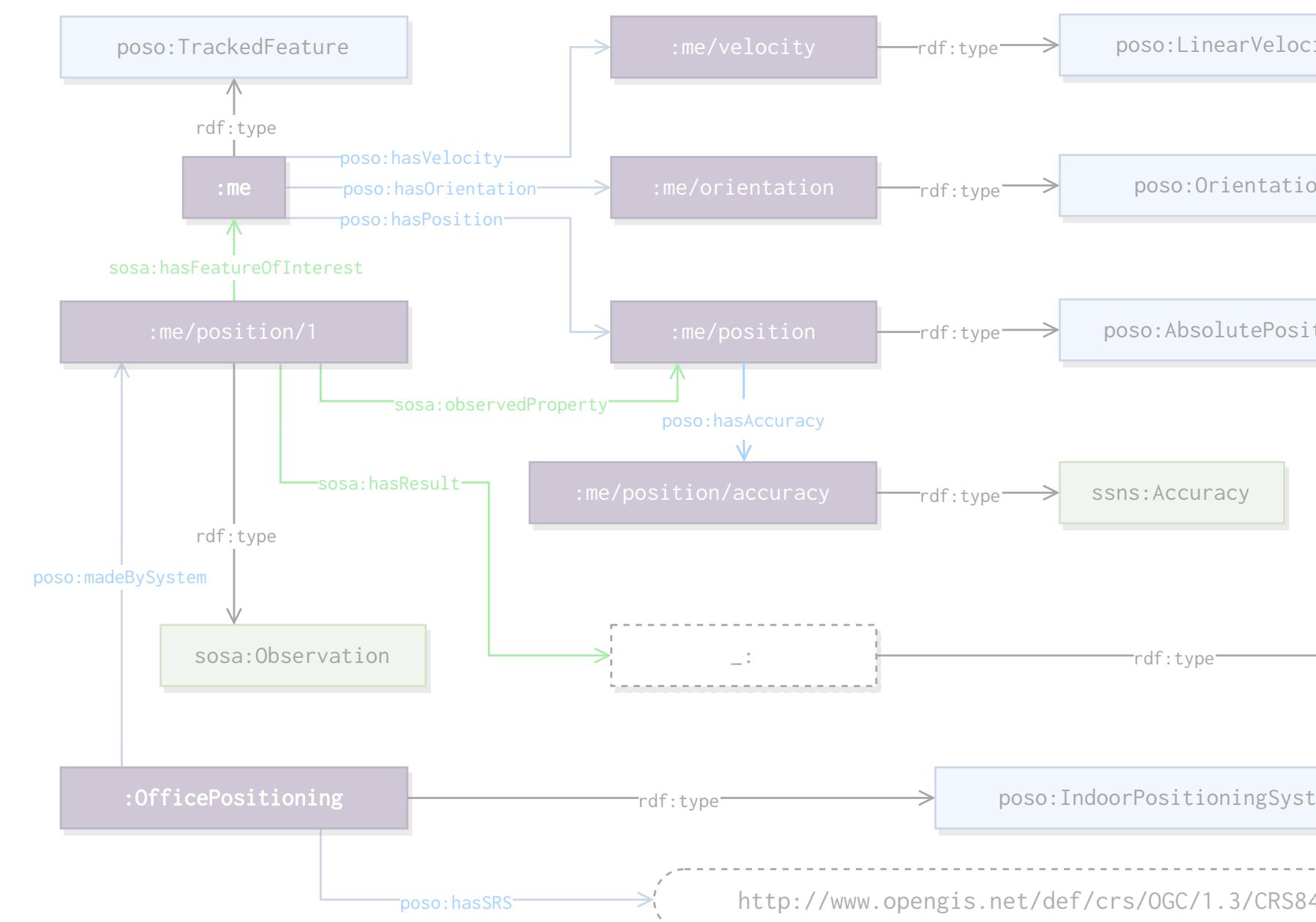


POSO: A Generic Positioning System Ontology

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Vrije Universiteit Brussel*

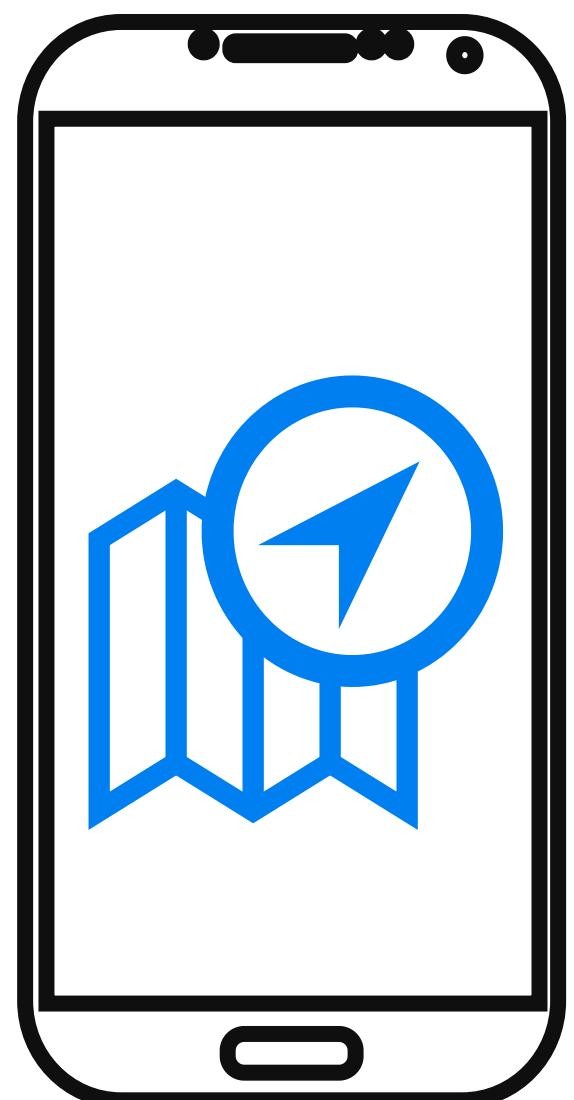
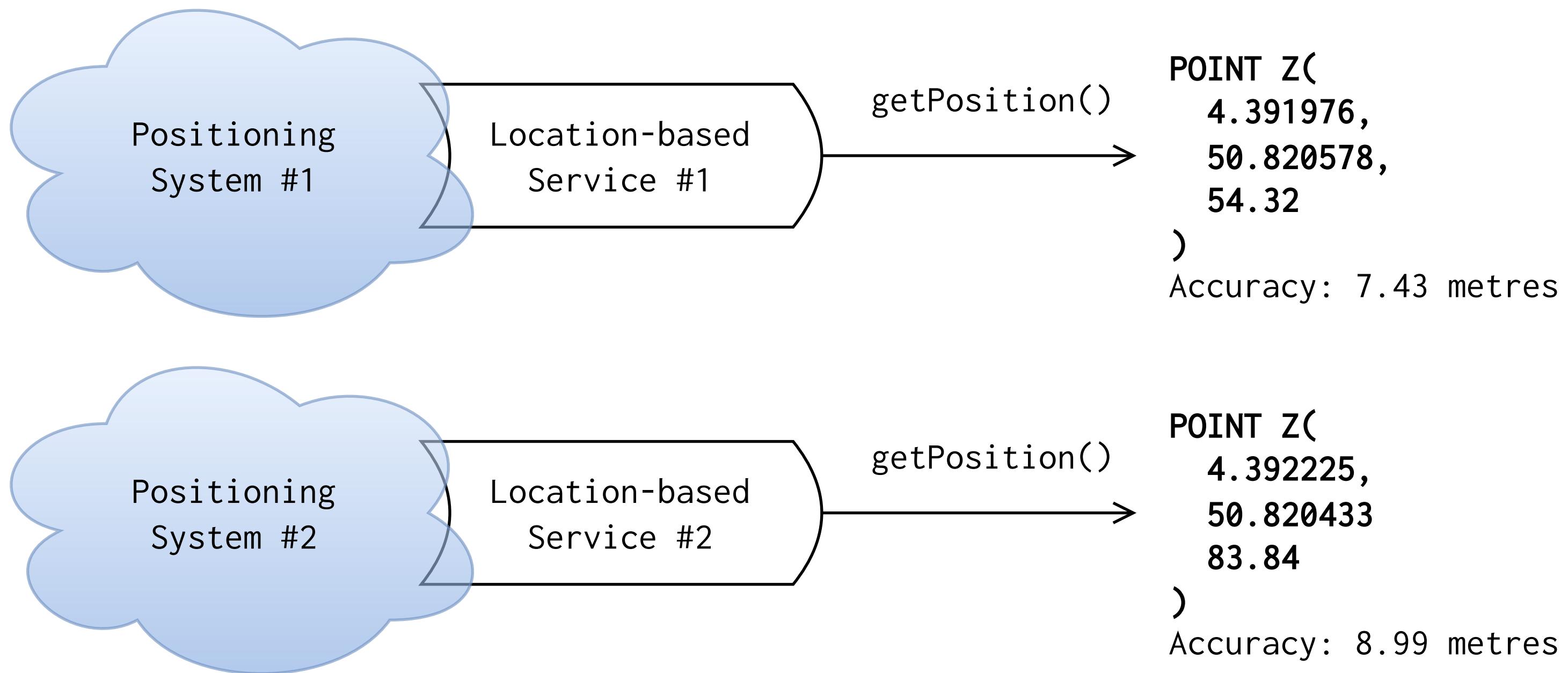


POsitioning System Ontology

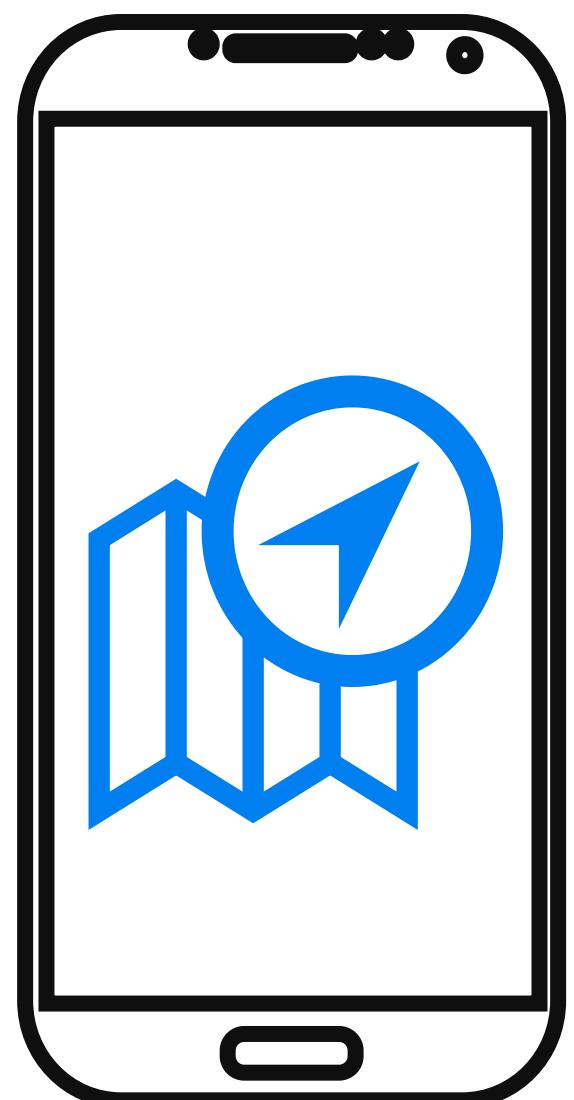
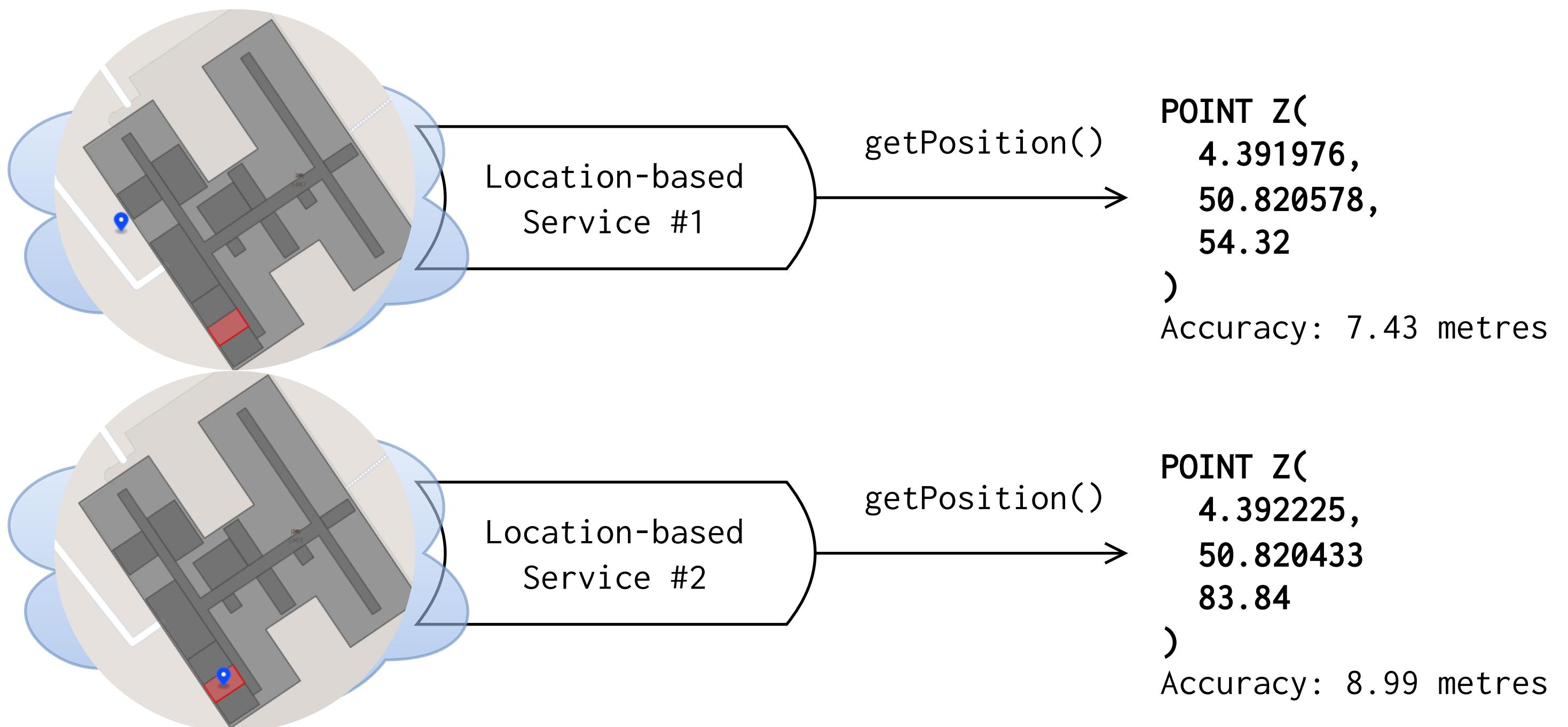
Introduction

*POSO provides the terminology needed to describe different **types of positioning systems**, the **algorithms** and technologies that they implement and the **data** that is produced by these systems.*

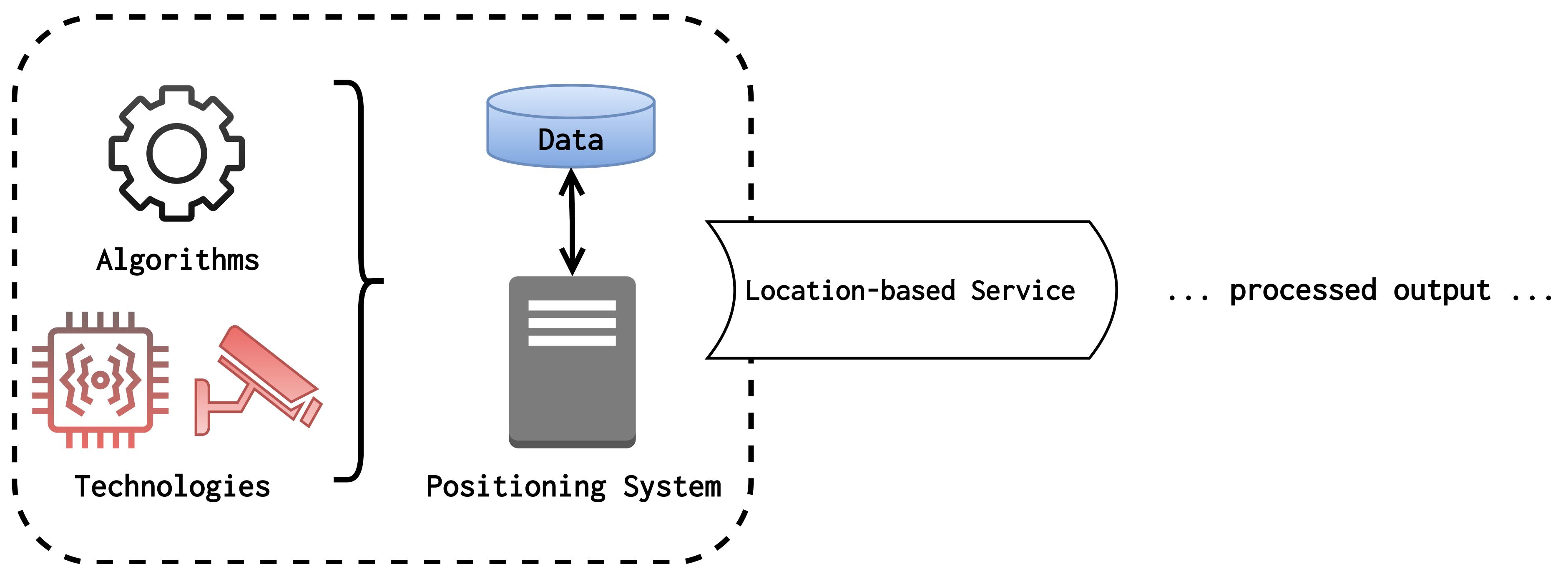
Location-based Services



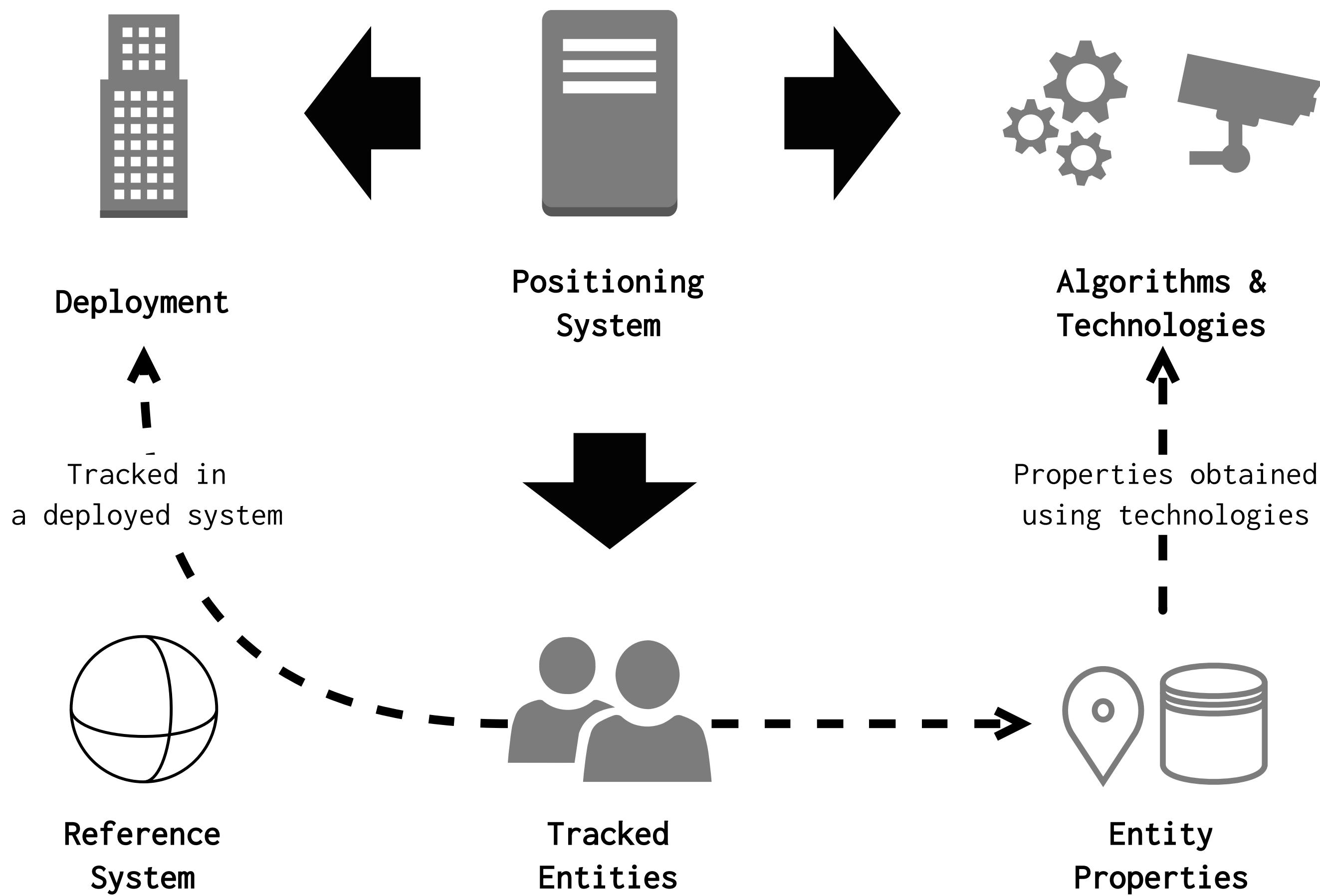
Location-based Services



Location-based Services ...

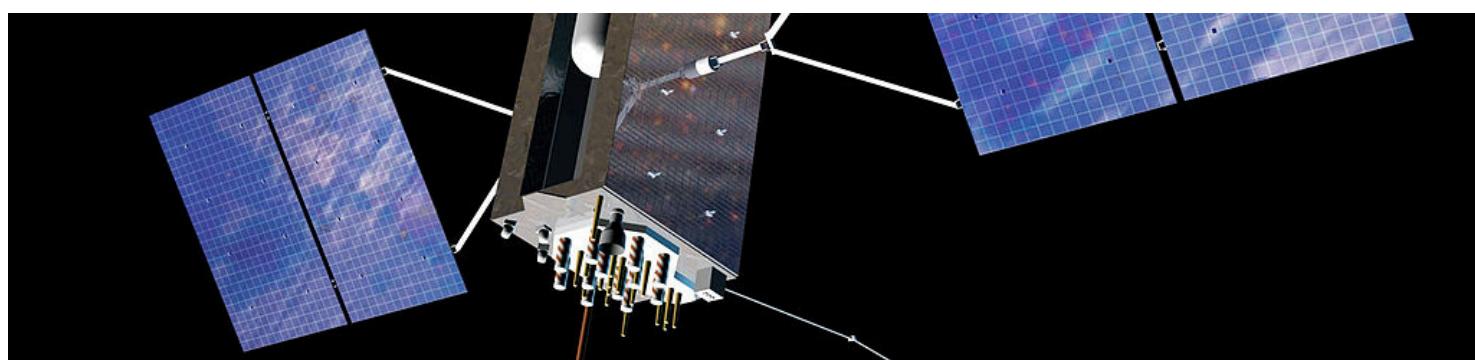


Positioning System



Positioning System ...

- ▶ Satellite positioning systems



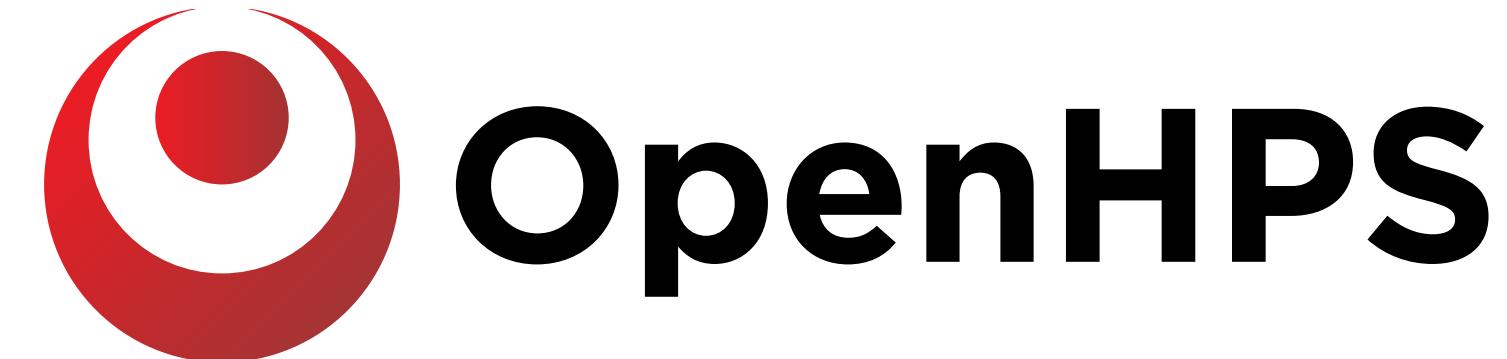
- ▶ Optical positioning systems



- ▶ Inertial positioning systems



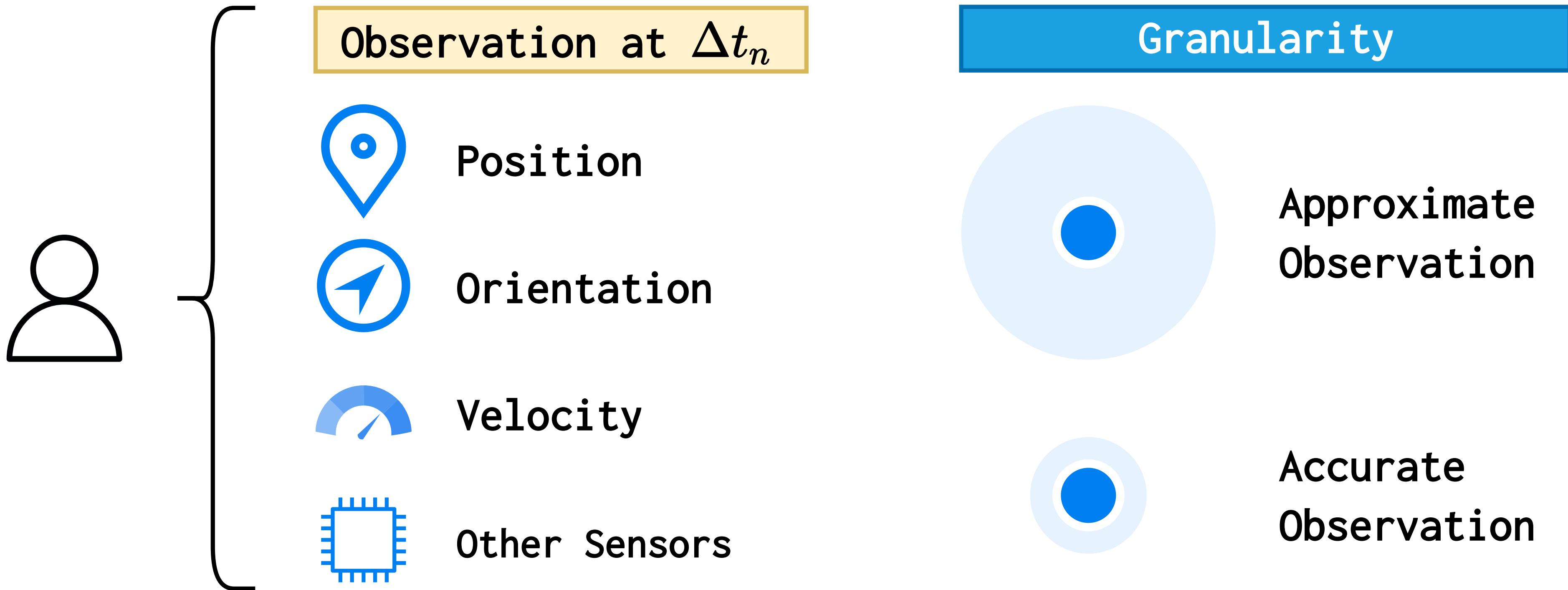
- ▶ Integrated positioning systems



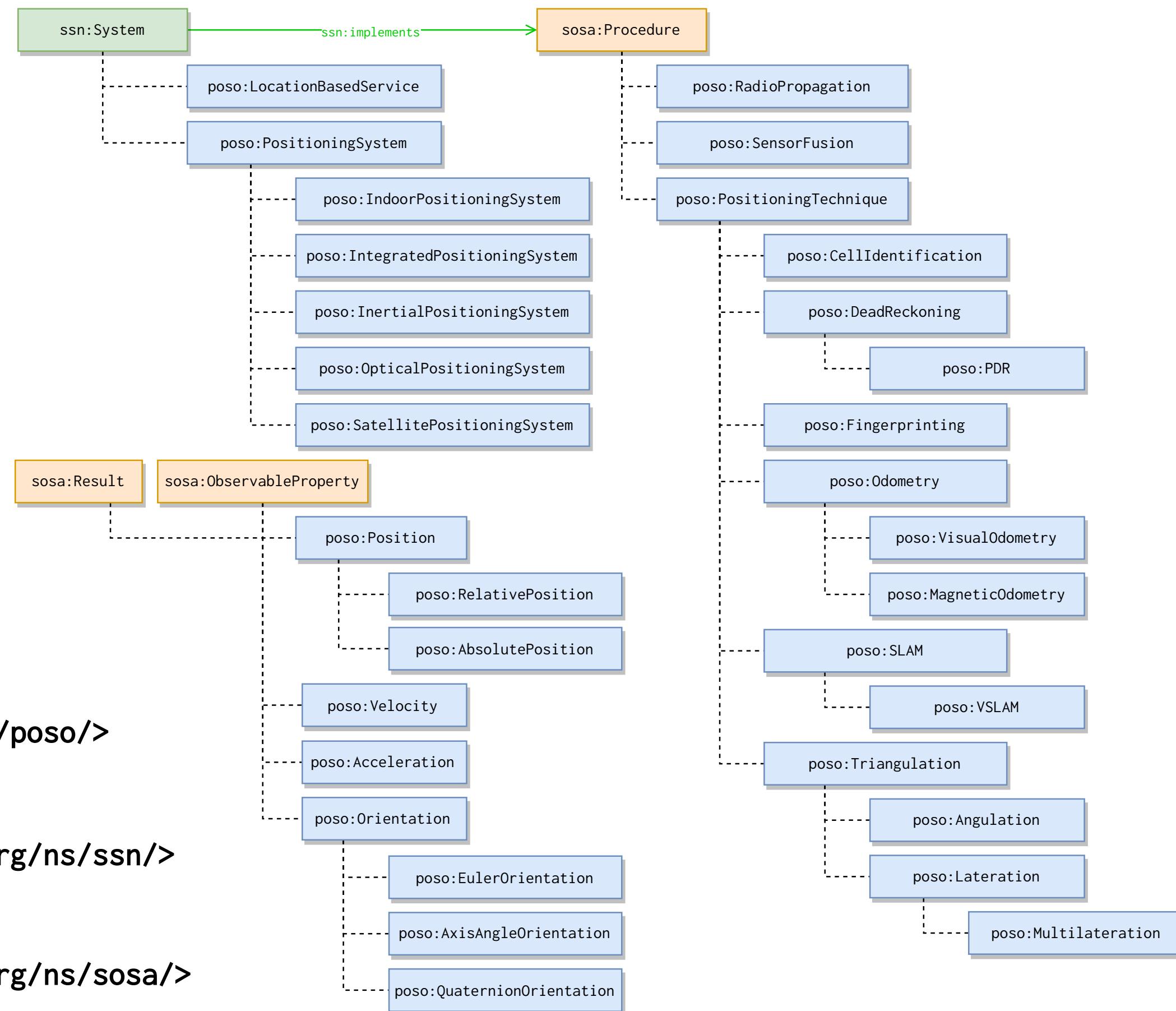
- ▶ Indoor positioning systems



Tracked Entities and Their Properties



Ontology Design



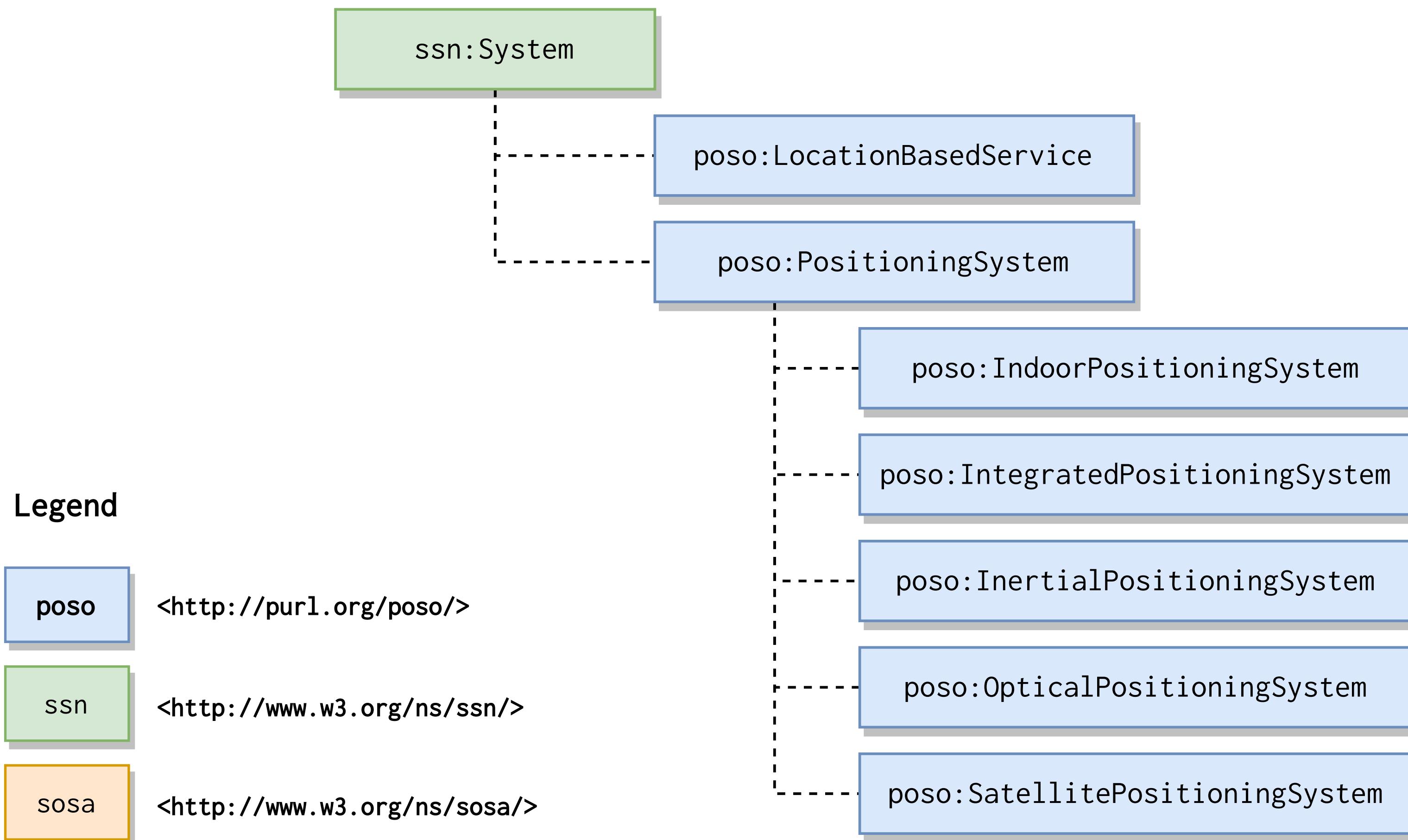
Legend

poso <http://purl.org/poso/>

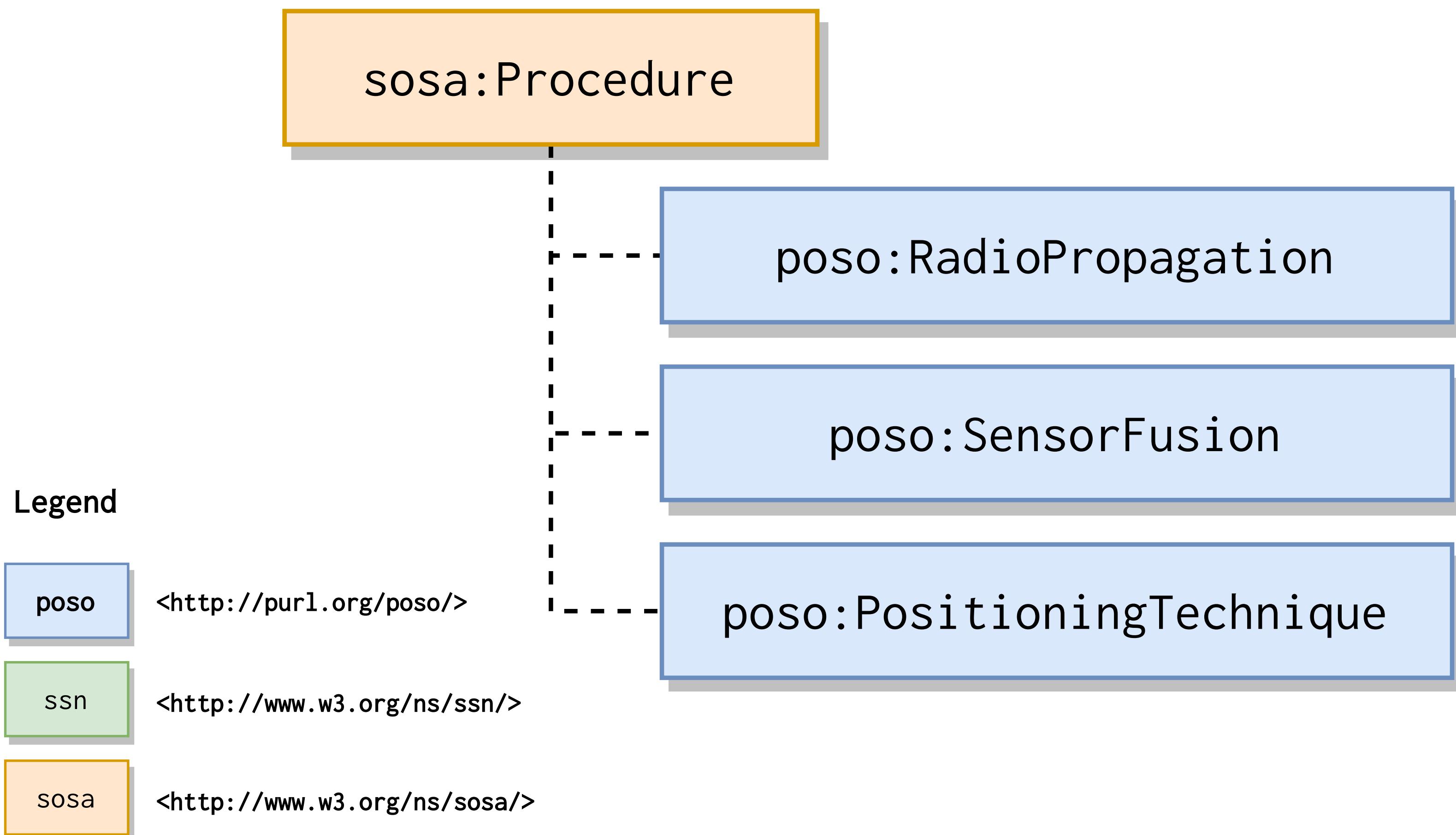
ssn <http://www.w3.org/ns/ssn/>

sosa <http://www.w3.org/ns/sosa/>

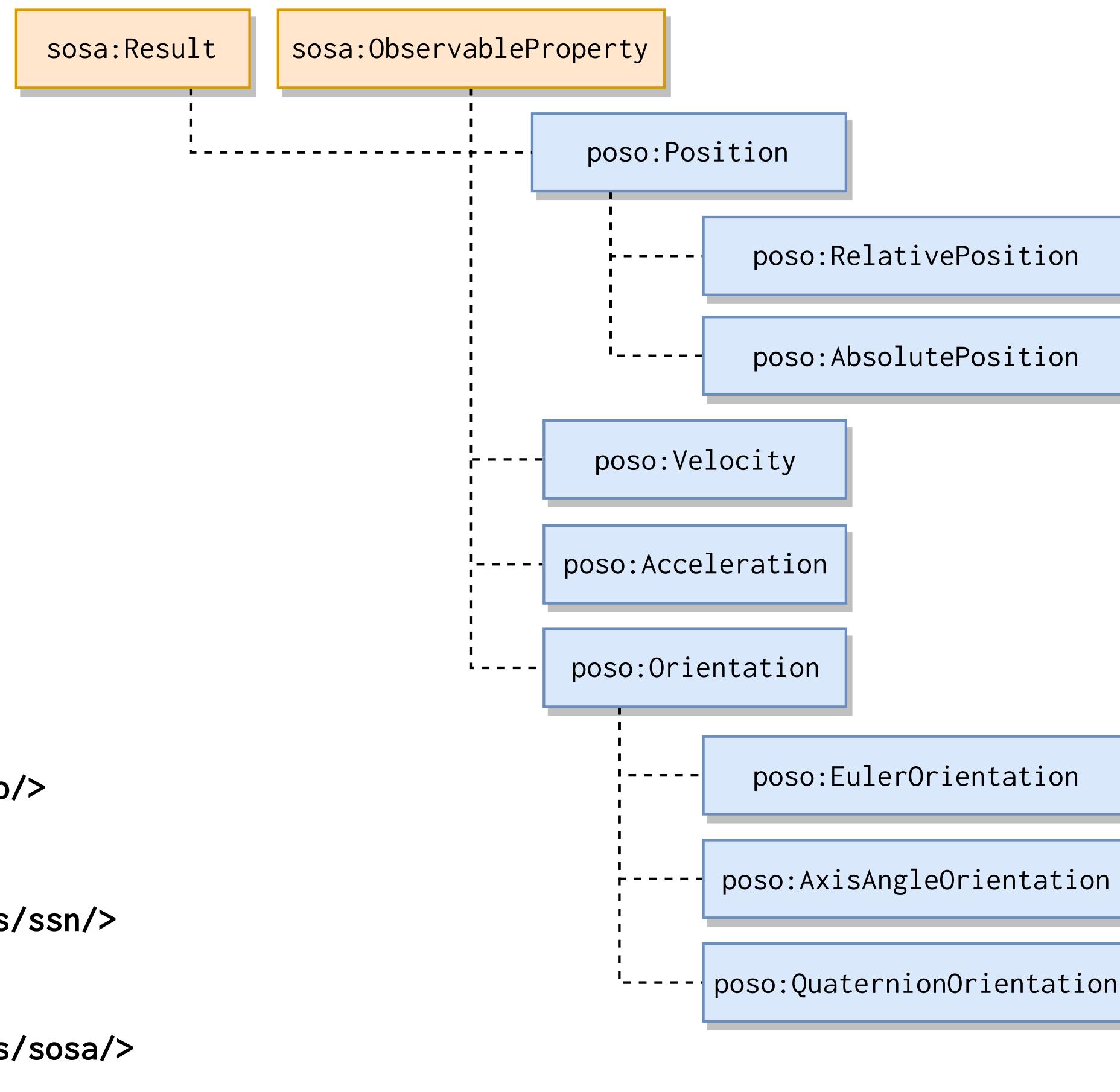
Ontology Design ...



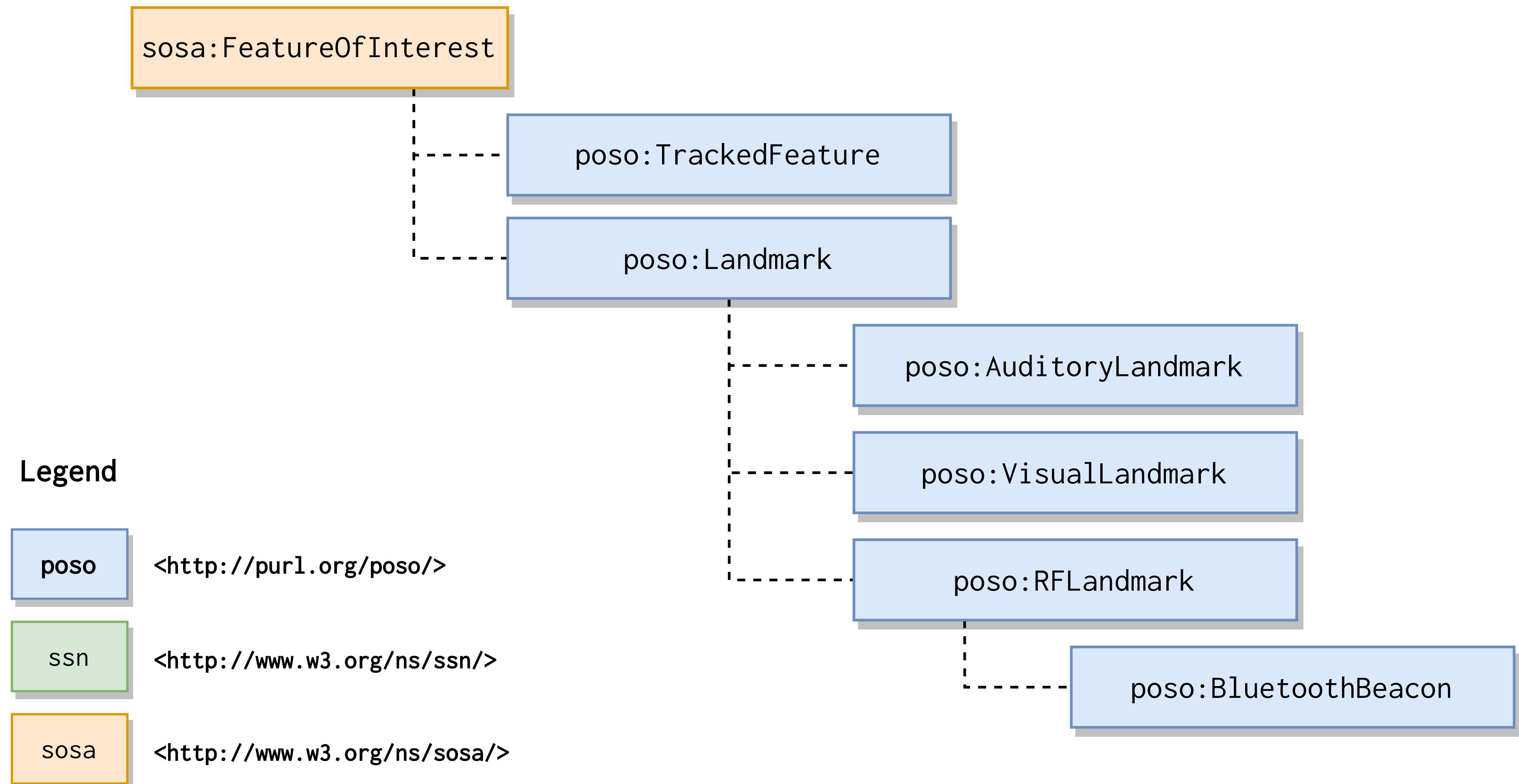
Ontology Design ...



Ontology Design ...



Ontology Design ...



POSO Common Module (posoc)

<http://purl.org/poso/common/>

- ▶ Adds common in-use positioning systems and location-based services
 - e.g. Global Positioning System, GeolocationAPI
- ▶ Adds common algorithm implementations
 - e.g. HectorSLAM, Trilateration, CSI fingerprinting
 - Adds graph shapes for algorithm input and output
- ▶ Adds common frameworks/platforms
 - e.g. IndoorAtlas, AnyPlace
- ▶ Adds common types of landmarks
 - e.g. iBeacon, Eddystone, AltBeacon

Usage

Positioning System

```
dbr:Some_University a ssn:Deployment .  
<deployment/building_a> a poso:IndoorDeployment, geosparql:Feature ;  
    rdfs:label "Building A"@en ;  
    geosparql:hasGeometry [  
        a geosparql:Geometry ;  
        geosparql:asWKT "...""^^geosparql:wktLiteral ] .  
  
<system/OPS> a poso:LocationBasedService ;  
    rdfs:label "Outdoor campus positioning"@en ;  
    ssn:hasSubSystem posoc:GPS ;  
    ssn:hasDeployment dbr:Some_University .  
<system/IPS> a poso:IndoorPositioningSystem ;  
    rdfs:label "Indoor campus positioning"@en ;  
    ssn:hasDeployment <deployment/building_a> ;  
    ssn:implements posoc:KNNFingerprinting .  
<system/CampusPositioning> a poso:IntegratedPositioningSystem ;  
    rdfs:label "Hybrid campus positioning system"@en ;  
    ssn:hasSubSystem <system/OPS>, <system/IPS> ;  
    ssn:implements posoc:WeightedAccuracyFusion .
```

Usage

Positioning System

```
dbr:Some_University a ssn:Deployment .  
<deployment/building_a> a poso:IndoorDeployment, geosparql:Feature ;  
    rdfs:label "Building A"@en ;  
    geosparql:hasGeometry [  
        a geosparql:Geometry ;  
        geosparql:asWKT "...""^^geosparql:wktLiteral ] .  
  
<system/OPS> a poso:LocationBasedService ;  
    rdfs:label "Outdoor campus positioning"@en ;  
    ssn:hasSubSystem posoc:GPS ;  
    ssn:hasDeployment dbr:Some_University .  
<system/IPS> a poso:IndoorPositioningSystem ;  
    rdfs:label "Indoor campus positioning"@en ;  
    ssn:hasDeployment <deployment/building_a> ;  
    ssn:implements posoc:KNNFingerprinting .  
<system/CampusPositioning> a poso:IntegratedPositioningSystem ;  
    rdfs:label "Hybrid campus positioning system"@en ;  
    ssn:hasSubSystem <system/OPS>, <system/IPS> ;  
    ssn:implements posoc:WeightedAccuracyFusion .
```

Usage

Positioning System

```
dbr:Some_University a ssn:Deployment .  
<deployment/building_a> a poso:IndoorDeployment, geosparql:Feature ;  
    rdfs:label "Building A"@en ;  
    geosparql:hasGeometry [  
        a geosparql:Geometry ;  
        geosparql:asWKT "...""^^geosparql:wktLiteral ] .  
  
<system/OPS> a poso:LocationBasedService ;  
    rdfs:label "Outdoor campus positioning"@en ;  
    ssn:hasSubSystem posoc:GPS ;  
    ssn:hasDeployment dbr:Some_University .  
<system/IPS> a poso:IndoorPositioningSystem ;  
    rdfs:label "Indoor campus positioning"@en ;  
    ssn:hasDeployment <deployment/building_a> ;  
    ssn:implements posoc:KNNFingerprinting .  
<system/CampusPositioning> a poso:IntegratedPositioningSystem ;  
    rdfs:label "Hybrid campus positioning system"@en ;  
    ssn:hasSubSystem <system/OPS>, <system/IPS> ;  
    ssn:implements posoc:WeightedAccuracyFusion .
```

Usage

Positioning System

```
dbr:Some_University a ssn:Deployment .
<deployment/building_a> a poso:IndoorDeployment, geosparql:Feature ;
  rdfs:label "Building A"@en ;
  geosparql:hasGeometry [
    a geosparql:Geometry ;
    geosparql:asWKT "..."^^geosparql:wktLiteral ] .

<system/OPS> a poso:LocationBasedService ;
  rdfs:label "Outdoor campus positioning"@en ;
  ssn:hasSubSystem posoc:GPS ;
  ssn:hasDeployment dbr:Some_University .
<system/IPS> a poso:IndoorPositioningSystem ;
  rdfs:label "Indoor campus positioning"@en ;
  ssn:hasDeployment <deployment/building_a> ;
  ssn:implements posoc:KNNFingerprinting .
<system/CampusPositioning> a poso:IntegratedPositioningSystem ;
  rdfs:label "Hybrid campus positioning system"@en ;
  ssn:hasSubSystem <system/OPS>, <system/IPS> ;
  ssn:implements posoc:WeightedAccuracyFusion .
```

Usage

Tracked Feature and Properties

```
<me> a poso:TrackedFeature, foaf:Person ;
  foaf:name "Maxim Van de Wynckel"@en ;
  poso:hasPosition <me/position> ;
  poso:hasOrientation <me/orientation> .
<me/position> a poso:AbsolutePosition ;
  rdfs:comment "Absolute position of Maxim Van de Wynckel"@en ;
  poso:hasAccuracy <me/position/accuracy> .
<me/position/accuracy> a ssns:Accuracy ;
  schema:maxValue "2.0"^^xsd:float ; schema:unitCode unit:M .

<me/orientation> a poso:Orientation ;
  rdfs:comment: "Orientation of Maxim Van de Wynckel"@en ;
  poso:hasAccuracy <me/orientation/accuracy> .
<me/orientation/accuracy> a ssns:Accuracy ;
  schema:maxValue "15.0"^^xsd:float ; schema:unitCode unit:Deg .
```

Usage

Observation

```
<position/1654350300000> a sosa:Observation ;
  sosa:hasFeatureOfInterest <me> ;
  sosa:observedProperty <me/position> ;
  sosa:resultTime "2022-06-04T15:55:00+02:00"^^xsd:dateTimeStamp ;
  poso:usedSystem <system/OPS> ;
  sosa:hasResult [ a geosparql:Geometry ;
    geosparql:hasSpatialAccuracy [ a qudt:QuantityValue ;
      qudt:unit unit:CentiM ; qudt:numericValue "28"^^xsd:float ] ;
    geosparql:asWKT """
      <http://www.opengis.net/def/crs/OGC/1.3/CRS84>
      Point(4.888028 50.31397)"""
    ""^^geosparql:wktLiteral ;
    geosparql:dimension 2 ] .
```

Usage

Observation ...

```
<position/1647513000000> a sosa:Observation ;
  sosa:hasFeatureOfInterest <me> ;
  sosa:observedProperty <me/position> ;
  sosa:resultTime "2022-03-17T11:30:00+01:00"^^xsd:dateTimeStamp ;
  sosa:usedProcedure posoc:KNNFingerprinting ;
  poso:usedSystem <system/IPS> ;
  sosa:hasResult [ a poso:AbsolutePosition ;
    poso:inDeployment <deployment/building_a> ;
    poso:hasAccuracy [ a ssns:Accuracy ;
      schema:maxValue "25.0"^^xsd:float ;
      schema:unitCode unit:CentiM ] ;
    poso:xAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "5"^^xsd:double ] ;
    poso:yAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "6"^^xsd:double ] ;
    poso:zAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "3.5"^^xsd:double ] ] .
```

Usage

Observation ...

```
<position/1647513000000> a sosa:Observation ;
  sosa:hasFeatureOfInterest <me> ;
  sosa:observedProperty <me/position> ;
  sosa:resultTime "2022-03-17T11:30:00+01:00"^^xsd:dateTimeStamp ;
  sosa:usedProcedure posoc:KNNFingerprinting ;
  poso:usedSystem <system/IPS> ;
  sosa:hasResult [ a poso:AbsolutePosition ;
    poso:inDeployment <deployment/building_a> ;
    poso:hasAccuracy [ a ssns:Accuracy ;
      schema:maxValue "25.0"^^xsd:float ;
      schema:unitCode unit:CentiM ] ;
    poso:xAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "5"^^xsd:double ] ;
    poso:yAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "6"^^xsd:double ] ;
    poso:zAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "3.5"^^xsd:double ] ] .
```

Usage

Observation ...

```
<position/1647513000000> a sosa:Observation ;
  sosa:hasFeatureOfInterest <me> ;
  sosa:observedProperty <me/position> ;
  sosa:resultTime "2022-03-17T11:30:00+01:00"^^xsd:dateTimeStamp ;
  sosa:usedProcedure posoc:KNNFingerprinting ;
  poso:usedSystem <system/IPS> ;
  sosa:hasResult [ a poso:AbsolutePosition ;
    poso:inDeployment <deployment/building_a> ;
    poso:hasAccuracy [ a ssns:Accuracy ;
      schema:maxValue "25.0"^^xsd:float ;
      schema:unitCode unit:CentiM ] ;
    poso:xAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "5"^^xsd:double ] ;
    poso:yAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "6"^^xsd:double ] ;
    poso:zAxisValue [ a qudt:QuantityValue ;
      qudt:unit unit:M ; qudt:numericValue "3.5"^^xsd:double ] ] .
```

Usage

Relative Position

```
<landmark/wap_1> a poso:Landmark ;
    rdfs:label "Wireless Access Point 1"@en ;
    poso:hasPosition [ a poso:AbsolutePosition ;
        poso:hasAccuracy [ ... ] ;
        poso:xAxisValue [ ... ] ; poso:yAxisValue [ ... ] ; poso:zAxisValue [ ... ] ] .
<me/position/relative/wap_1> a poso:RelativeDistance ;
    ssn:isPropertyOf <me> ; # Relative distance from <me> ...
    poso:isRelativeTo <landmark/wap_1> ; # to <landmark/wap_1>
    rdfs:comment "Relative position of Maxim Van de Wynckel to WAP_1"@en .
<position/relative/wap_1/1646891100000> a sosa:Observation ;
    sosa:hasFeatureOfInterest <me>, <landmark/wap_1> ;
    sosa:observedProperty <me/position/relative/wap_1> ;
    sosa:resultTime "2022-03-10T06:45:00+01:00"^^xsd:dateTimeStamp ;
    poso:madeBySystem <system/IPS> ;
    sosa:usedProcedure posoc:LDPL ; # Log-distance path loss
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:Meter ; qudt:value "3.7"^^xsd:double ] ;
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:DeciB_M ; qudt:value "-82"^^xsd:integer ] .
```

Usage

Relative Position

```
<landmark/wap_1> a poso:Landmark ;
    rdfs:label "Wireless Access Point 1"@en ;
    poso:hasPosition [ a poso:AbsolutePosition ;
        poso:hasAccuracy [ ... ] ;
        poso:xAxisValue [ ... ] ; poso:yAxisValue [ ... ] ; poso:zAxisValue [ ... ] ] .
<me/position/relative/wap_1> a poso:RelativeDistance ;
    ssn:isPropertyOf <me> ; # Relative distance from <me> ...
    poso:isRelativeTo <landmark/wap_1> ; # to <landmark/wap_1>
    rdfs:comment "Relative position of Maxim Van de Wynckel to WAP_1"@en .
<position/relative/wap_1/1646891100000> a sosa:Observation ;
    sosa:hasFeatureOfInterest <me>, <landmark/wap_1> ;
    sosa:observedProperty <me/position/relative/wap_1> ;
    sosa:resultTime "2022-03-10T06:45:00+01:00"^^xsd:dateTimeStamp ;
    poso:madeBySystem <system/IPS> ;
    sosa:usedProcedure posoc:LDPL ; # Log-distance path loss
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:Meter ; qudt:value "3.7"^^xsd:double ] ;
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        qudt:unit unit:DeciB_M ; qudt:value "-82"^^xsd:integer ] .
```

Usage

Relative Position

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<landmark/wap_1> a poso:Landmark ;
    rdfs:label "Wireless Access Point 1"@en ;
    poso:hasPosition [ a poso:AbsolutePosition ;
        poso:hasAccuracy [ ... ] ;
        poso:xAxisValue [ ... ] ; poso:yAxisValue [ ... ] ; poso:zAxisValue [ ... ] ] .
<me/position/relative/wap_1> a poso:RelativeDistance ;
    ssn:isPropertyOf <me> ; # Relative distance from <me> ...
    poso:isRelativeTo <landmark/wap_1> ; # to <landmark/wap_1>
    rdfs:comment "Relative position of Maxim Van de Wynckel to WAP_1"@en .
<position/relative/wap_1/1646891100000> a sosa:Observation ;
    sosa:hasFeatureOfInterest <me>, <landmark/wap_1> ;
    sosa:observedProperty <me/position/relative/wap_1> ;
    sosa:resultTime "2022-03-10T06:45:00+01:00"^^xsd:dateTimeStamp ;
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    sosa:usedProcedure posoc:LDPL ; # Log-distance path loss
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:Meter ; qudt:value "3.7"^^xsd:double ] ;
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:DeciB_M ; qudt:value "-82"^^xsd:integer ] .
```

Usage

Relative Position

```
<landmark/wap_1> a poso:Landmark ;
    rdfs:label "Wireless Access Point 1"@en ;
    poso:hasPosition [ a poso:AbsolutePosition ;
        poso:hasAccuracy [ ... ] ;
        poso:xAxisValue [ ... ] ; poso:yAxisValue [ ... ] ; poso:zAxisValue [ ... ] ] .
<me/position/relative/wap_1> a poso:RelativeDistance ;
    ssn:isPropertyOf <me> ; # Relative distance from <me> ...
    poso:isRelativeTo <landmark/wap_1> ; # to <landmark/wap_1>
    rdfs:comment "Relative position of Maxim Van de Wynckel to WAP_1"@en .
<position/relative/wap_1/1646891100000> a sosa:Observation ;
    sosa:hasFeatureOfInterest <me>, <landmark/wap_1> ;
    sosa:observedProperty <me/position/relative/wap_1> ;
    sosa:resultTime "2022-03-10T06:45:00+01:00"^^xsd:dateTimeStamp ;
    poso:madeBySystem <system/IPS> ;
    sosa:usedProcedure posoc:LDPL ; # Log-distance path loss
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:Meter ; qudt:value "3.7"^^xsd:double ] ;
    sosa:hasResult [ a qudt:QuantityValue ;
        qudt:unit unit:DeciB_M ; qudt:value "-82"^^xsd:integer ] .
```

Conclusion and Future Work

- ▶ We presented the new **POSO** ontology
 - Describe positioning systems, their algorithms and technologies
 - Describe observations and the type of observation
- ▶ Additional poso-common module for common algorithms and systems
- ▶ Interoperability between positioning systems
- ▶ Future alignment modules for sensors and specific algorithms



-  <https://github.org/OpenHPS/POSO>
-  <https://poso.info/1.0/>
-  <http://purl.org/poso/>
-  <http://purl.org/poso/common/>