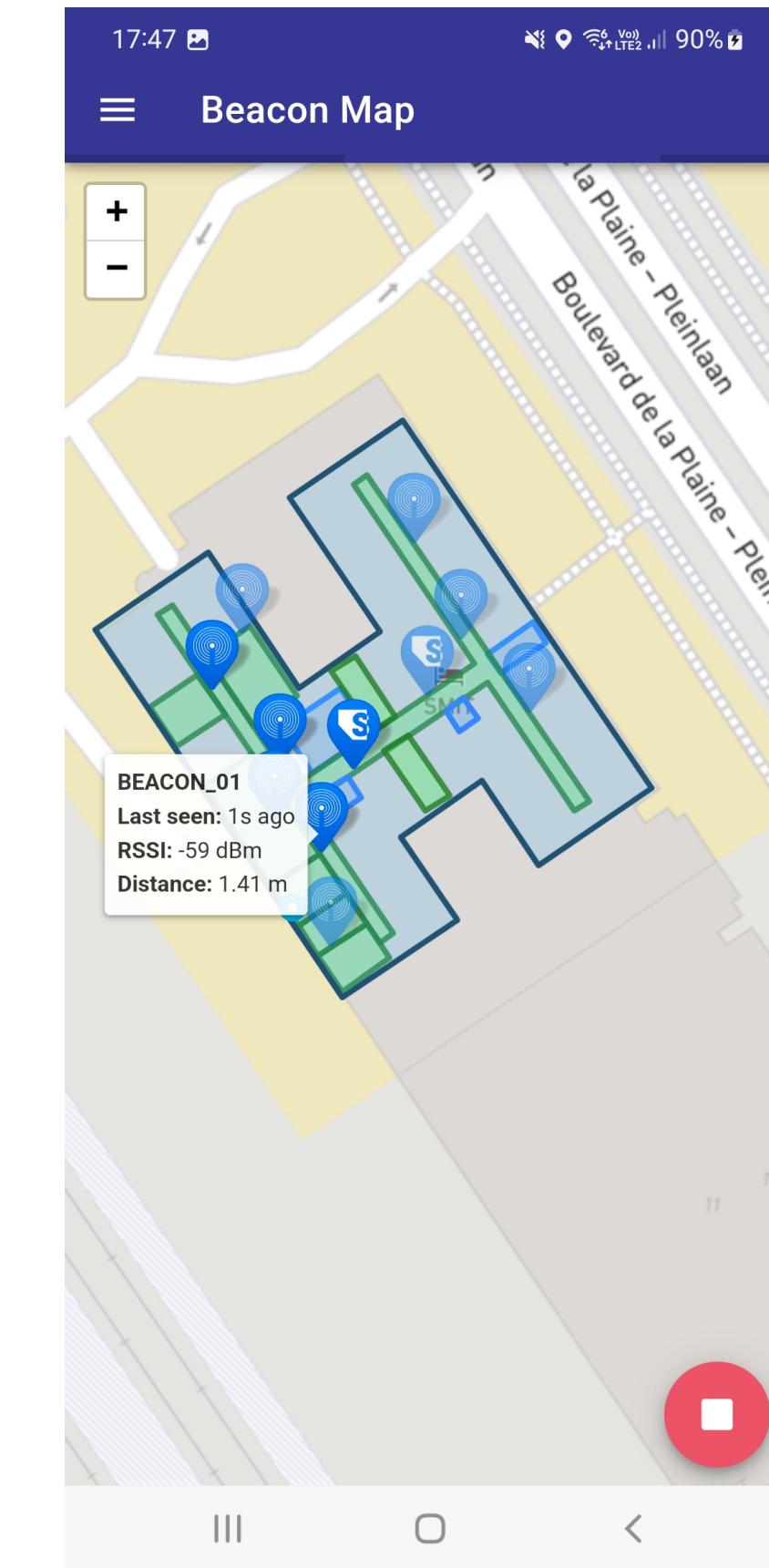
HTTP GET (Accept: text/turtle,  
application/rdf+xml)

Linked data response

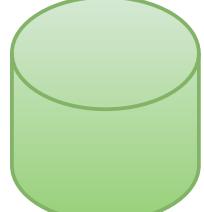
**POSO**



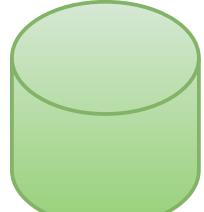
Open  
Geospatial  
Consortium



Check cache



Cache <namespace>  
and all beacons  
within response



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# SemBeacon > Bluetooth Specification

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## BLE 4.X

**SemBeacon Advertisement Data (31 bytes)** Bluetooth 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)** Bluetooth 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'	

# SemBeacon > Bluetooth Specification

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## Flags

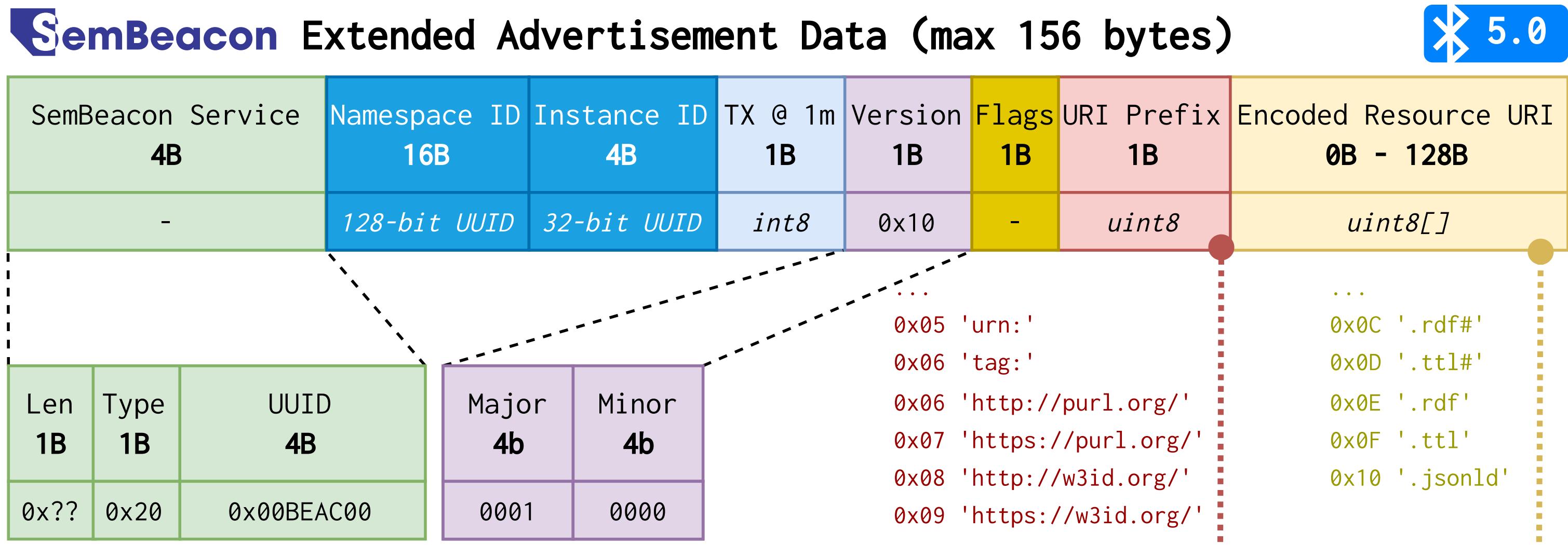
Based on UriBeacon, Bluetooth IPS and Eddystone frames

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	<i>Reserved for future use.</i>	

# SemBeacon > Bluetooth Specification

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## BLE 5.X (Work in Progress)



# SemBeacon > Namespace and Instance



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

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

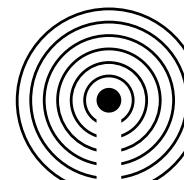


`http://other.org/beacons.ttl#`

```
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`



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



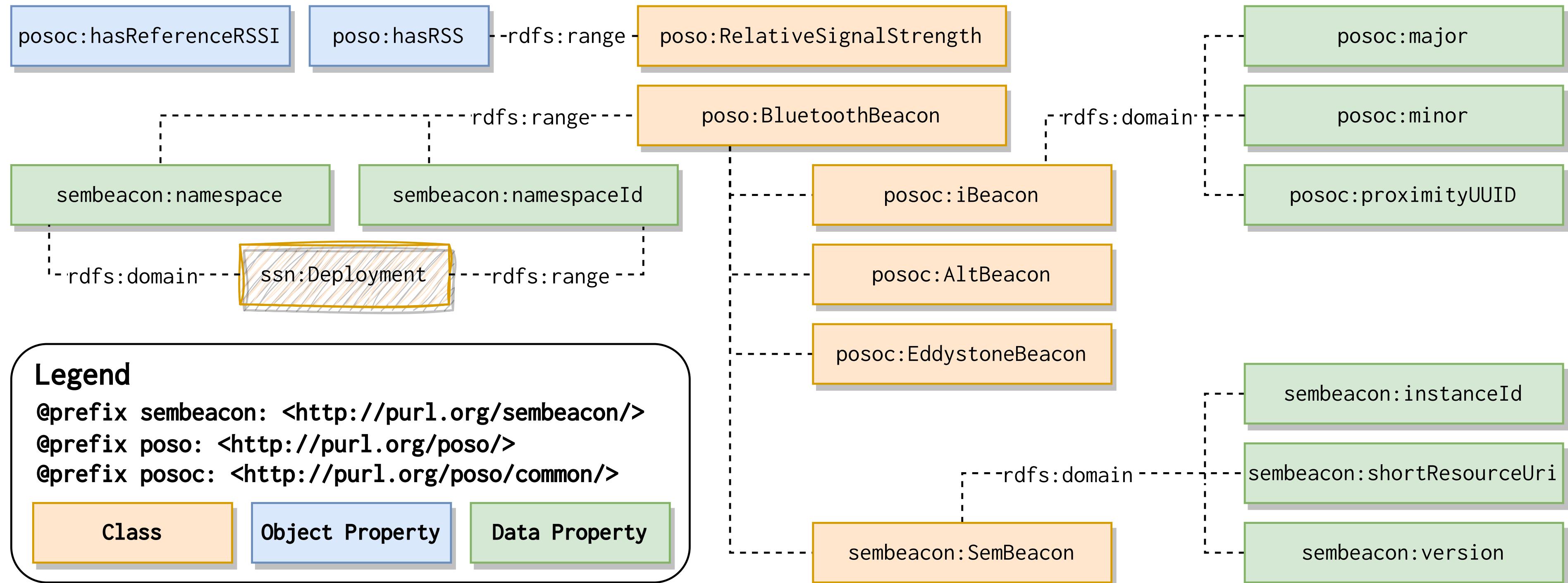
**Namespace ID:** 0x08483bc99d448c83bff6cb9d5bccd40d  
**Instance ID:** 0x00000001  
**Resource URI:** `http://other.org/beacons.ttl#b1`  
**Short Resource URI:** `https://tinyurl.com/bdmbu7jb`



**Type:** AltBeacon  
**ID:** 0x08483bc99d448c83bff6cb9d5bccd40d00000003



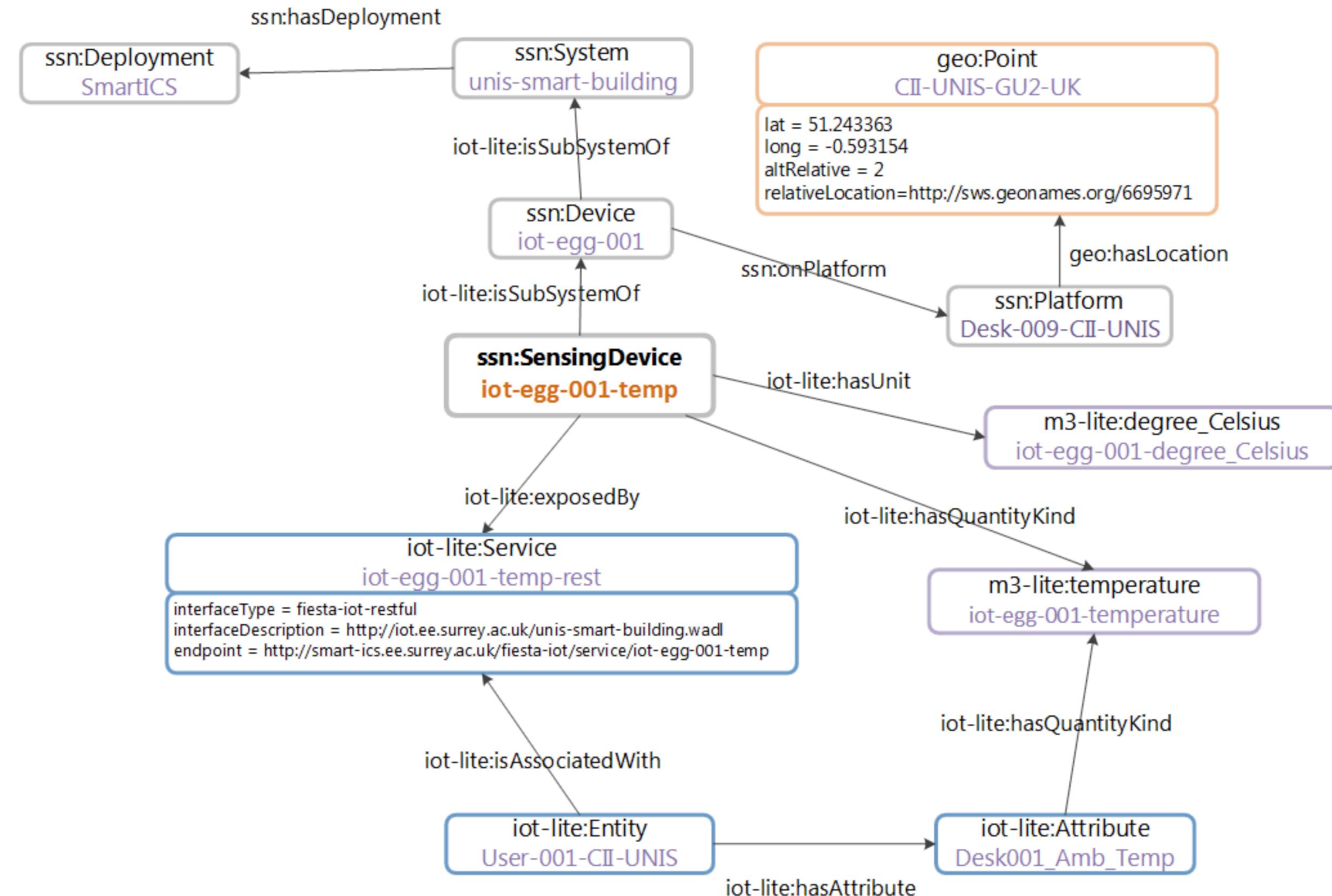
# SemBeacon > POSO Extension



# SemBeacon > Device Interactions

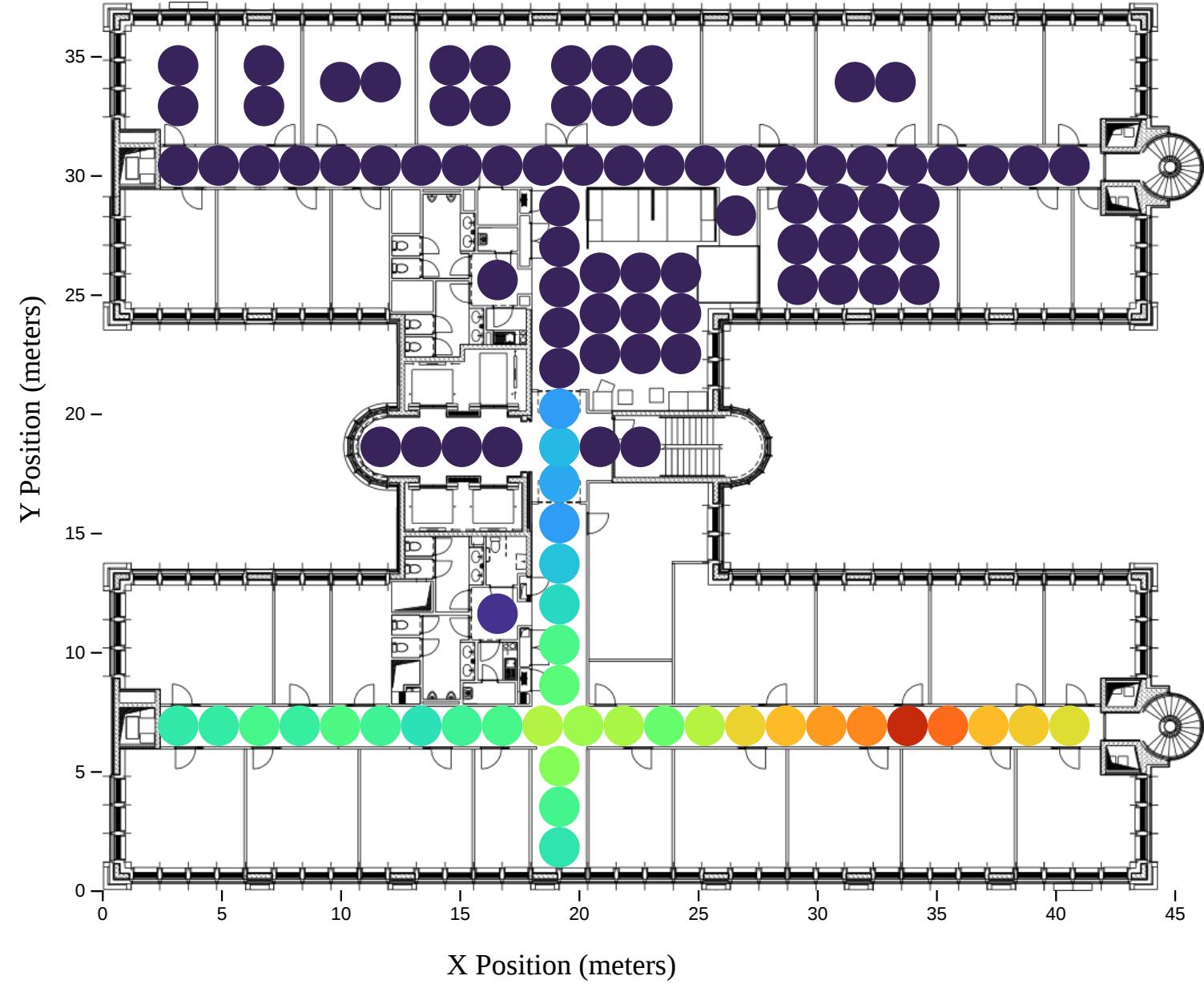
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M. Bermudez-Edo, T. Elsaleh et al. "IoT-Lite Ontology", November 2015

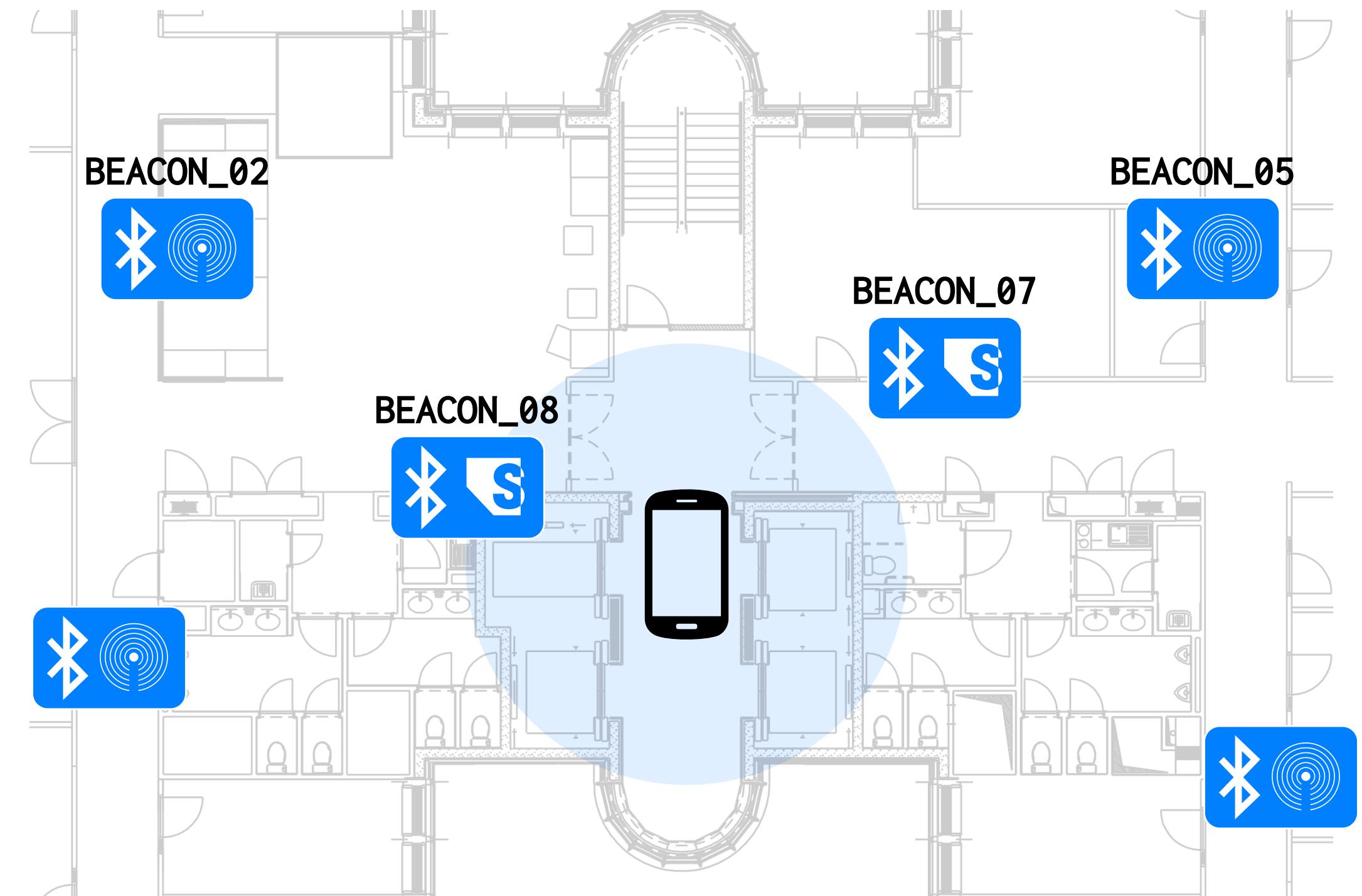


# Demonstrator > Dataset & Recreation

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



# 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:double;  
        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.
```

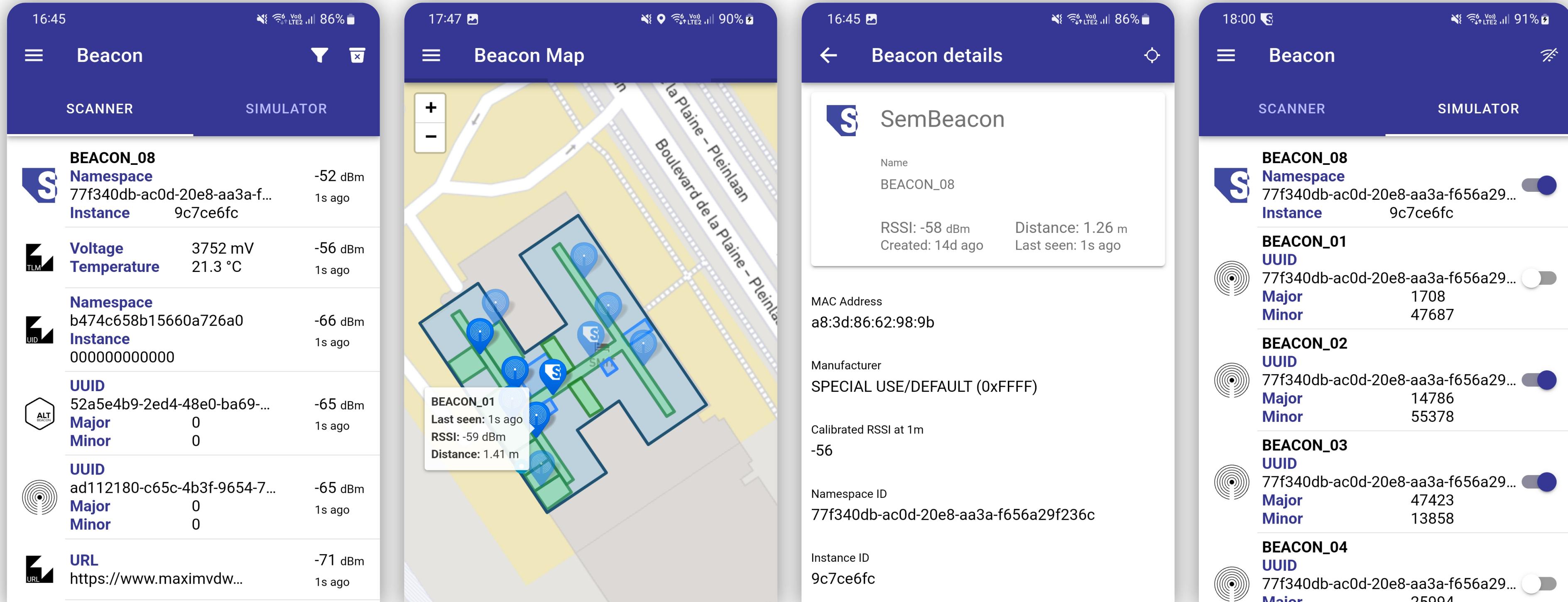
# Demonstrator > Transformation

<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 50.82044181(
    4.3922413107 50.820372691 92, 4.3918880594 50.820703046 92, 4.3920500197 50.82077216!
    ...
    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,
    4.392237888085379 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