

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

---

Maxim Van de Wynckel, Beat Signer

*Web & Information Systems Engineering Lab*  
*Vrije Universiteit Brussel*



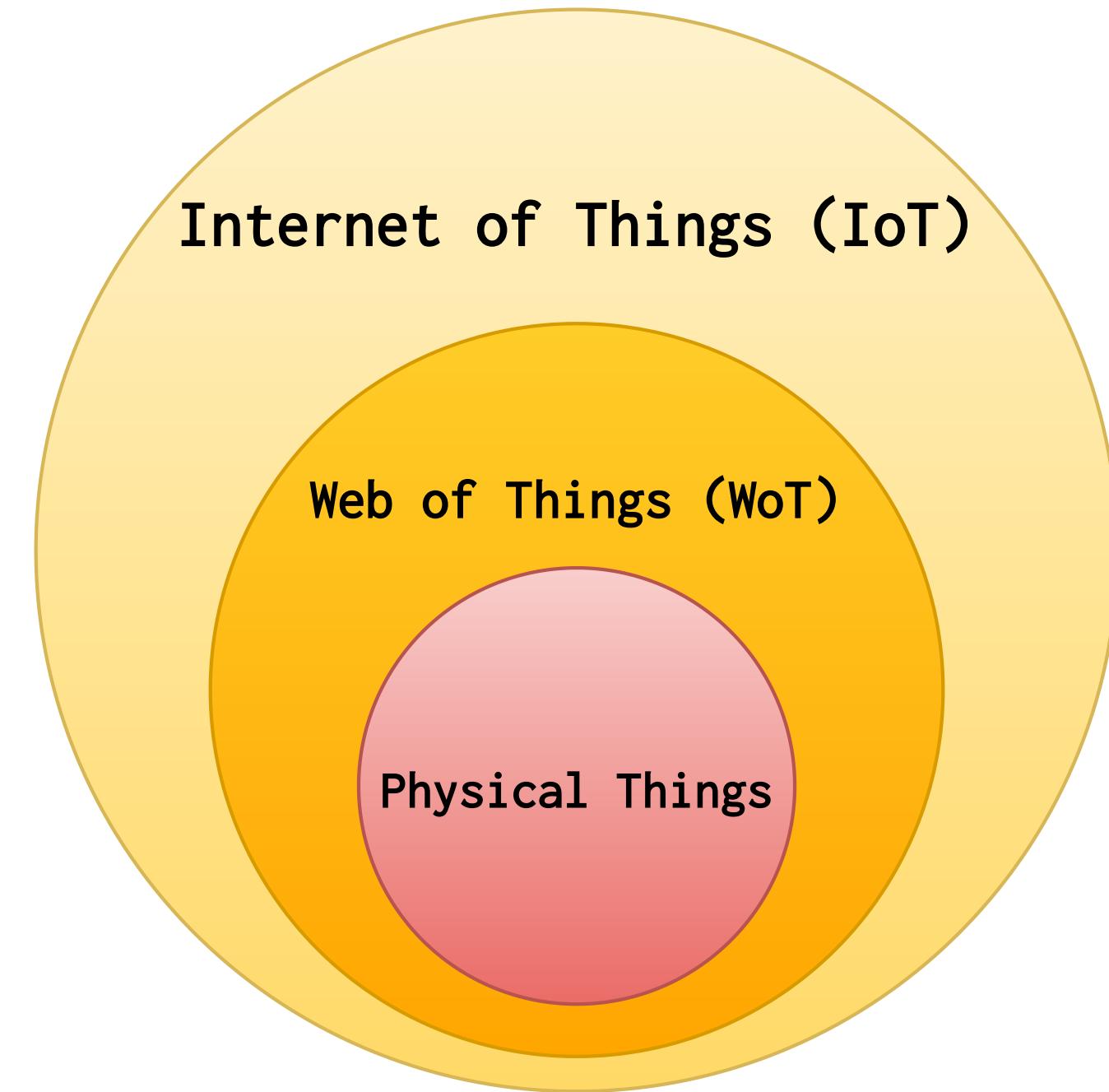
WEB & INFORMATION  
SYSTEMS ENGINEERING



# Overview

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

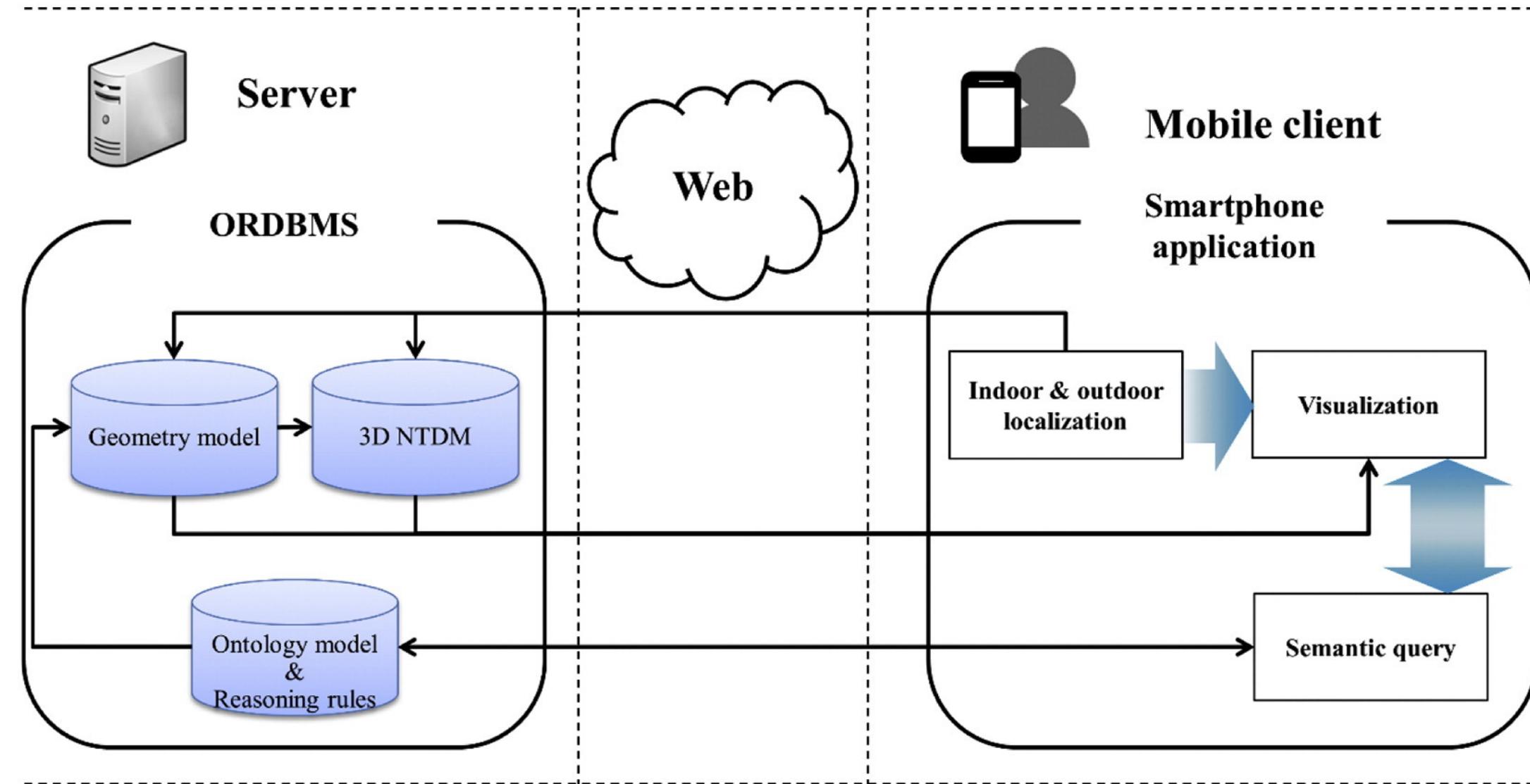
- W3C Web of Things (WoT) Thing Description 1.1



# Problem Statement

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

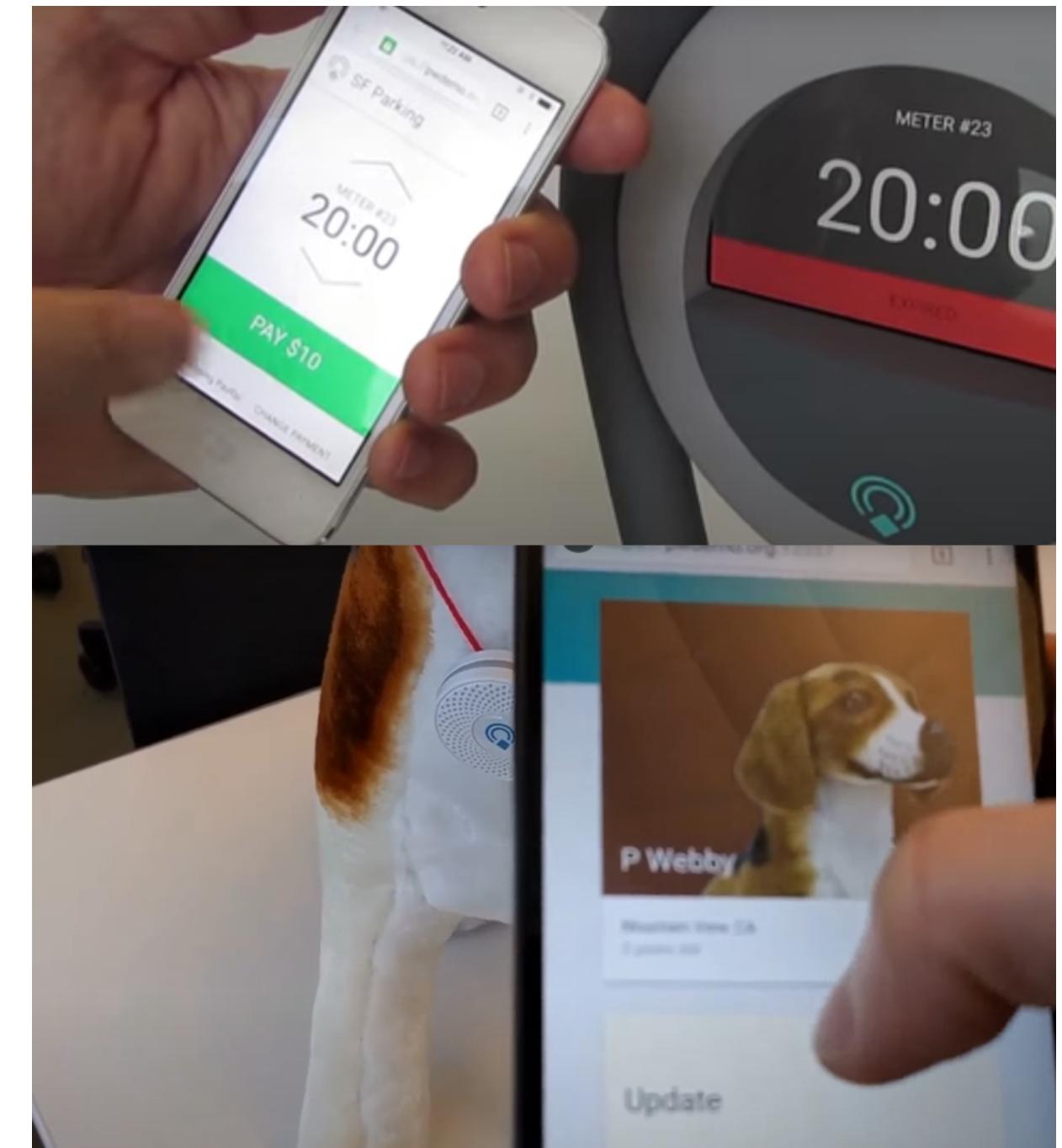
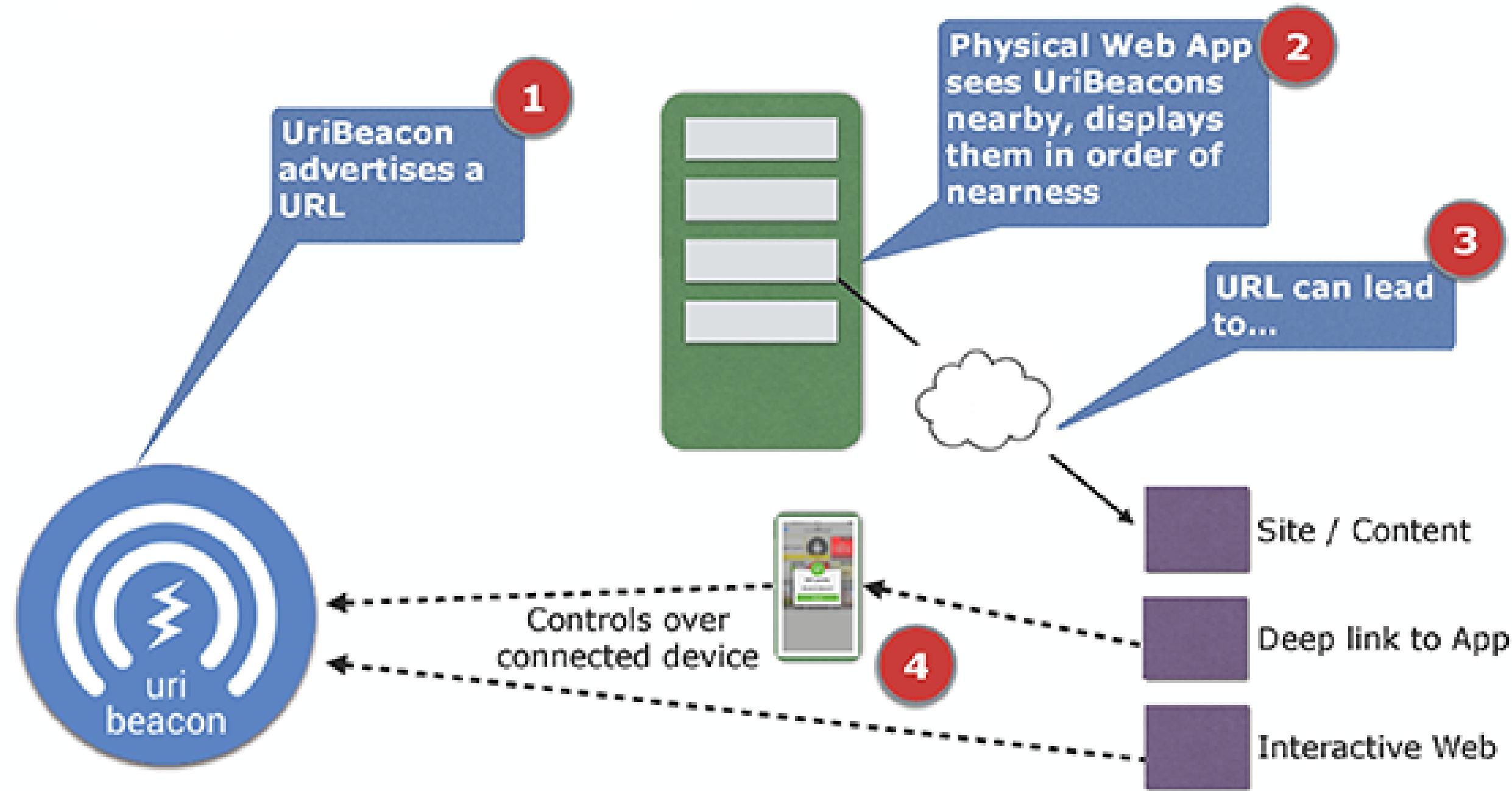
# Related Work



- HP CoolTown Beacon (2000) [26]

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

# Related Work ...

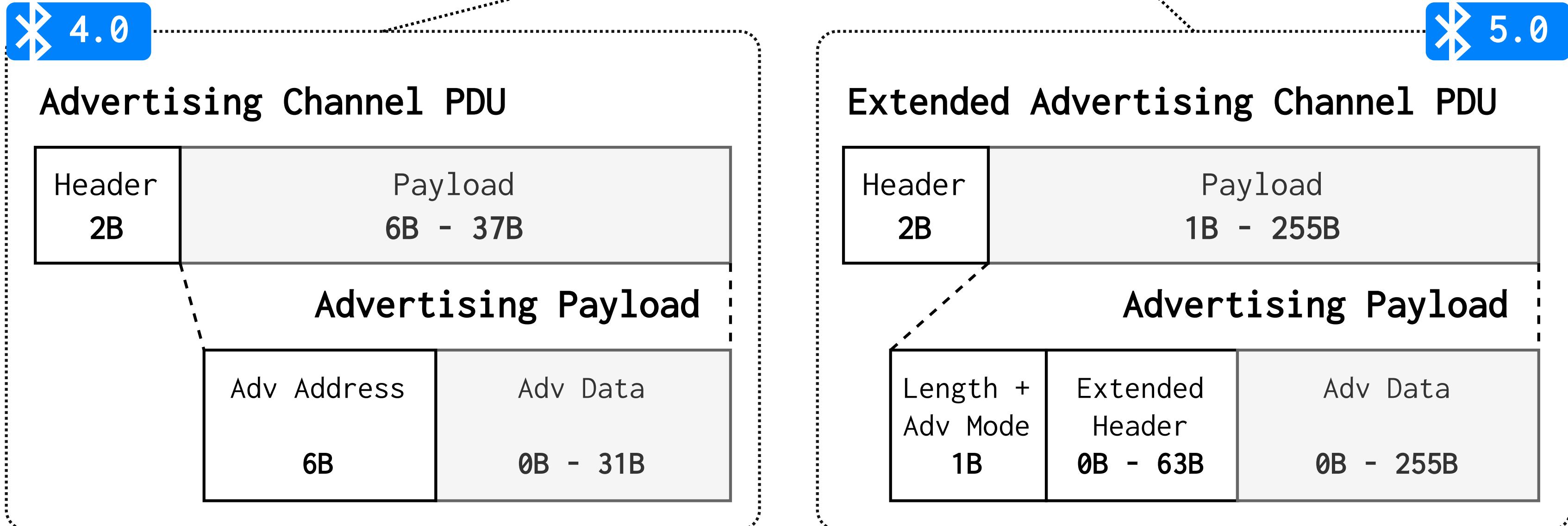
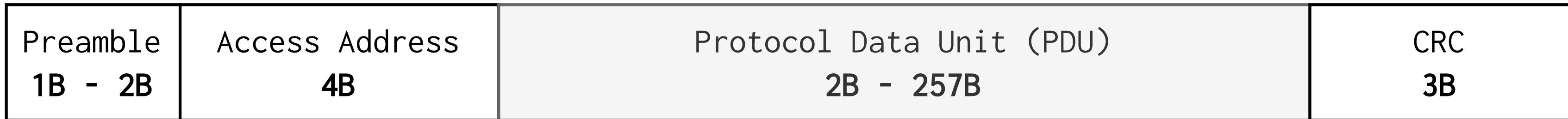


- Manfred Sneps-Sneppe, Dmitry Namiot, "On Physical Web models" (2016)

# Bluetooth Low Energy (BLE)

S

## BLE Packet



# BLE Specifications ...

S

## Eddystone Advertisement Data (max 31 bytes)

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	<i>int8</i>	<i>uint8[]</i>	<i>uint8[]</i>	0x0000

**URL**

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

# BLE Specifications ...

S

## 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>	-

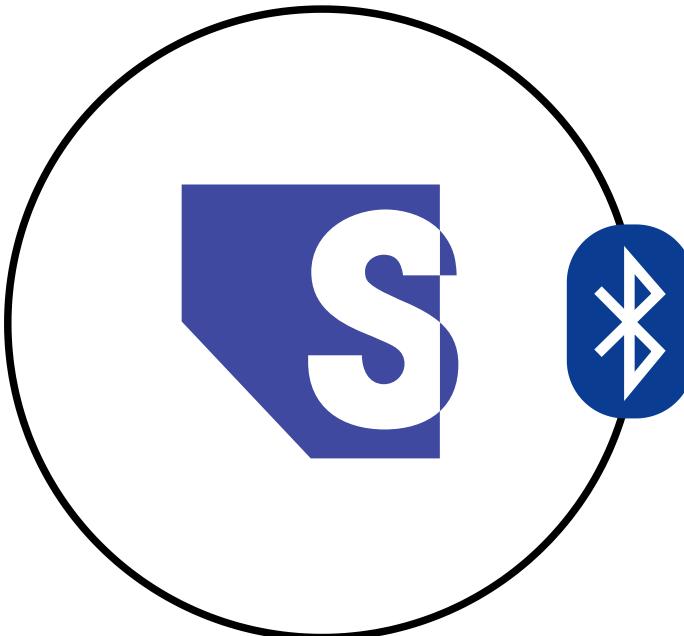
# BLE Specifications ...

## Bluetooth IPS Advertisement Data (24 bytes)

Adv Flags	Len	Type	Flags	Lat	Long	North	East	TX Power	Floor	Altitude	Uncertainty	RFU
3B	1B	1B	1B	4B	4B	2B	2B	1B	1B	2B	1B	1B

Bit (MSB)	Description
0	Presence of coordinates in advertising packet
1	Coordinate system used (WGS84 or <i>local</i> )
2	Presence of TX Power field in advertising packet
3	Presence of Altitude field in advertising packet
4	Presence of Floor Number in advertising packet
5	Presence of Uncertainty in advertising packet
6	Location Name available in GATT database

# SemBeacon Solution



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

I do not know your namespace

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



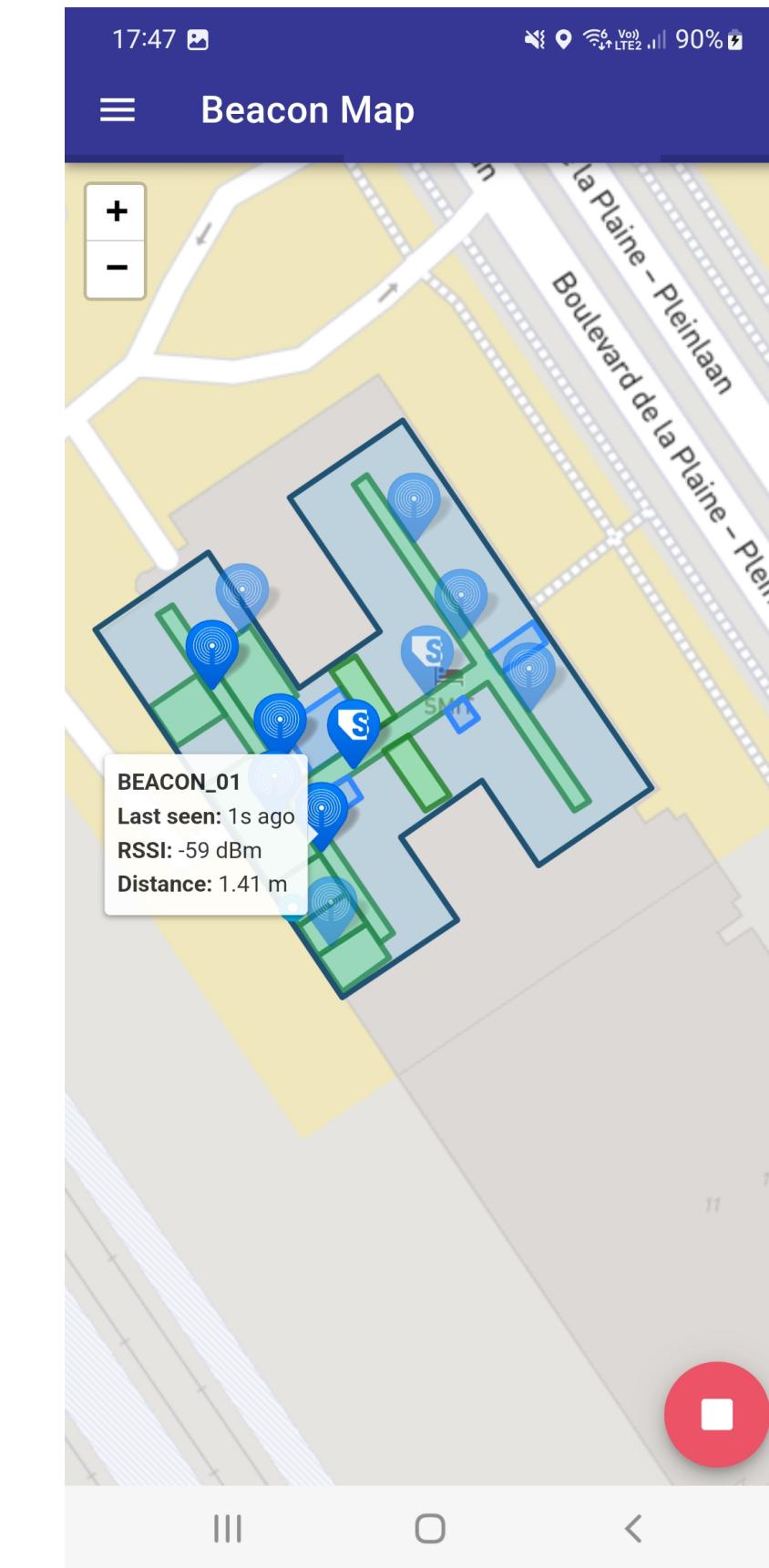
HTTP GET (Accept: text/turtle,  
application/rdf+xml)

Linked data response

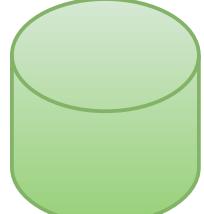
**POSO**



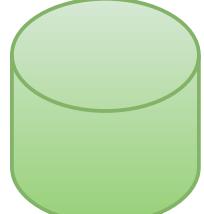
Open  
Geospatial  
Consortium



Check cache



Cache <namespace>  
and all beacons  
within response



S

# SemBeacon > Bluetooth Specification

## 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	-	

Len 1B	Type 1B	UUID 2B	Frame 1B	TX @ 0m 1B	URI Prefix 1B	Encoded Short Resource URI 0B - 17B	Bluetooth 4.0
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

S

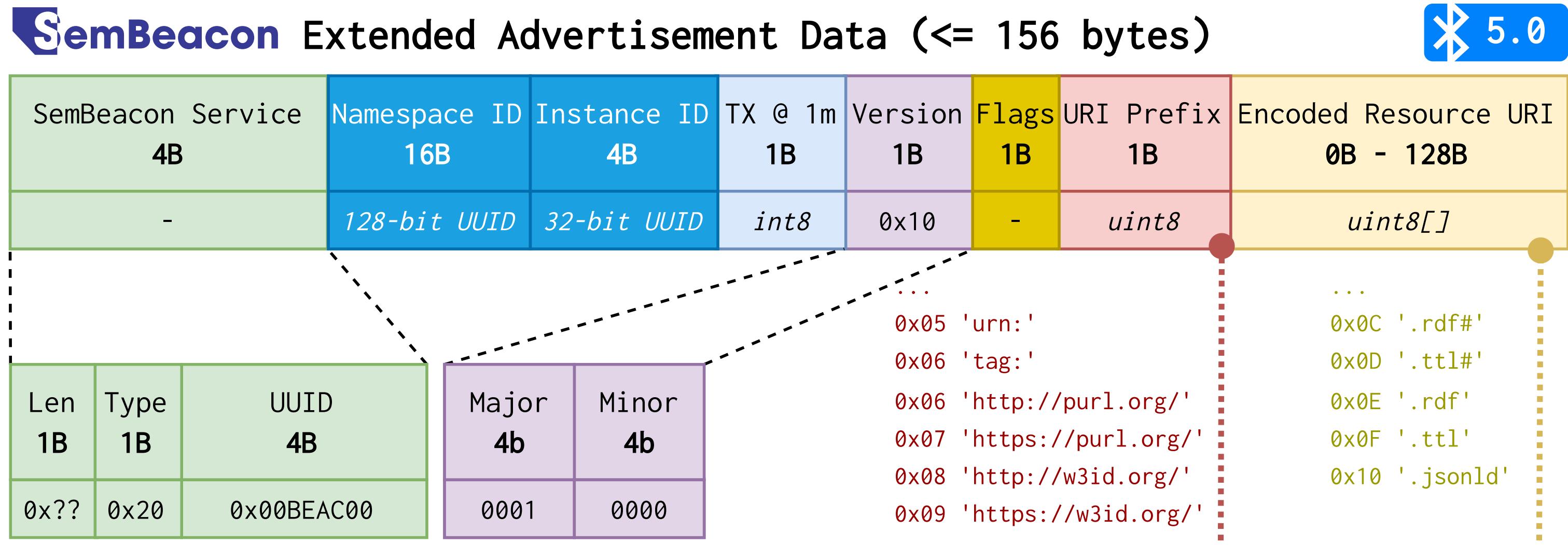
## Flags

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

## 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>

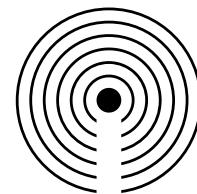


Namespace ID: **0x08483bc99d448c83bff6cb9d5bccd40d**

Instance ID: **0x00000001**

Resource URI: <http://other.org/beacons.ttl#b1>

Short Resource URI: <https://tinyurl.com/bdmbu7jb>



Type: iBeacon

UUID: **0x24d72e569889db5328be761d8488688d**

Major: **0x0000**

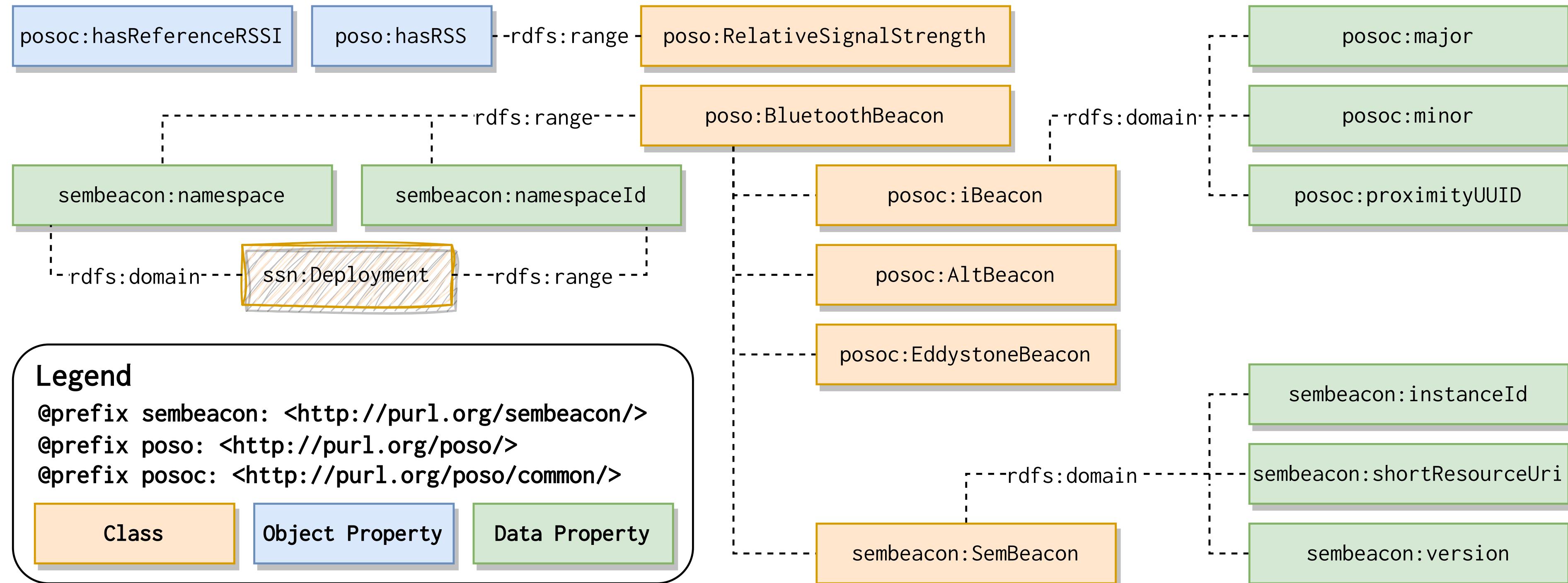
Minor: **0x0003**



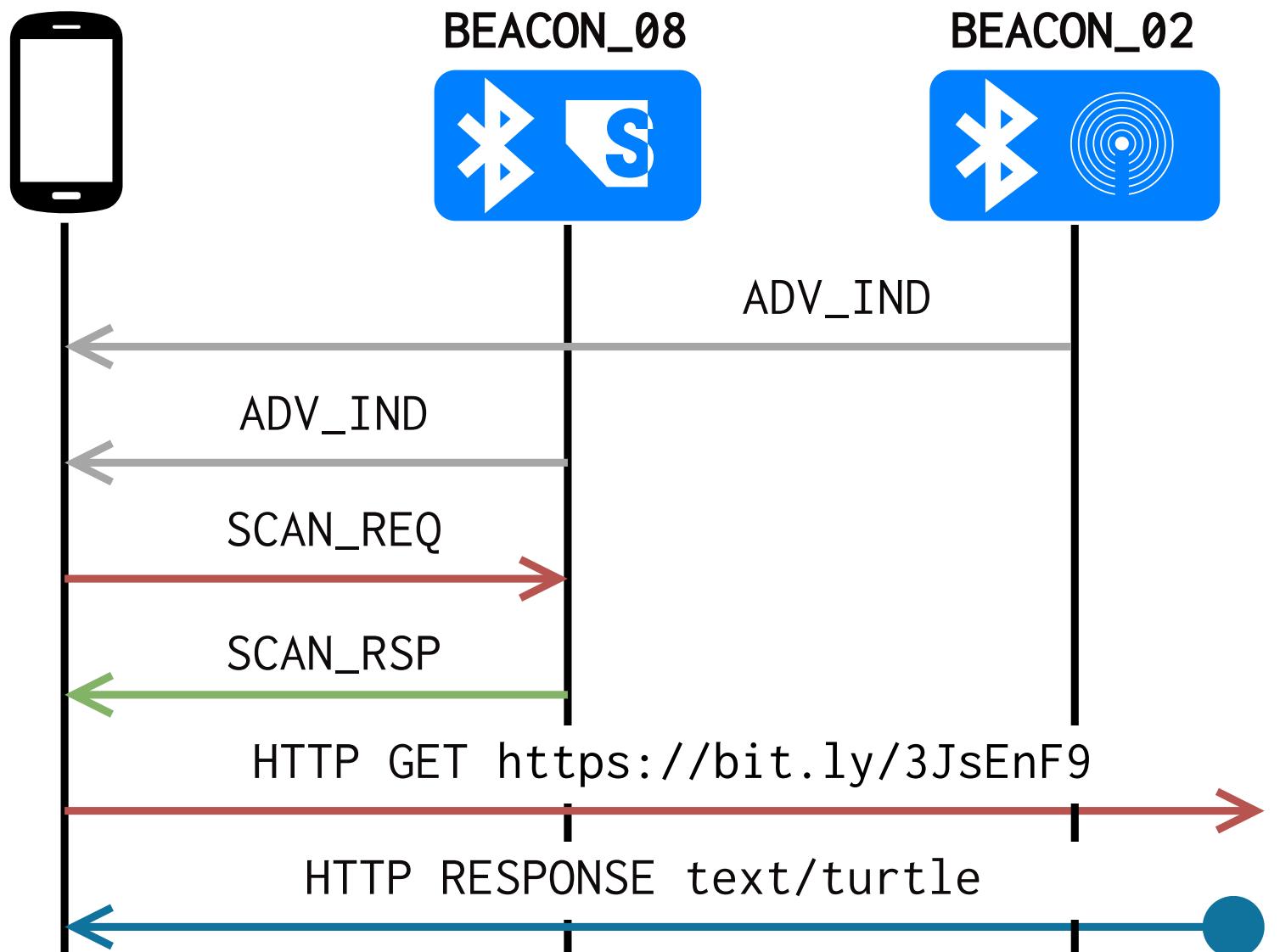
Type: AltBeacon

ID: **0x08483bc99d448c83bff6cb9d5bccd40d00000003**

# SemBeacon > POSO Extension



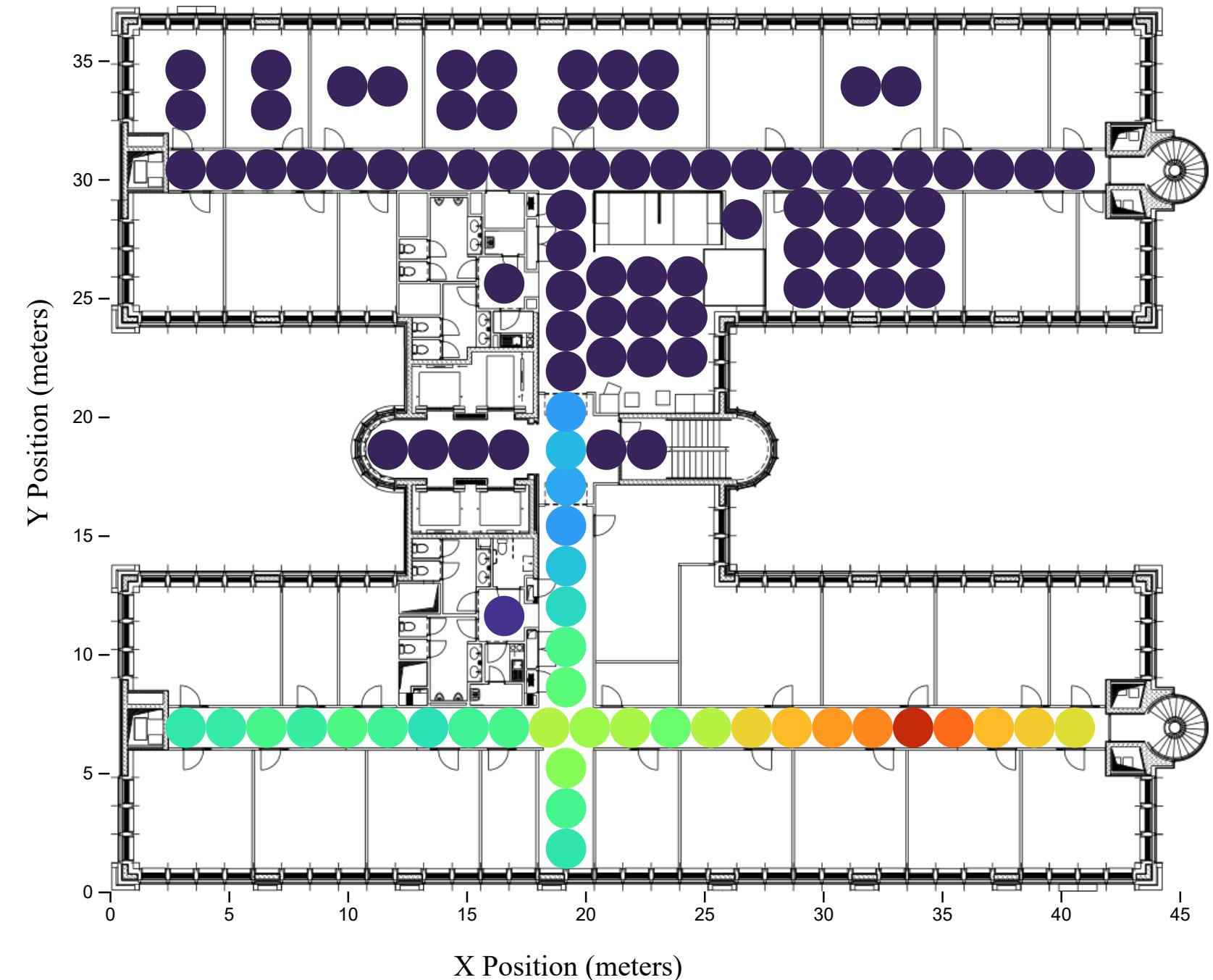
# SemBeacon > Method of Discovery



```
:building_a a ssn:Deployment ;
  rdfs:label "Building A" ;
  sembeacon:namespaceId "e19c5e1ed6a14d..."^^xsd:hexBinary .

:room_a1_2 a sembeacon:SemBeacon ;
  rdfs:label "SemBeacon Room A1.2"@en ;
  rdfs:isDefinedBy <http://sembeacon.org/example.ttl#> ;
  sembeacon:namespace :building_a ;
  sembeacon:instanceId "beac0101"^^xsd:hexBinary ;
  hardware:mac "00:11:22:33:44:55" ;
  posoc:referenceRSSI [ # Reference RSSI is a ...
    # ... factory calibrated signal strength
  poso:hasRSS [
    qudt:unit unit:Decib_M ; qudt:numericValue -56 ] ;
  # ... measured at a specific distance
  poso:hasRelativeDistance [
    unit:Meter ; qudt:value "1.0"^^xsd:double ] .
] ;
  poso:hasPosition [ a poso:AbsolutePosition ;
  poso:hasAccuracy [ ... ] ; poso:xAxisValue [ ... ] ;
  poso:yAxisValue [ ... ] ; poso:zAxisValue [ ... ] ] .
```

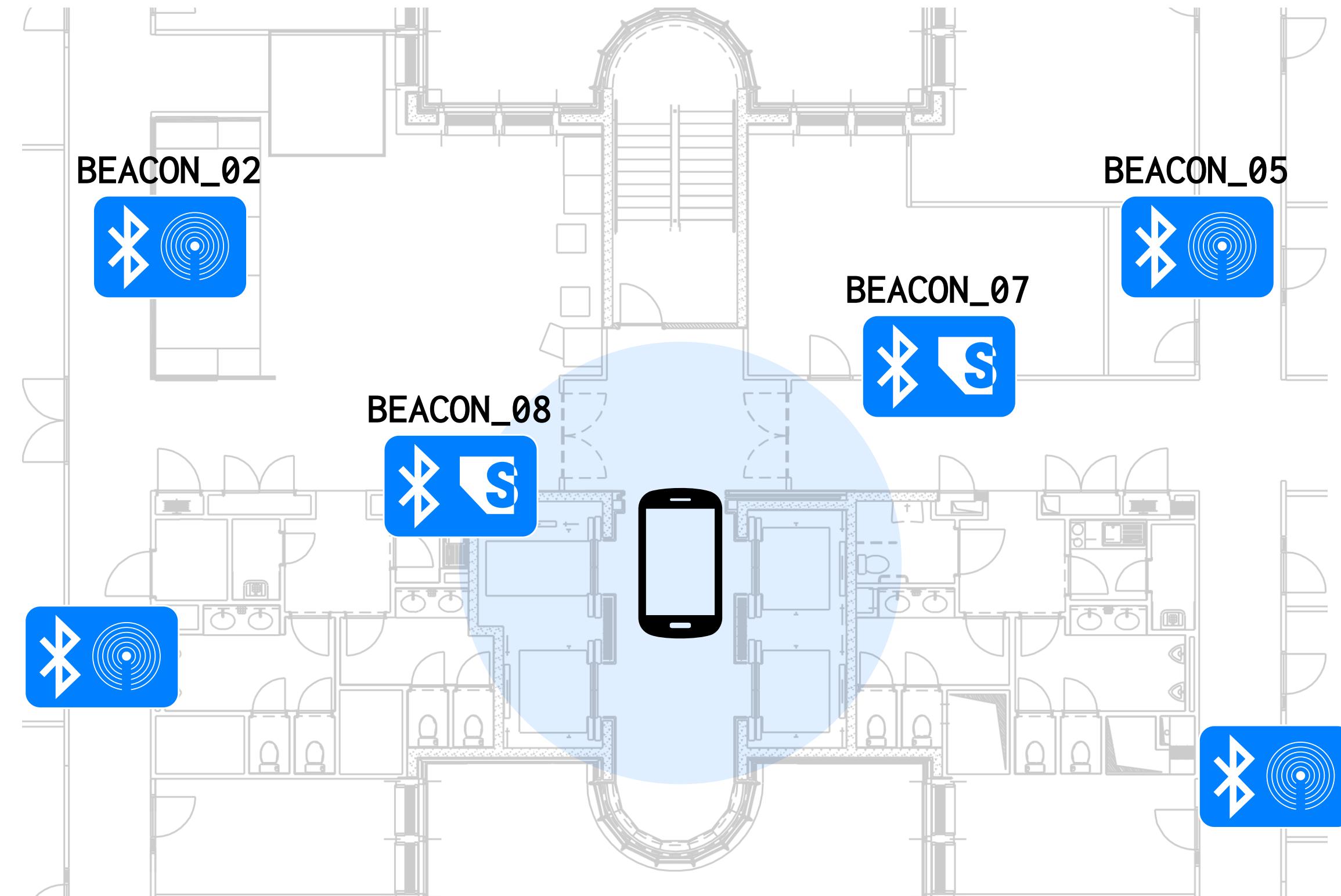
# Demonstrator > Dataset



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

# Demonstrator > Transformation

S



# Demonstrator > Transformation

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

```
: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" .
:pl9_3_lobby_2 a schema:Place, ssn:Deployment, sosa:FeatureOfInterest, ogc:SpatialObject;
  ogc:hasGeometry [ a ogc:Geometry;
    ogc:asWKT "POLYGON Z((4.392530671545053 50.820691696024596 92,
      4.392512343770305 50.82070883604012 92, 4.392448113920621 50.820681425129145 92,
      4.392466441718948 50.820664285113615 92, 4.392530671545053 50.820691696024596 95,
      4.3925123437703055 50.82070883604012 95, 4.392448113920621 50.820681425129145 95,
      4.392466441718948 50.82066428511362 95,
      4.392530671545053 50.820691696024596 92))"^^ogc:wktLiteral;
    ogc:coordinateDimension 3; ogc:spatialDimension 3; ogc:dimension 3 ];
  rdfs:label "Lobby #2" .
```

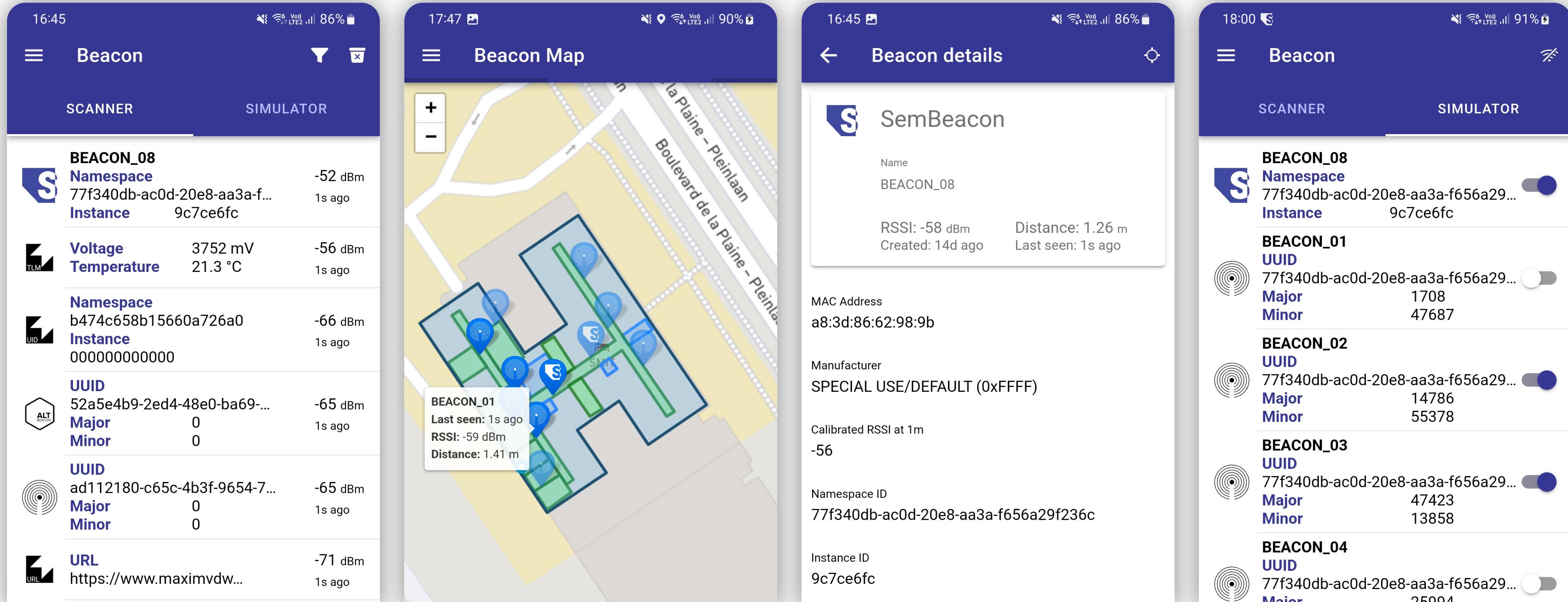
# Demonstrator > Transformation

<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)"^^xsd:wktLiteral;
    ogc:coordinateDimension 3; ogc:spatialDimension 3; ogc:dimension 3;
    dcmi:created "2023-06-22T21:12:23.638Z"^^xsd:dateTime;
    schema:latitude "50.82057562786"^^xsd:double; schema:longitude "4.392253994600"^^xsd:double;
    schema:elevation "93.5999999962"^^xsd:double ];
  posoc:hasReferenceRSSI [ a poso:RelativeSignalStrength;
    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 > Mobile Application

- ▶ Scans and Simulates SemBeacon, iBeacon, AltBeacon and Eddystone
- ▶ Extracts and visualizes 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

- We presented our semantic beacon solution called SemBeacon
- Backwards compatible, offline identification
- Expandable with additional vocabularies
- Expanding to non-BLE beacons (e.g. Ultrawide-band)
- Expanding the vocabulary to facilitate device interactions



- <https://github.com/SemBeacon/>
- <https://sembeacon.org/>
- [Android App on Google Play Store](#)
- Slides can be found on the website

# (Extra) iOS and iBeacon

