

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

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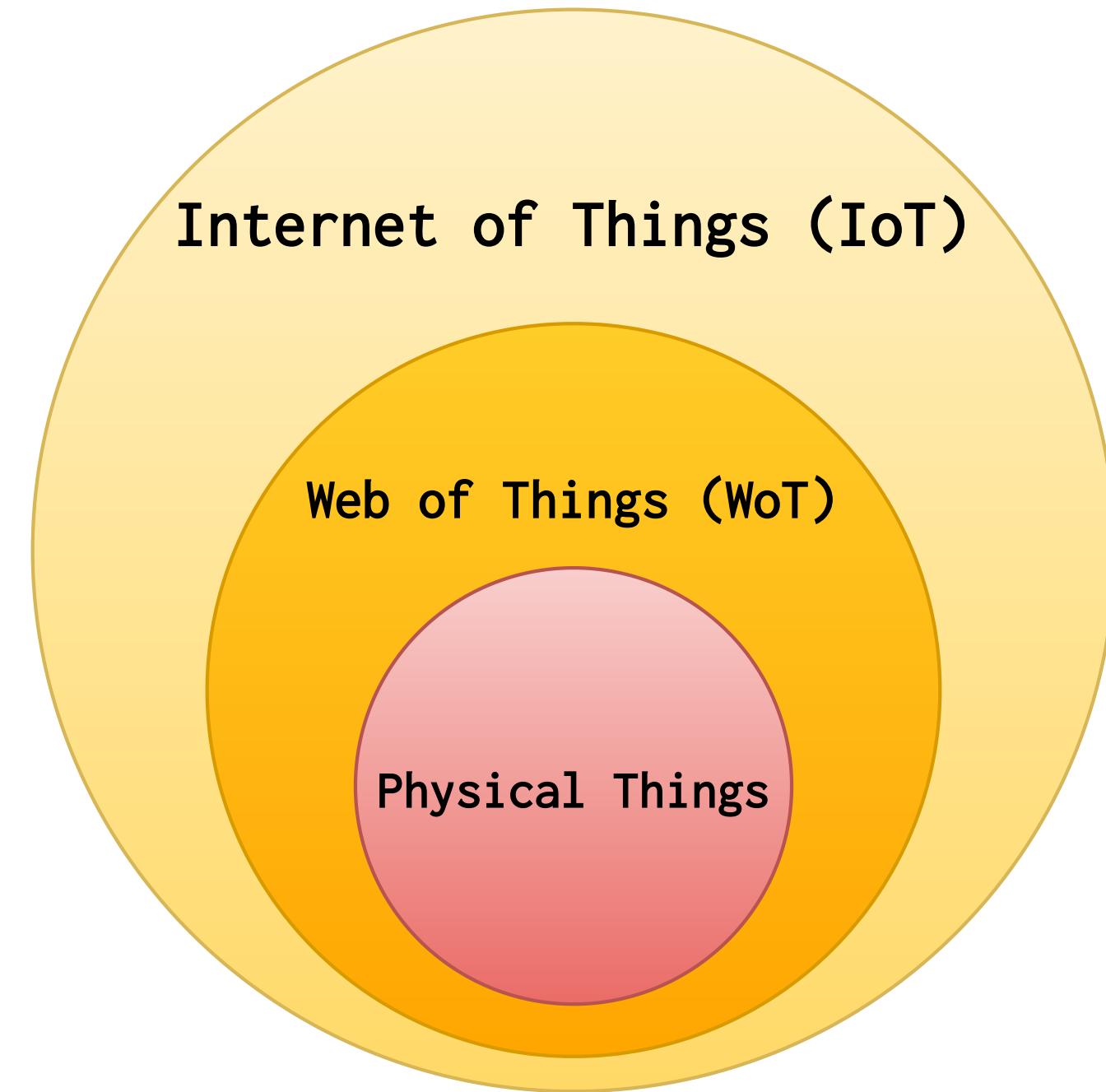
WEB & INFORMATION
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Overview

*"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

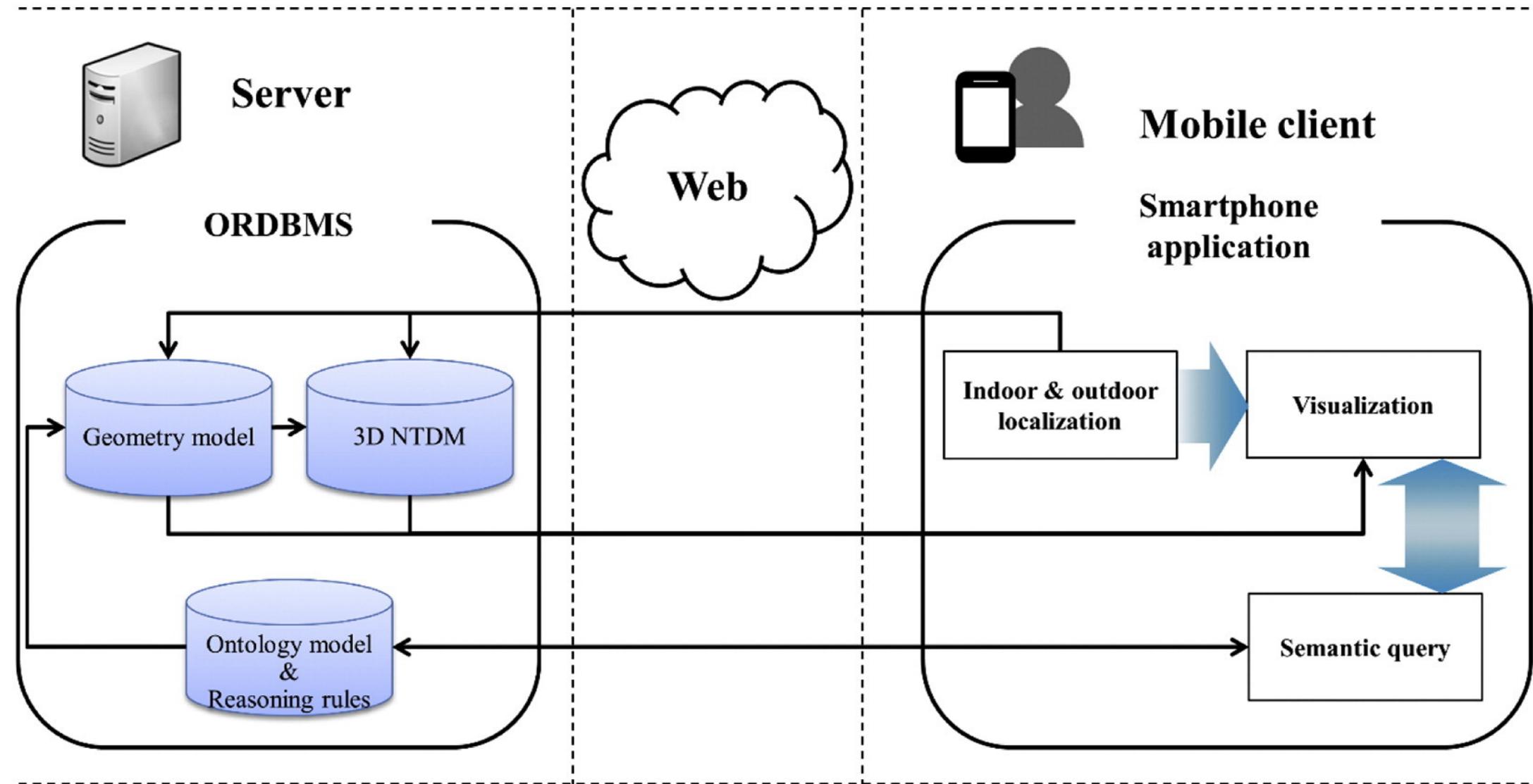


Problem Statement

"How to discover and track Physical Things indoors?"



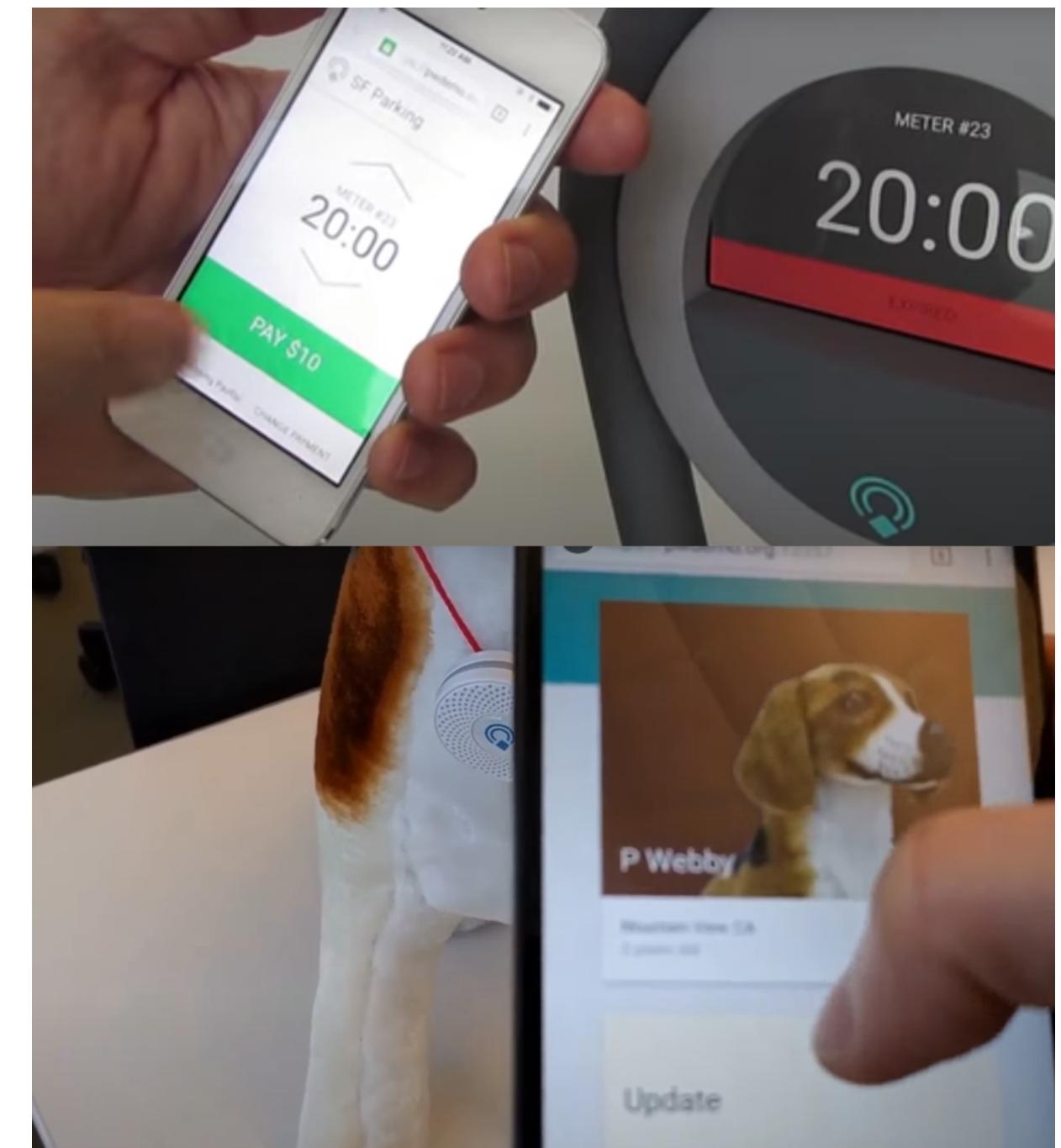
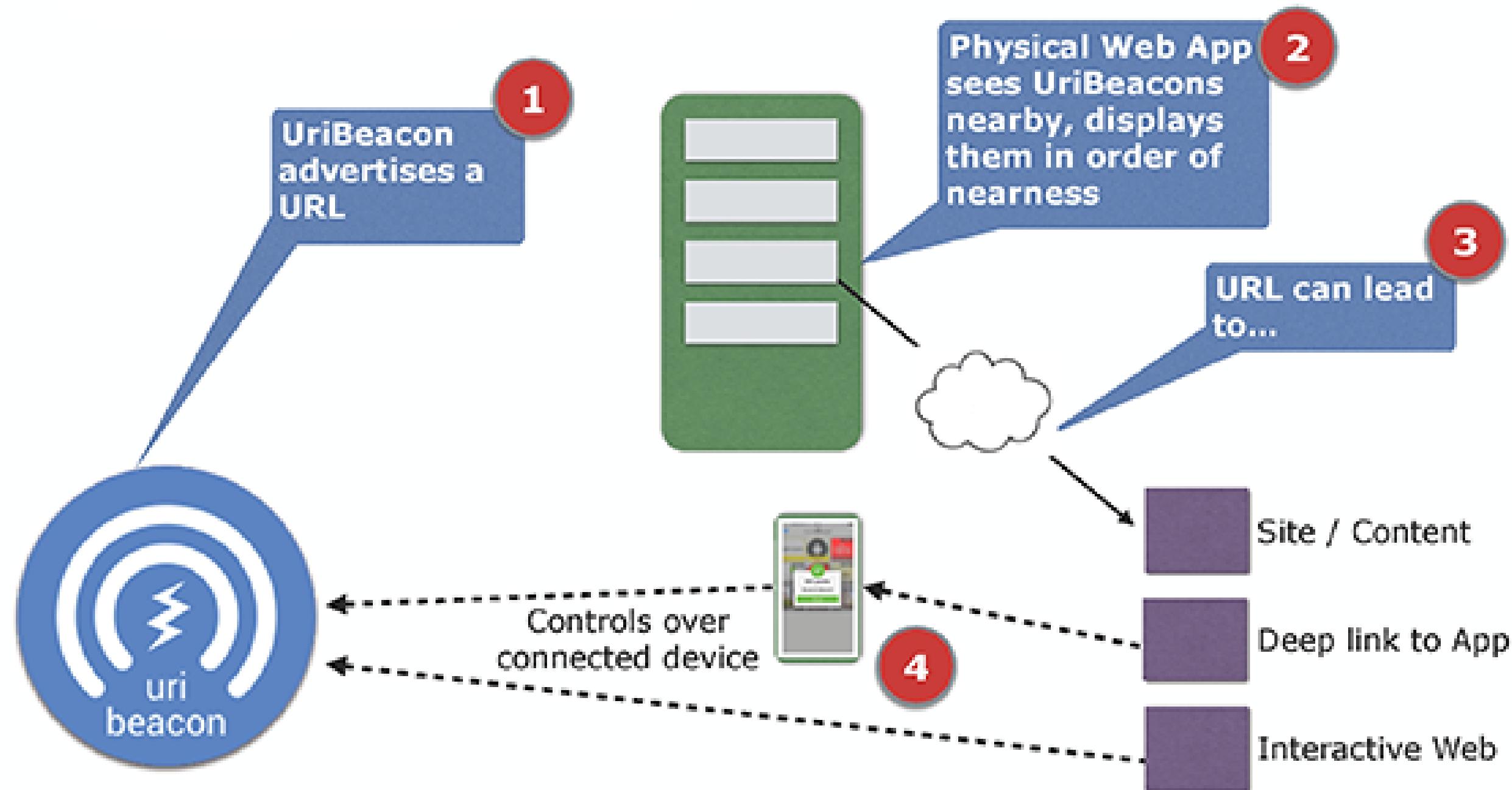
Related Work



- HP CoolTown Beacon (2000) [26]

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

Related Work ...

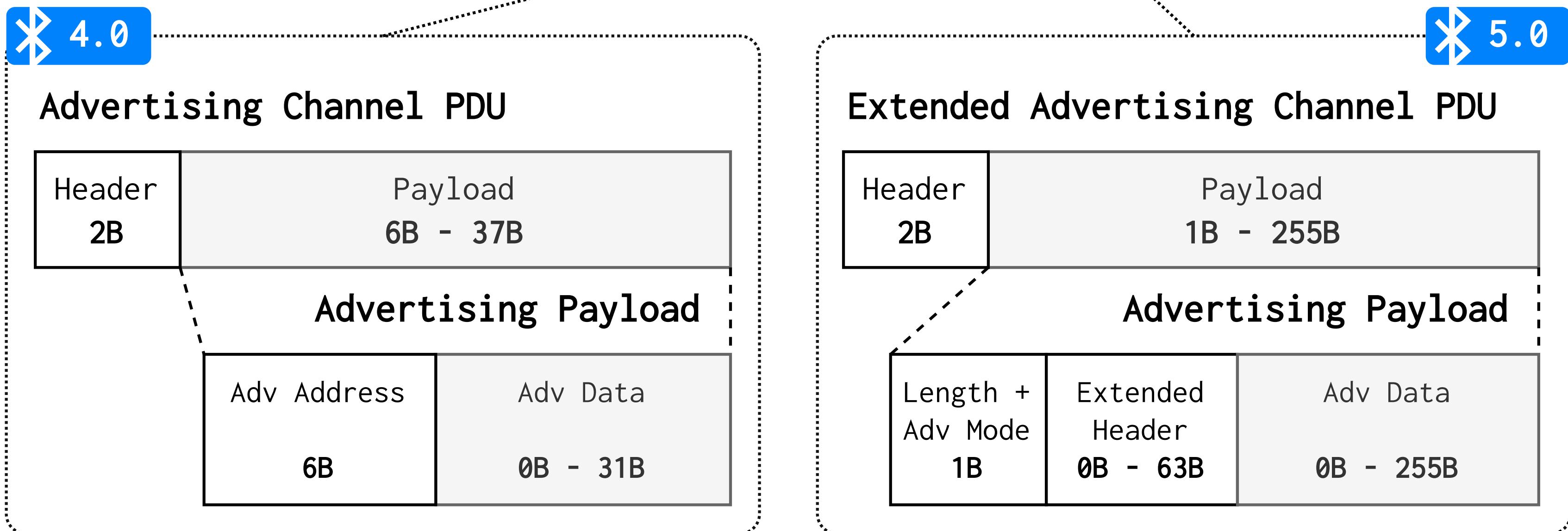


- Manfred Sneps-Sneppe, Dmitry Namiot, "On Physical Web models" (2016)

BLE Specifications

S

BLE Packet



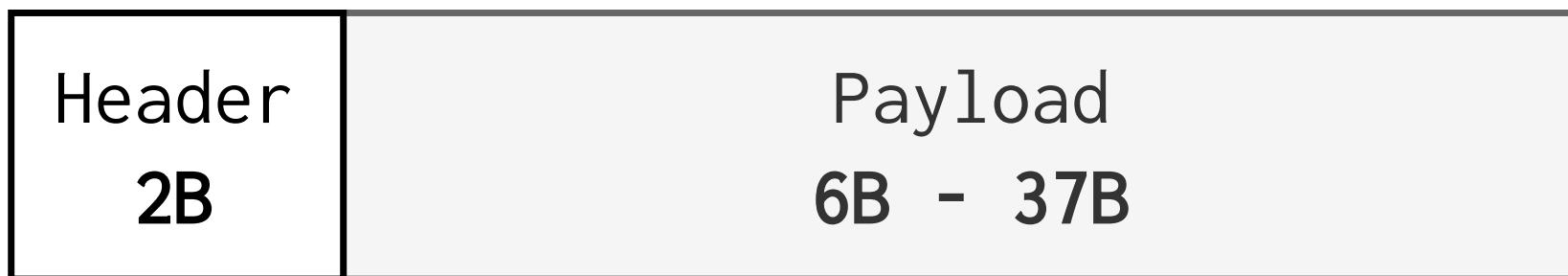
BLE Specifications

S

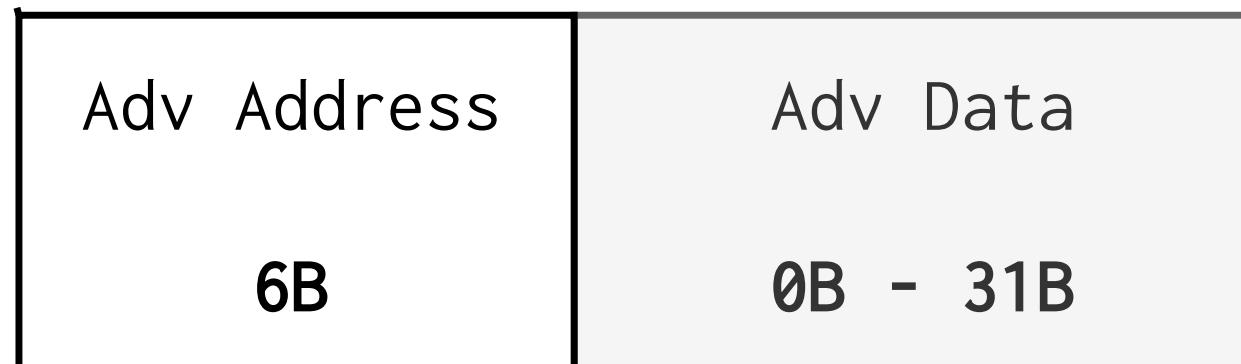
BLE Packet



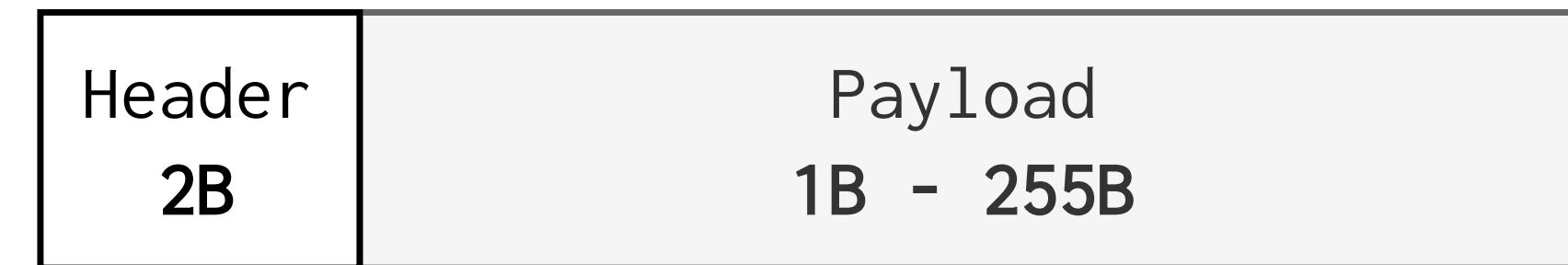
Advertising Channel PDU



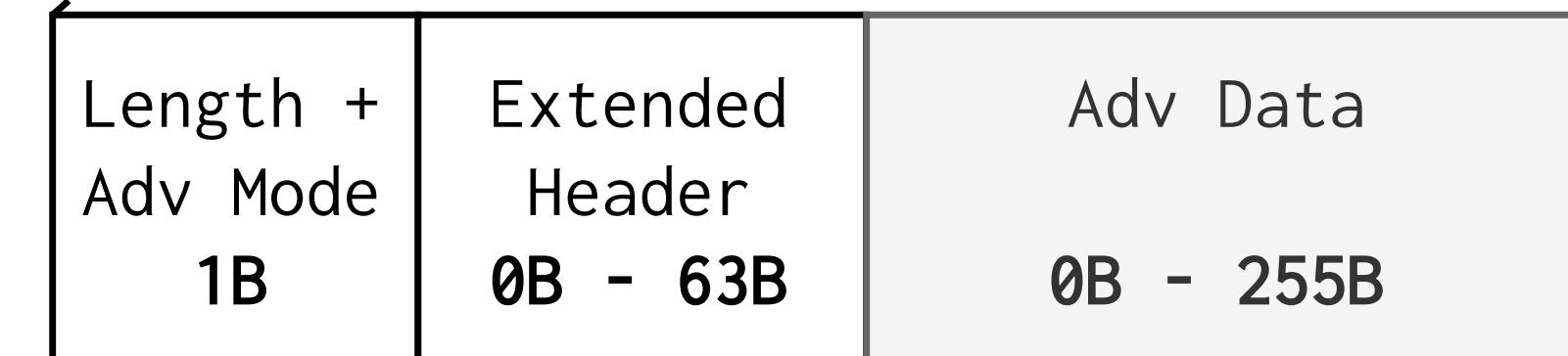
Advertising Payload



Extended Advertising Channel PDU



Advertising Payload



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

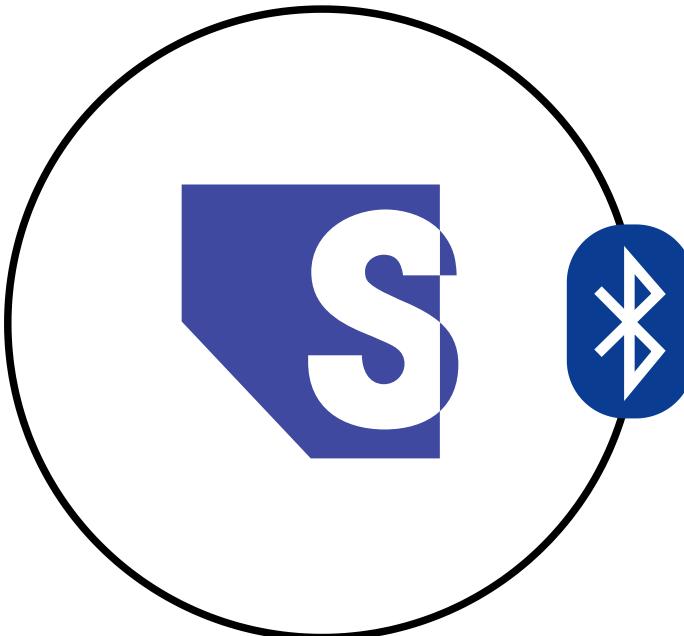
S

Bluetooth IPS Advertisement Data (24 bytes)

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



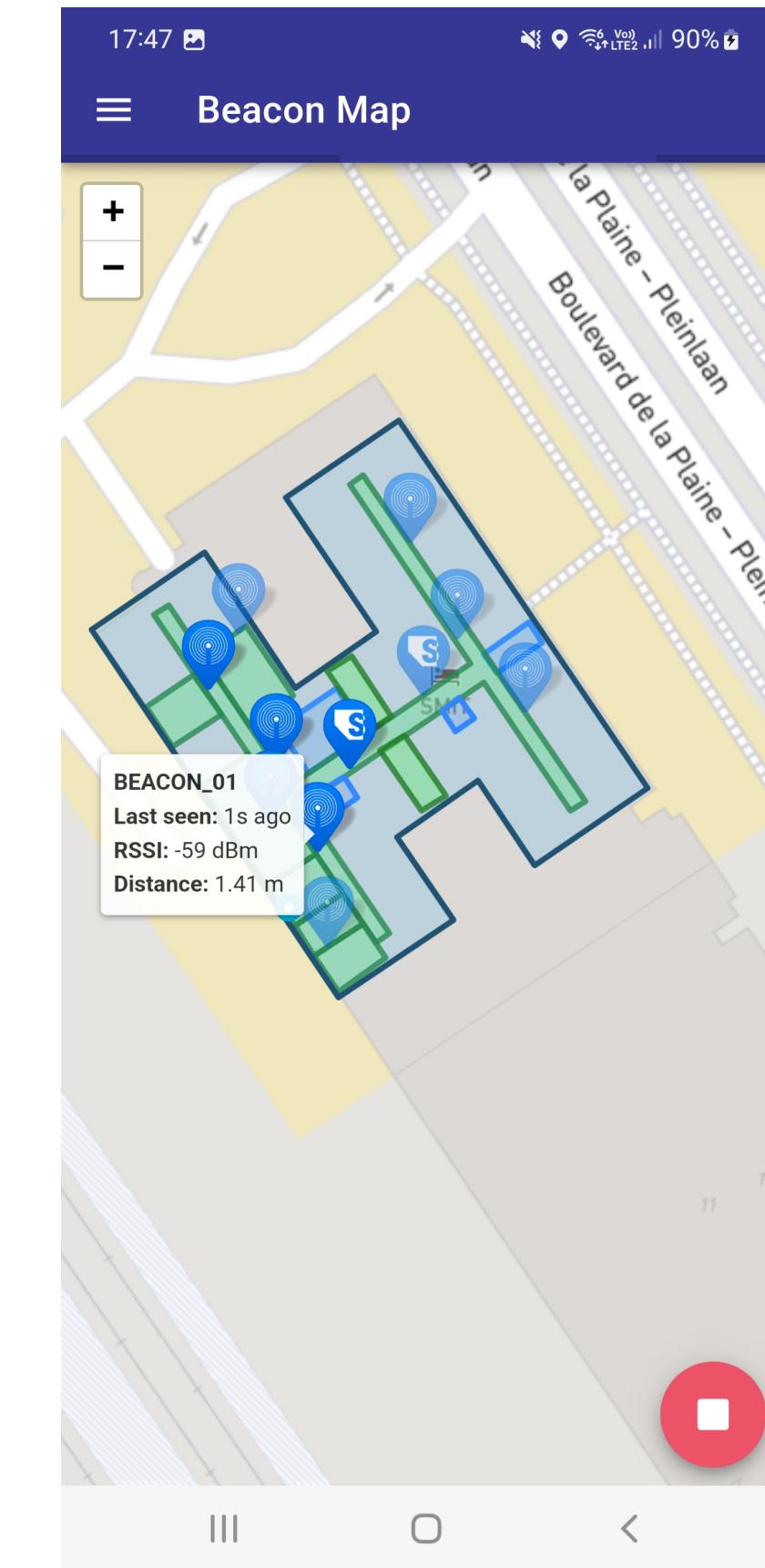
HTTP GET (Accept: text/turtle,
application/rdf+xml)

Linked data response

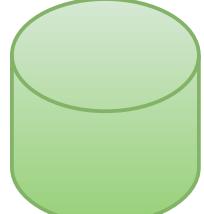
POSO



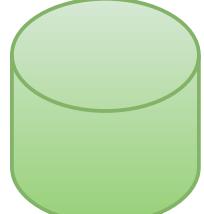
Open
Geospatial
Consortium



Check cache



Cache <namespace>
and all beacons
within response



S

SemBeacon Solution

BLE 4.X

SemBeacon Advertisement Data (31 bytes) 

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 (<= 24 bytes) 

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 Solution

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>	

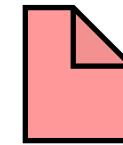
SemBeacon Solution

Namespace and Instance Identifier



<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**

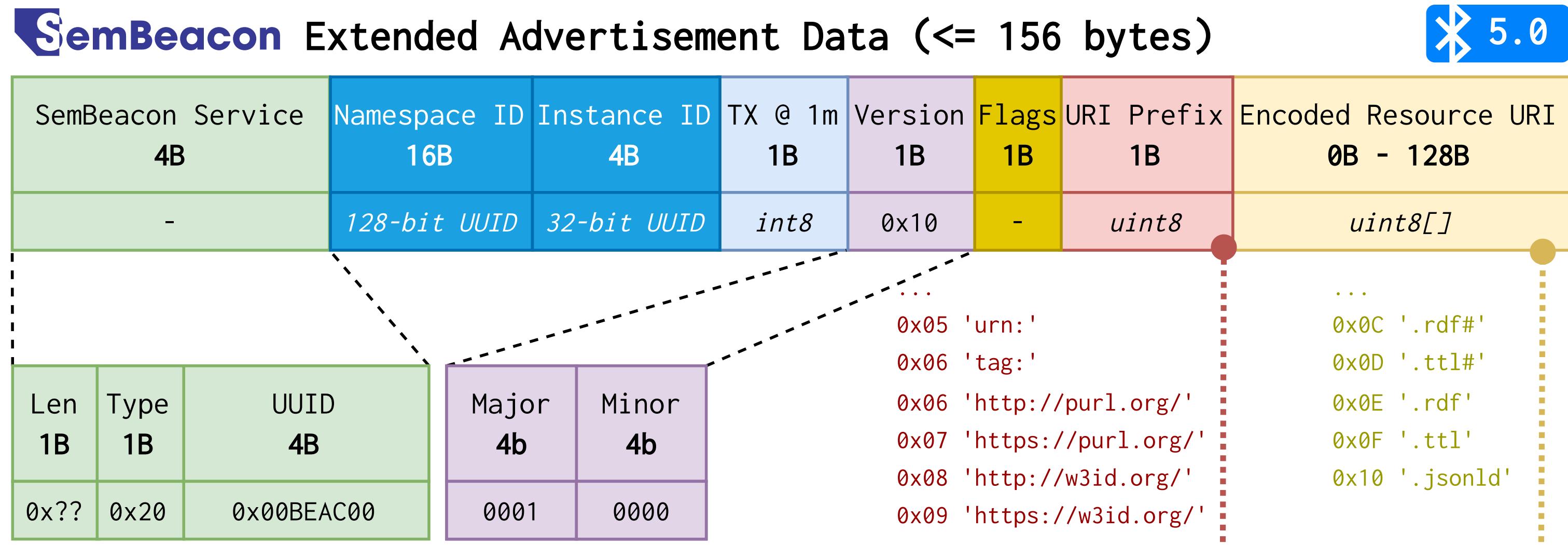


Type: AltBeacon

ID: **0x08483bc99d448c83bff6cb9d5bccd40d00000003**

SemBeacon Solution

BLE 5.X (Work in Progress)



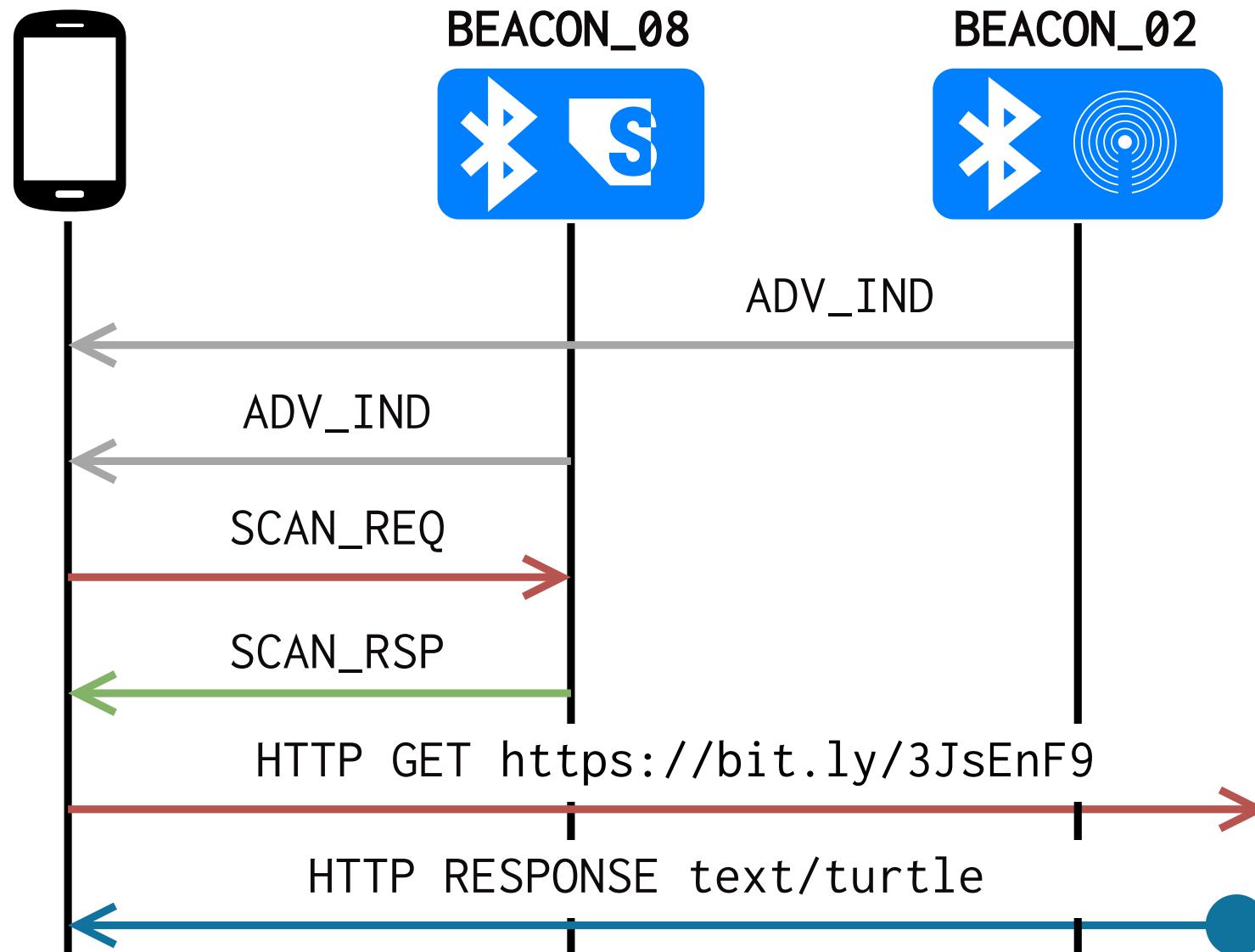
SemBeacon Solution

Ontology and POSO Extension



SemBeacon Solution

Method of Discovery

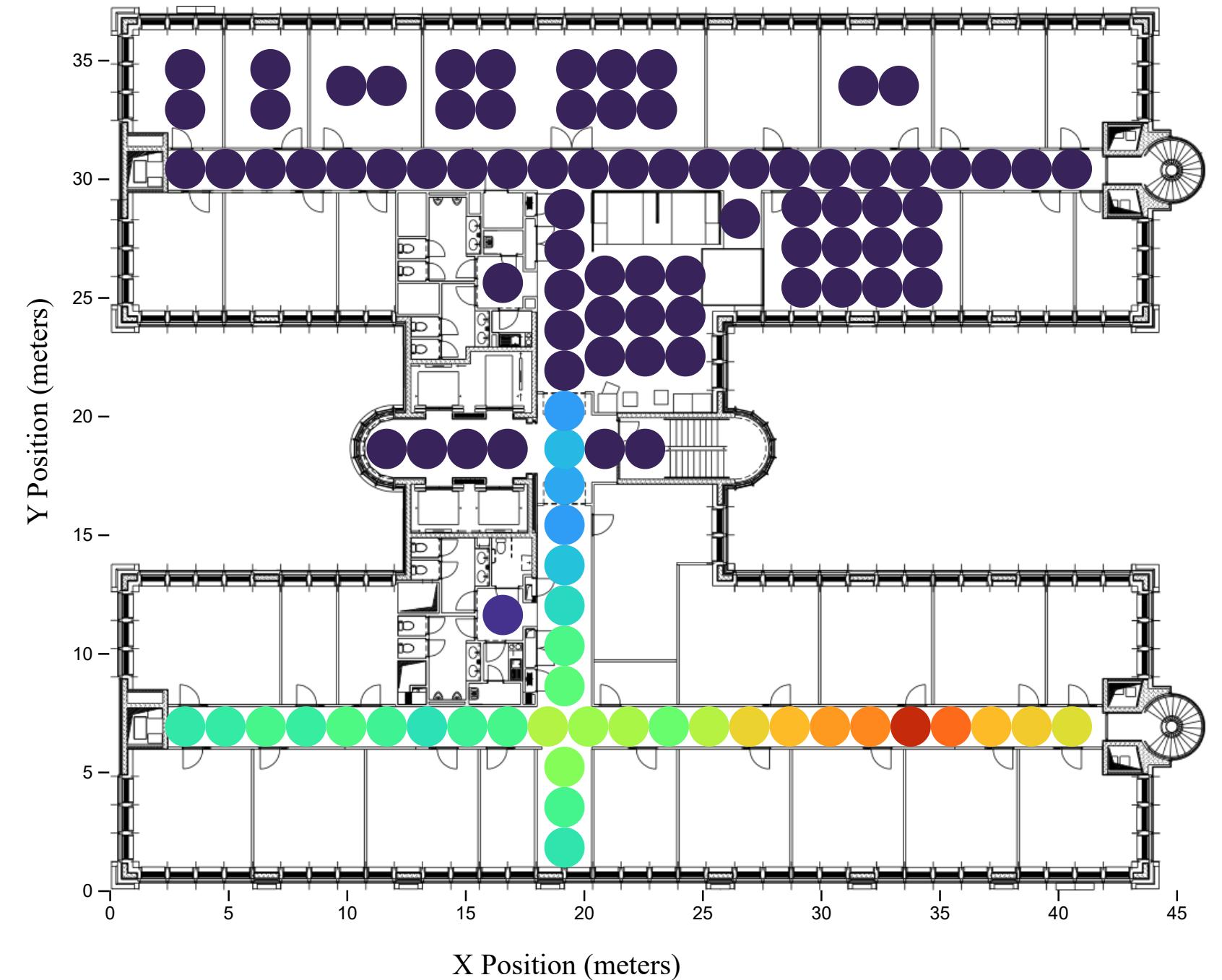


```
:building_a a ssn:Deployment ;
  rdfs:label "Building A" ;
  sembeacon:namespaceId "e19c5e1ed6a14d..."^^xsd:hexBinary .

: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

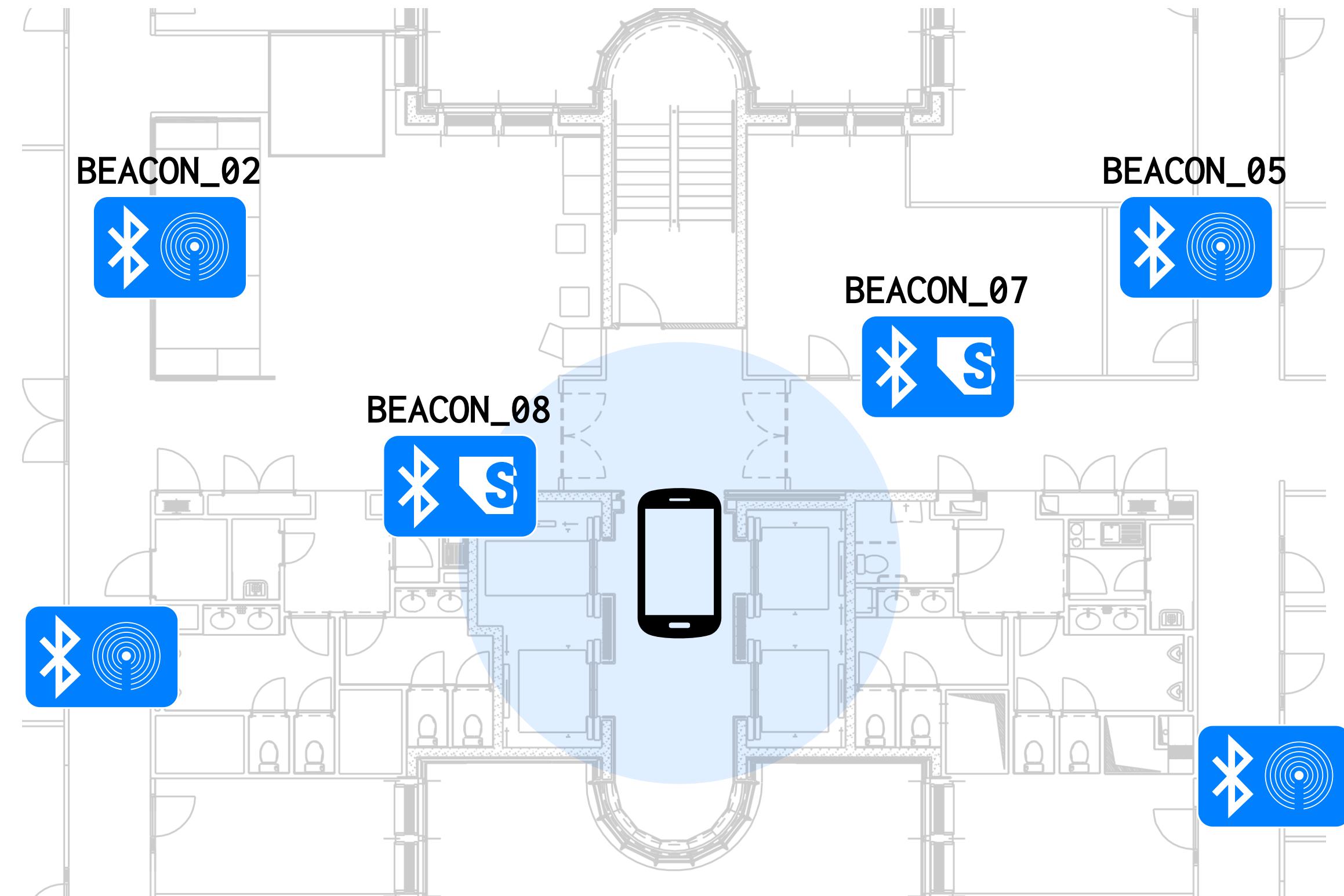
Dataset



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

Demonstrator

Transformation



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, 4.39223788808538 50.82065085654958 92, 4.392281317197596 50.82061024217639 92);
    ogc:coordinateDimension 3;
    ogc:spatialDimension 3;
    ogc:dimension 3
  ];
  rdfs:label "Lobby #1";
  dcmi:created "2023-06-22T21:12:23.585Z"^^xsd:dateTime.
: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 50.8207088360401 92, 4.392512343770305 50.8207088360401 92, 4.392530671545053 50.820691696024596 92);
    ogc:coordinateDimension 3;
    ogc:spatialDimension 3;
    ogc:dimension 3
  ];
  rdfs:label "Lobby #2";
  dcmi:created "2023-06-22T21:12:23.586Z"^^xsd:dateTime.
```

Demonstrator

Transformation

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

```
:BEACON_08 a sosa:FeatureOfInterest, ogc:SpatialObject, poso:RFLandmark, poso:BluetoothBeacon, sembeacon:  
    rdfs:label "BEACON_08";  
    dcmi:created "2023-06-22T21:12:23.637Z"^^xsd:dateTime;  
    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;  
        dcmi:created "2023-06-22T21:12:23.638Z"^^xsd:dateTime;  
        schema:latitude "50.82057562786381"^^xsd:double;  
        schema:longitude "4.392253994600526"^^xsd:double;  
        schema:elevation "93.5999999962747"^^xsd:double  
    ];  
    posoc:hasReferenceRSSI [  
        a poso:RelativeSignalStrength;  
        poso:hasRSS [  
            a qudt:QuantityValue;  
            qudt:unit unit:DeciB_M;  
            qudt:numericValue -56  
        ];
```

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

The mobile application interface consists of four main screens:

- Beacon View (Left):** Shows a list of detected beacons. It includes columns for Name, Namespace, Instance, RSSI, and Last seen. It also has tabs for SCANNER and SIMULATOR.
- Beacon Map (Second from Left):** A map view showing the locations of detected beacons as blue circles with signal strength bars. A callout box shows details for BEACON_01.
- Beacon details (Third from Left):** A detailed view for a specific SemBeacon. It shows fields for Name (BEACON_08), RSSI (-58 dBm), Distance (1.26 m), Created (14d ago), Last seen (1s ago), MAC Address (a8:3d:86:62:98:9b), Manufacturer (SPECIAL USE/DEFAULT (0xFFFF)), and Calibrated RSSI at 1m (-56).
- Scanner/Simulator View (Right):** Shows a list of beacons with their details. It includes tabs for SCANNER and SIMULATOR, and a toggle switch for each beacon's simulator mode.

Supplemental Material

- ▶ Android Application to scan and broadcast SemBeacons
- ▶ Arduino ESP32 Library to advertise SemBeacon
- ▶ Native Android library extension to identify SemBeacons
- ▶ TypeScript library to create and detect SemBeacons

Conclusion and Future Work

- We presented our semantic beacon solution called SemBeacon
- Expanding to non-BLE beacons (e.g. Ultrawide-band)
- Expanding the vocabulary to facilitate device interactions
- Web Bluetooth Scanning for SemBeacons



<https://github.com/SemBeacon/>
<https://sembeacon.org/>

(Extra) iOS and iBeacon

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