

# Indoor Positioning Using the OpenHPS Framework

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# What is OpenHPS?



## An Open Source Hybrid Positioning System

OpenHPS

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Data Object

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Data Frame

Data frames are envelopes that are transmitted and processed through a positioning model. These frames are created by source nodes (e.g. sensors) and contain one or more data objects needed to process the frame.

A frame should contain a single reading of a sensor (such as an image of a video stream or current acceleration) and not permanent or calculated information.

VideoDataFrame

uid

timestamp

source

CameraObject

uid: "camera",  
position: {  
  x: 2, y: 5, z: 3  
},  
projection: ...,  
width: 1280,  
height: 1024

Image

Detected object

DataObject

Detected object

DataObject

Detected object

IMUDataFrame

uid

timestamp

source

DataObject

uid: "imusensor",  
position: {  
  x: 0, y: 0,  
  linearVelocity: {  
    x: 1, y: 0  
  }  
}

Acceleration

Sensor Frequency

No additional objects

RDFDataFrame

uid

timestamp

source

RFRceiverObject

uid: "wifiscanner",  
relativePositions: [  
  {  
    obj: "AP1",  
    distance: 5  
  },  
  {  
    obj: "AP2",  
    distance: 8  
  }  
]

AP1 DataObject

uid: "AP1",  
position: {  
  x: 0, y:  
  }

AP2 DataObject

uid: "AP2",  
position: {  
  x: 15, y: 3  
}

Creating data frames

OpenHPS is a framework that processes sensor information to retrieve a position for one or more data objects. These objects are contained within an envelope called a data frame.

```
import { DataObject, DataFrame } from '@openhps/core';

const myObject = new DataObject("bsigner", "Beat Signer");
const frame = new DataFrame();
frame.addObject(myObject);

// (method) DataFrame.addObject(object: DataObject): void
```

A basic data frame supports the addition of objects. Extended versions of this basic data frame also add additional sensor data.

Creating a custom data frame

Similar to data objects, decorators have to be used to indicate a serializable data frame.

```
import {
  DataFrame,
  SerializableObject,
  SerializableMember
} from '@openhps/core';

@SerializableObject()
export class QRDataFrame extends DataFrame {
  public rawImage: any = undefined;
}
```

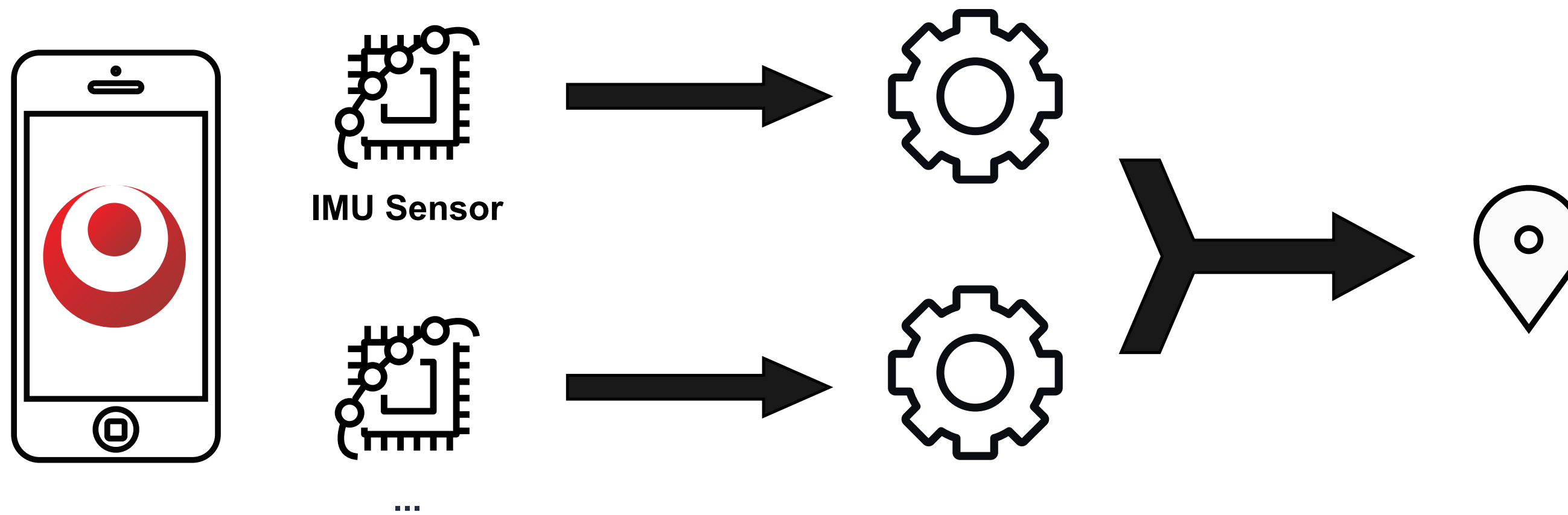
# What is OpenHPS?



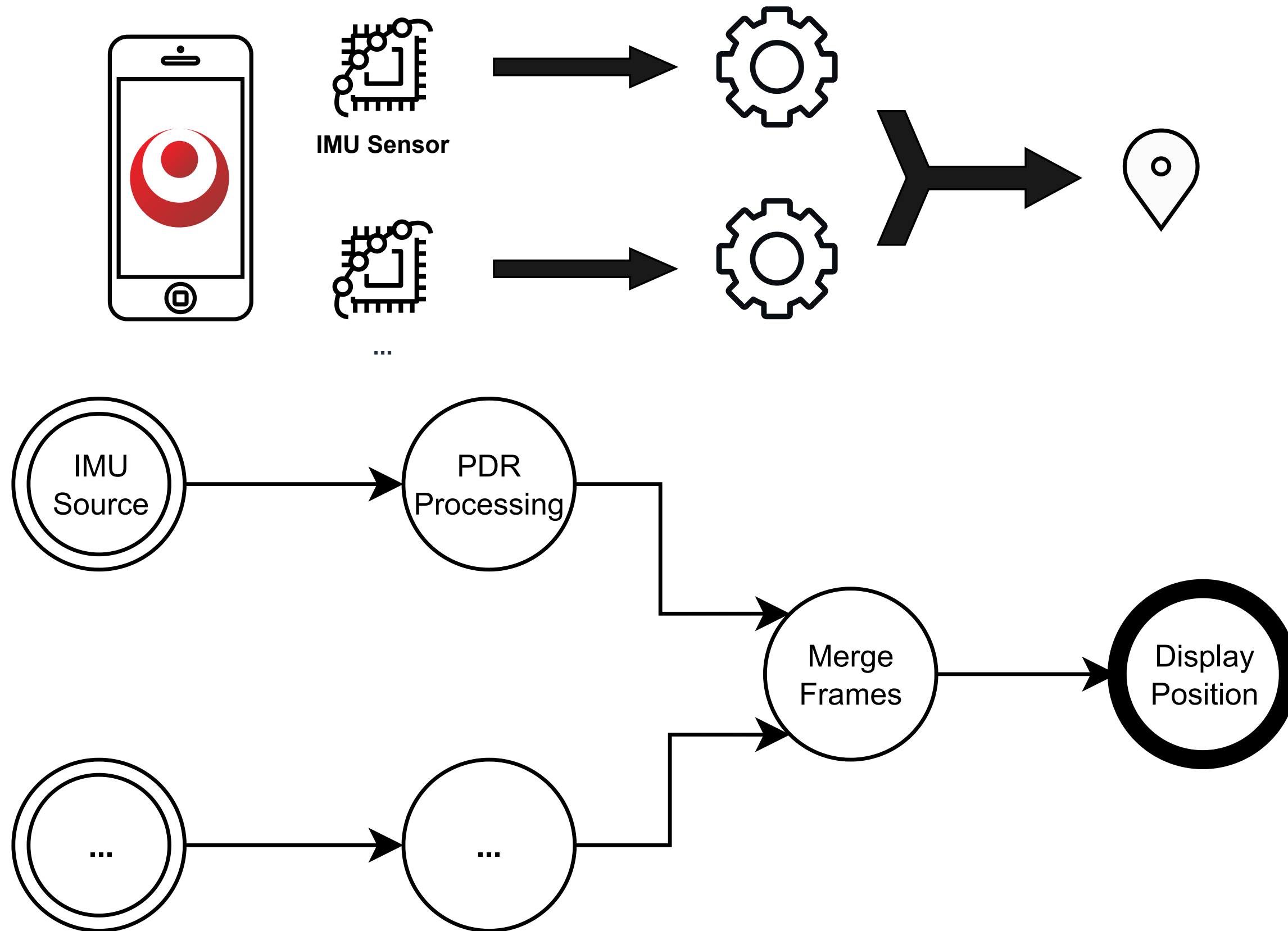
## An Open Source Hybrid Positioning System

- ▶ Any technology
- ▶ Any algorithm
- ▶ Various use cases
- ▶ Flexible processing and output
  - Accuracy over battery consumption, reliability, ...
- ▶ Aimed towards
  - Developers
  - Researchers

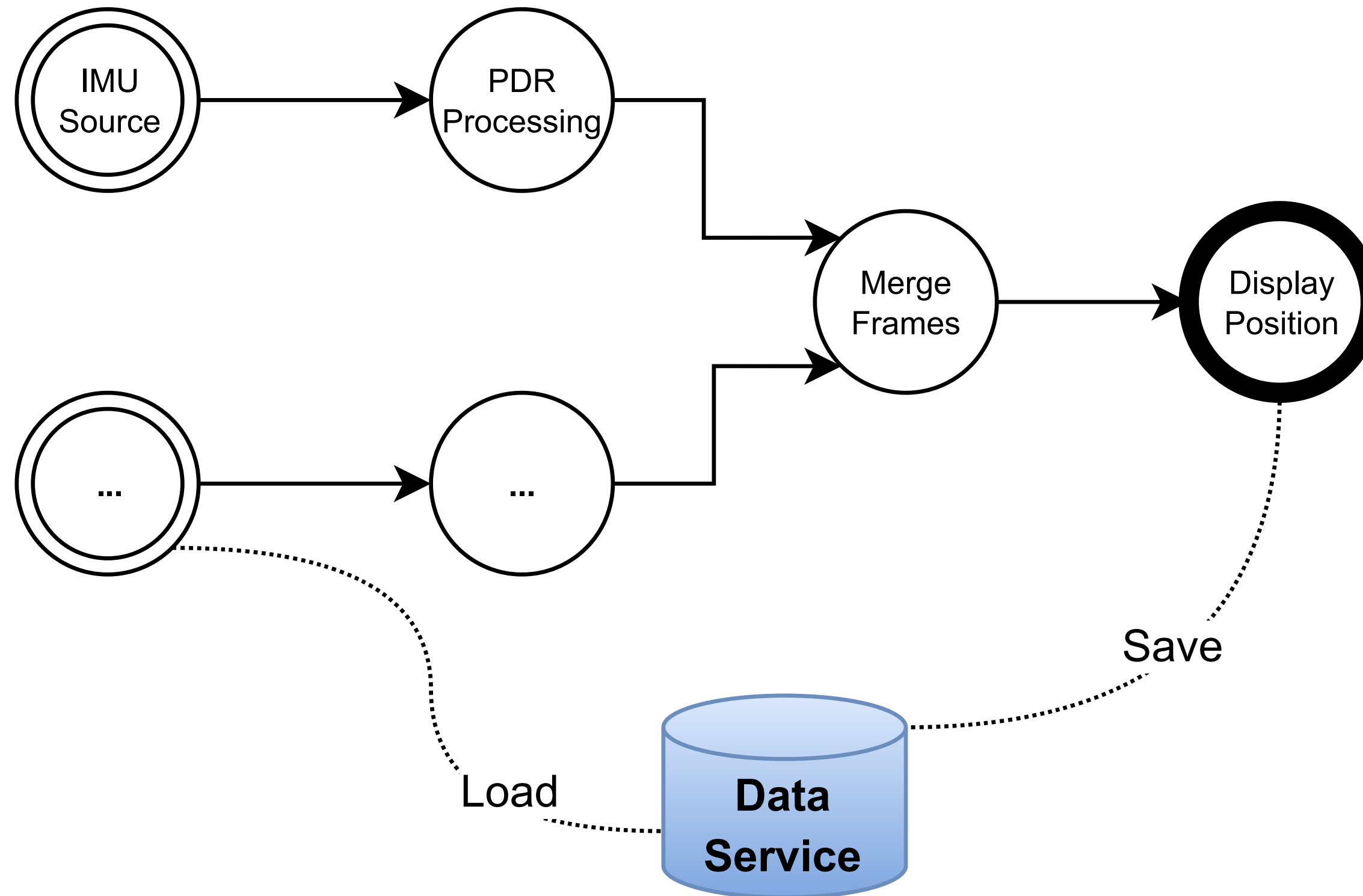
# Process Network Design



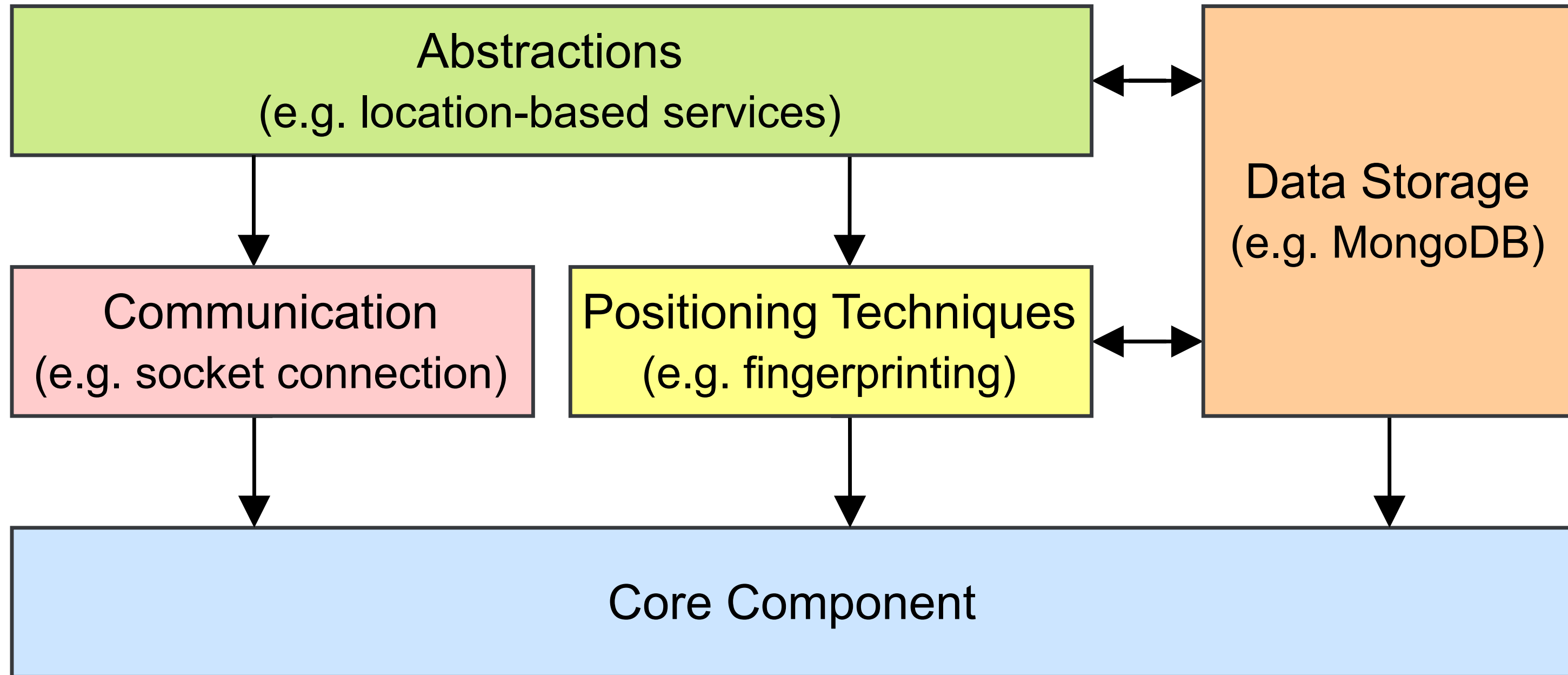
# Process Network Design ...



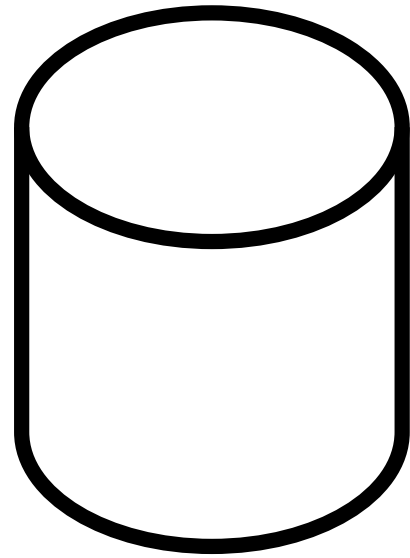
# Process Network Design ...



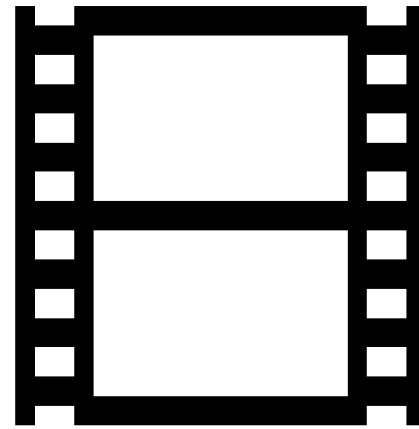
# Modularity



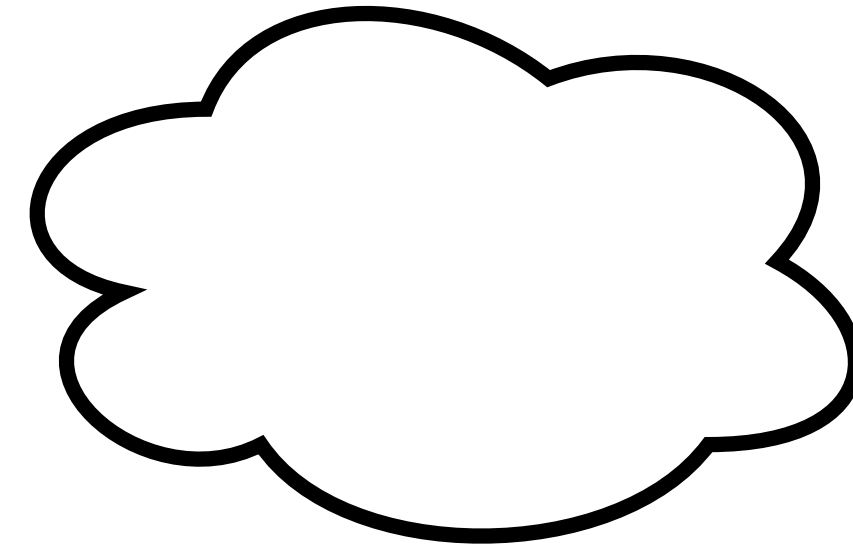
# Data Processing



**Knowledge**



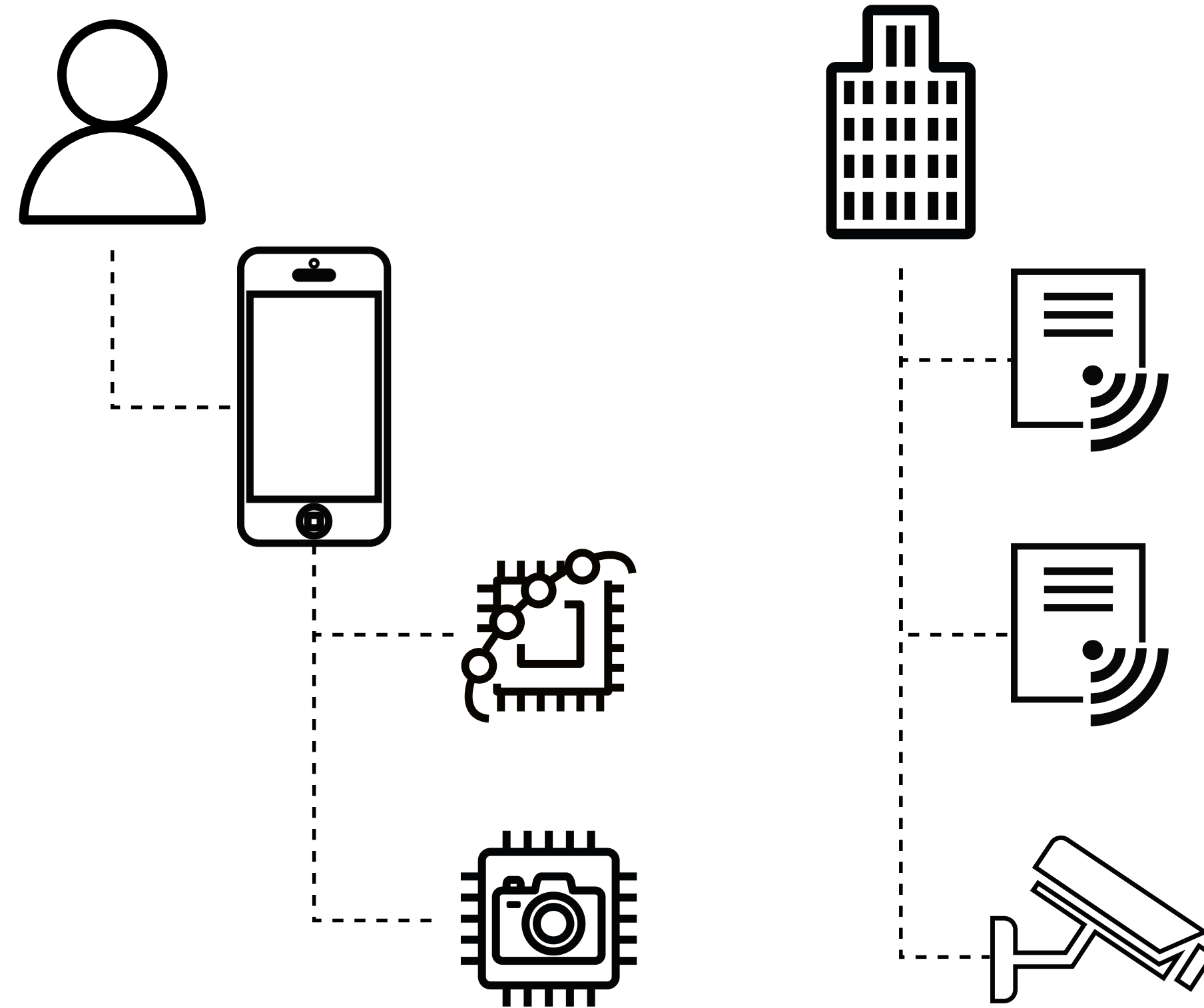
**Raw Data**



**Processed Data**



# DataObject



# Absolute and Relative Positions

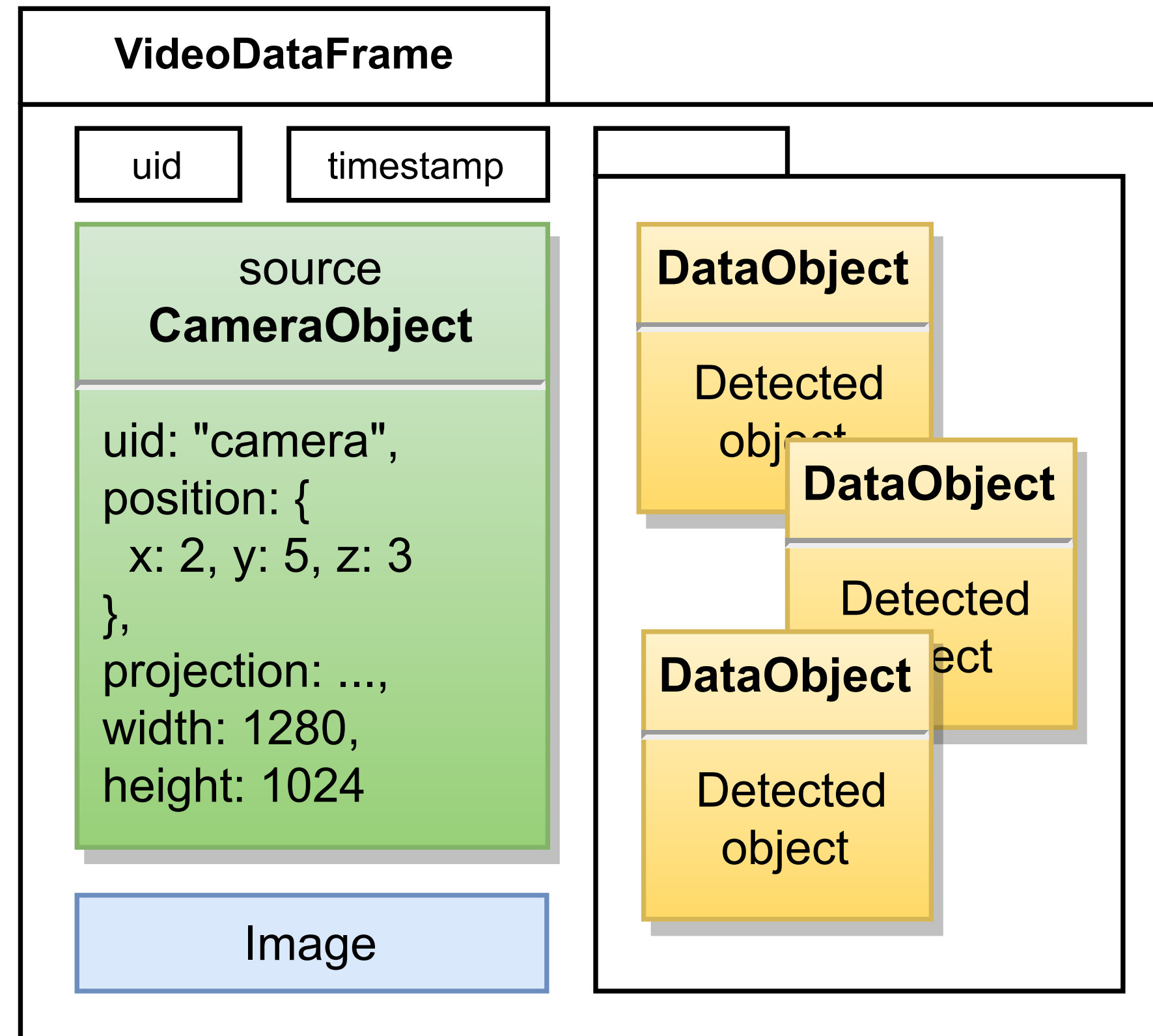
## Absolute

- ▶ 2D, 3D, Geographical, ...

## Relative

- ▶ Distance, angle, velocity, ...
- ▶ Relative to another *object*

# DataFrame



# SymbolicSpace

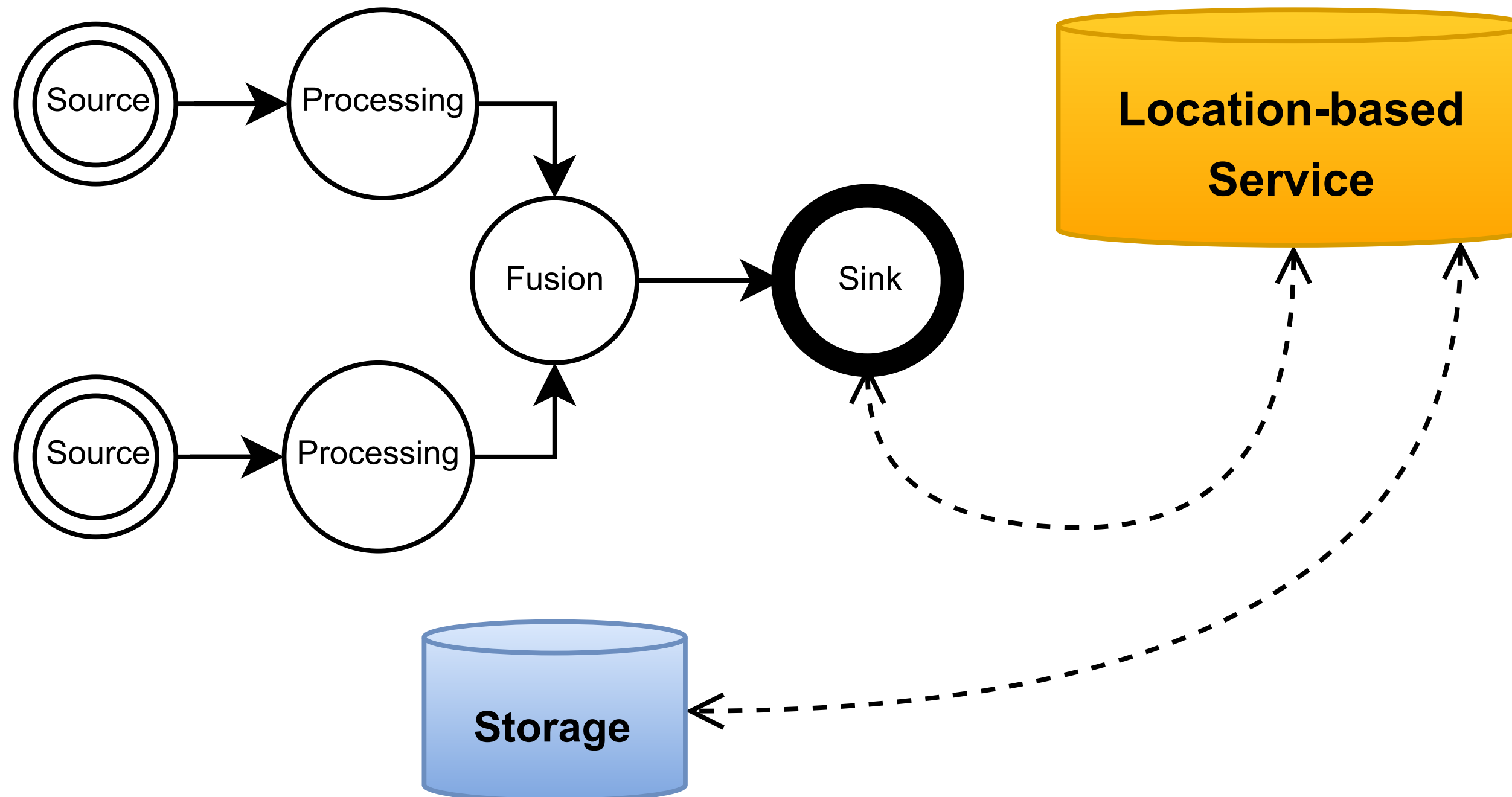
*An object that semantically defines a space*

- ▶ Spatial hierarchy
- ▶ Graph connectivity with other spaces
- ▶ Geocoding
- ▶ GeoJSON compatibility
- ▶ Can be used as a location
- ▶ Can be extended ...



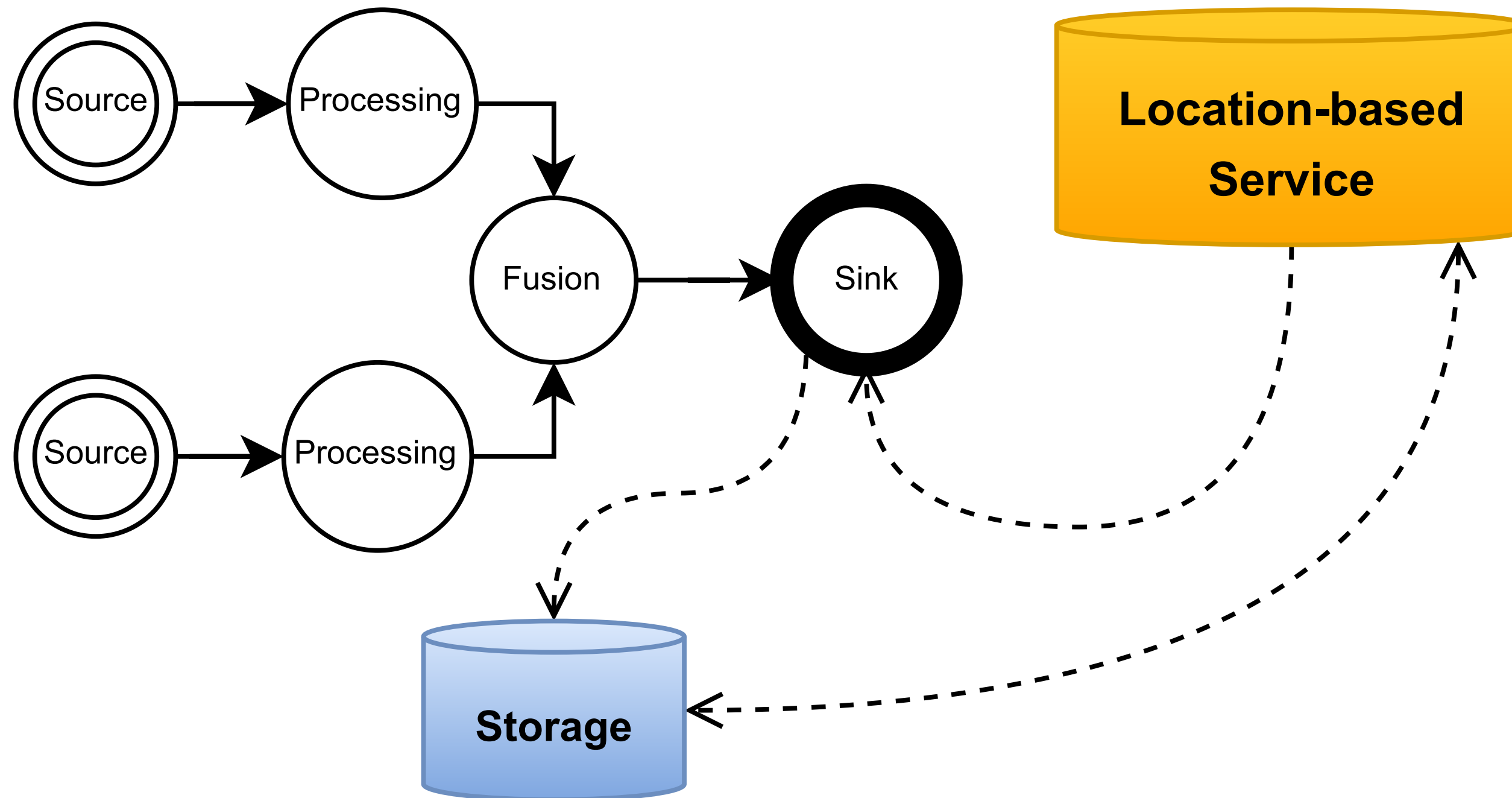
# Location-based Service

```
getCurrentPosition("me", ...)
```



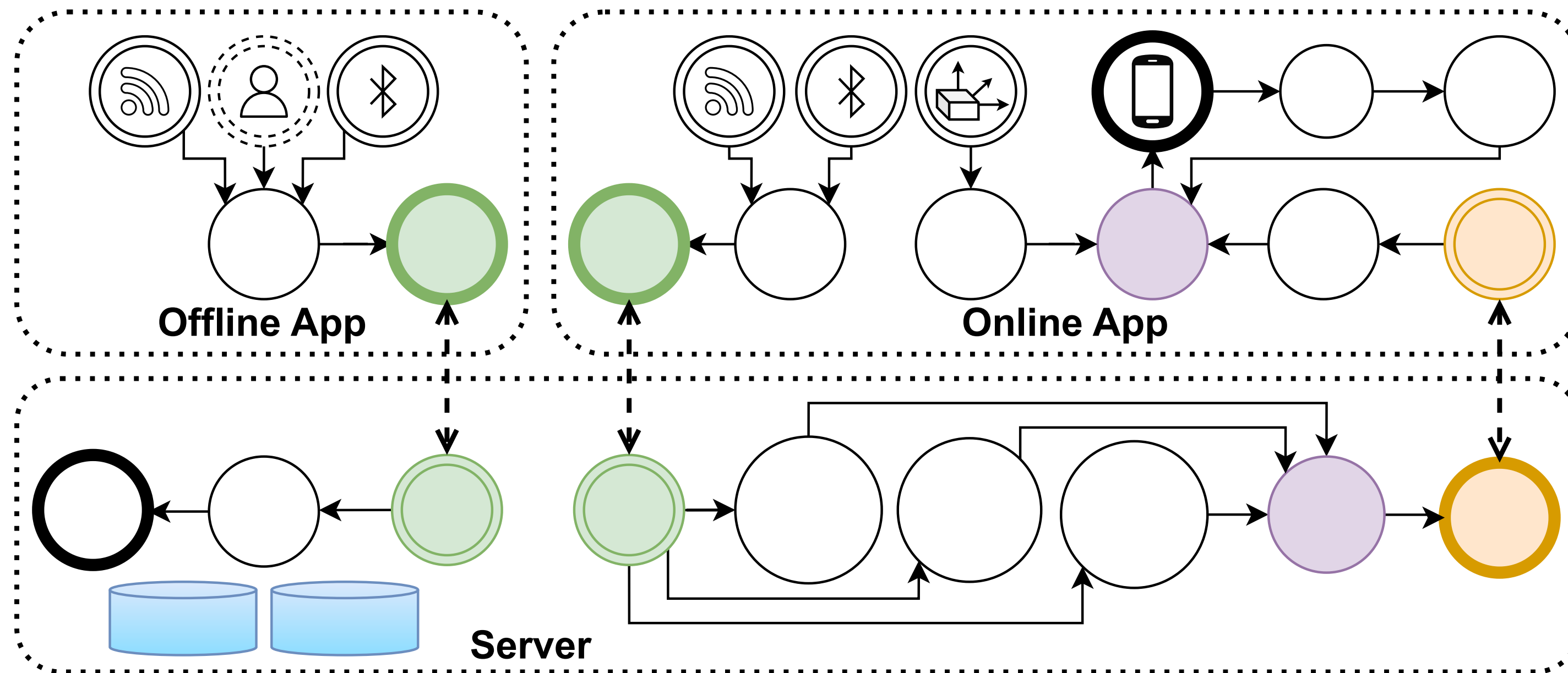
# Location-based Service ...

```
watchPosition("me", ...)
```

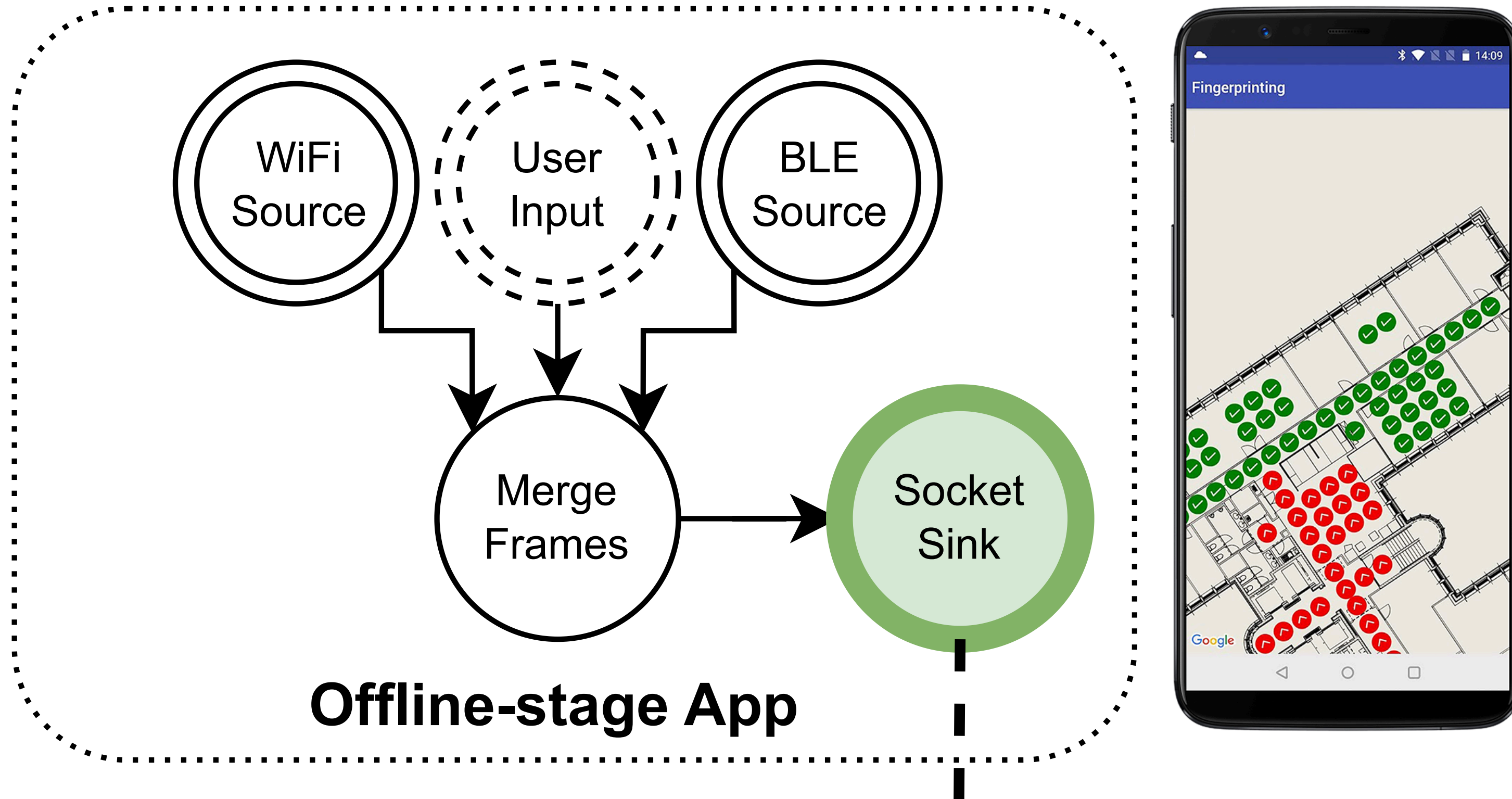


# Demonstration

- ▶ Indoor positioning **use case**
- ▶ Use **existing techniques**
- ▶ Validation of **flexibility** and modularity

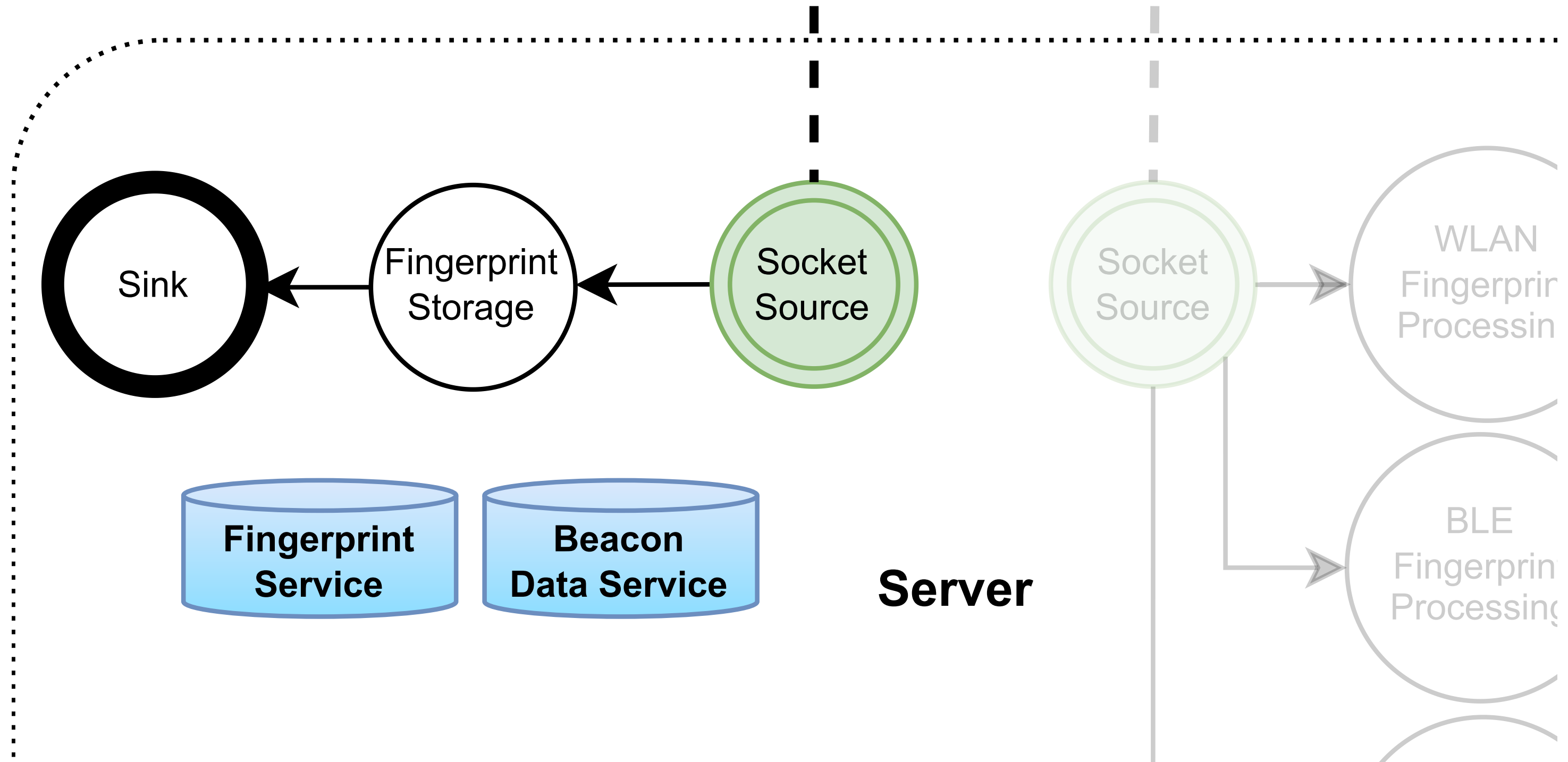


# Positioning Model

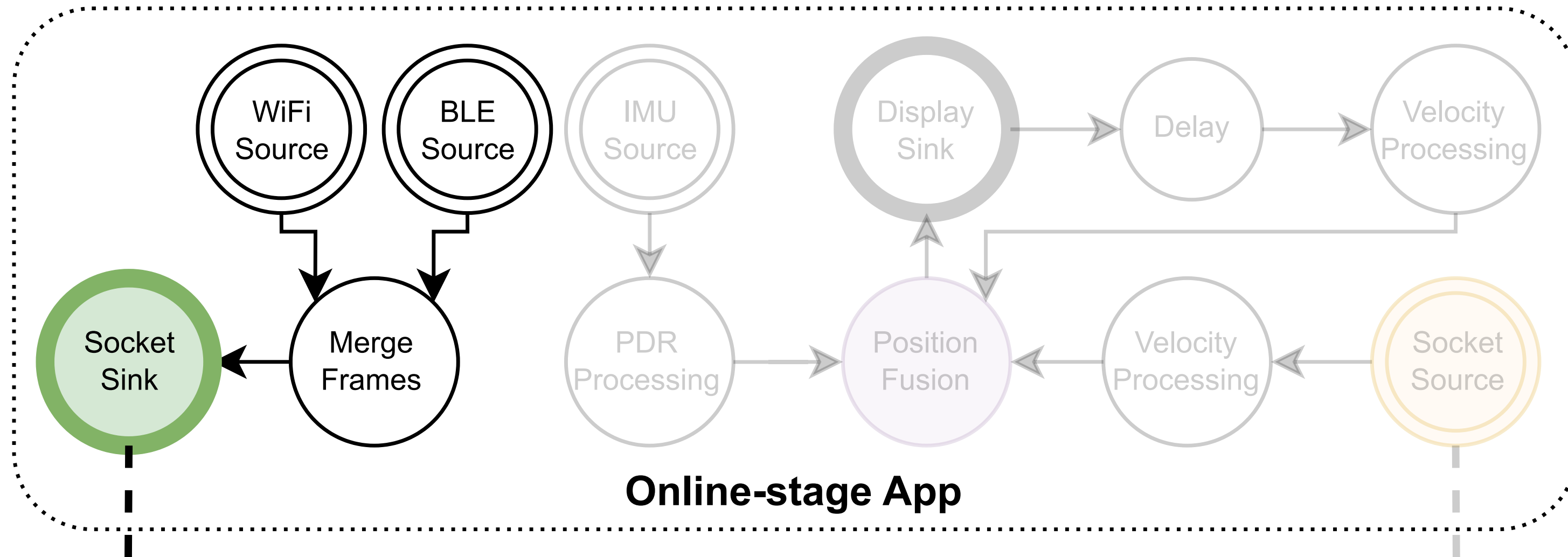




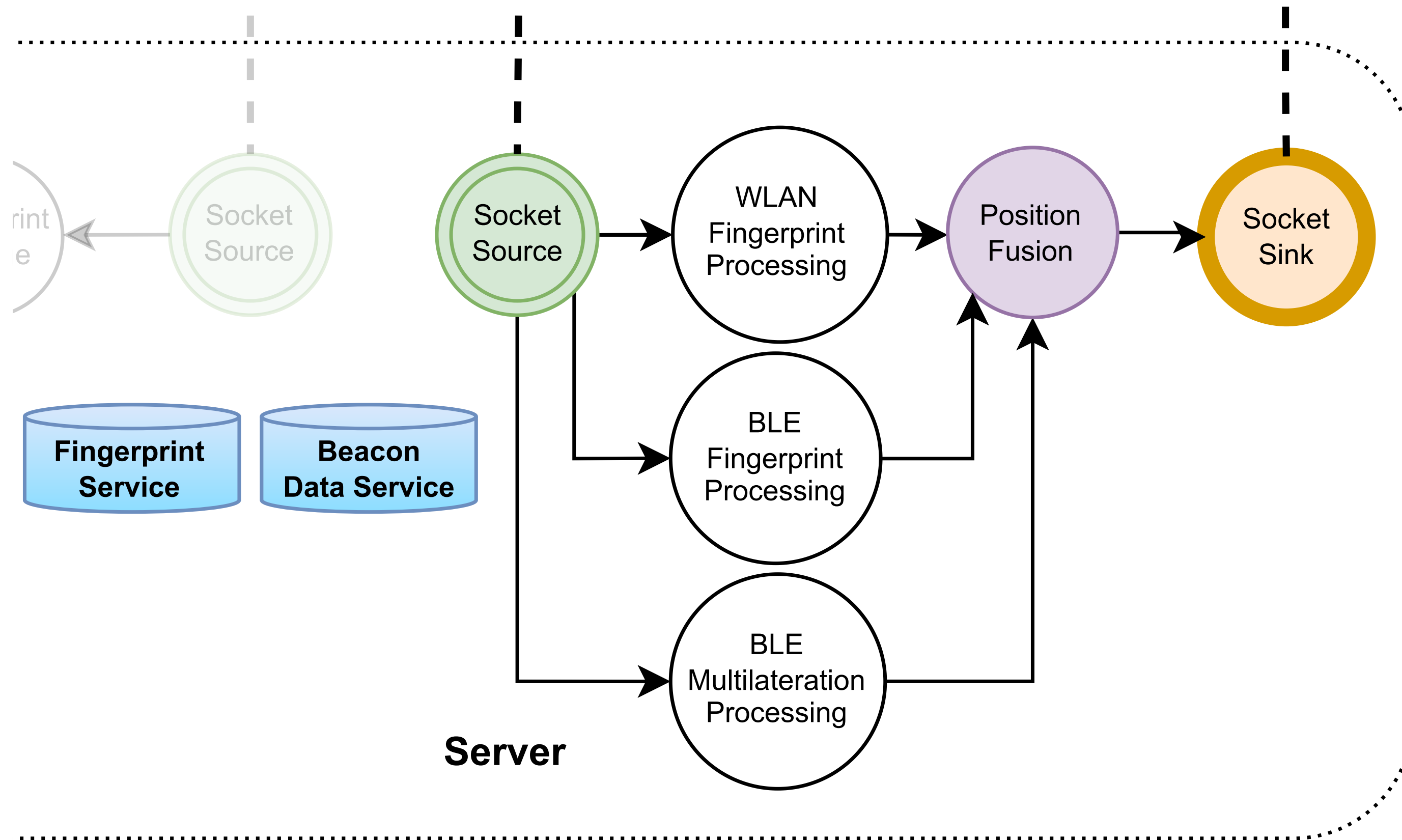
# Positioning Model ...



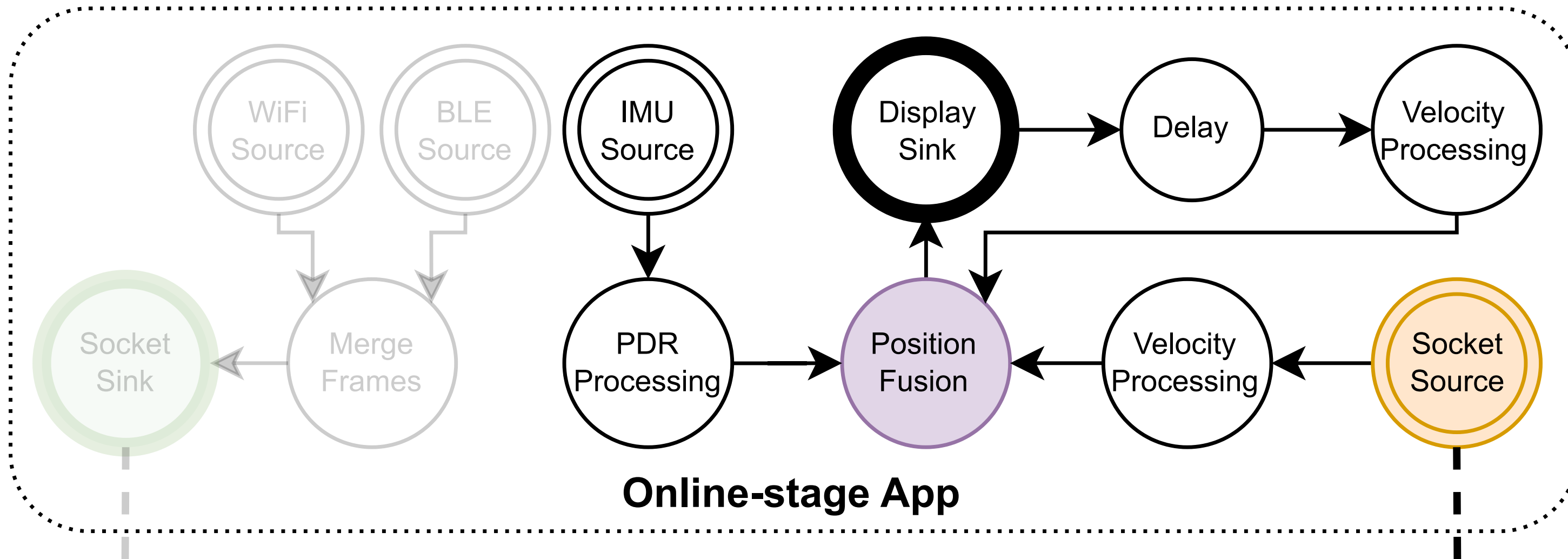
# Positioning Model ...



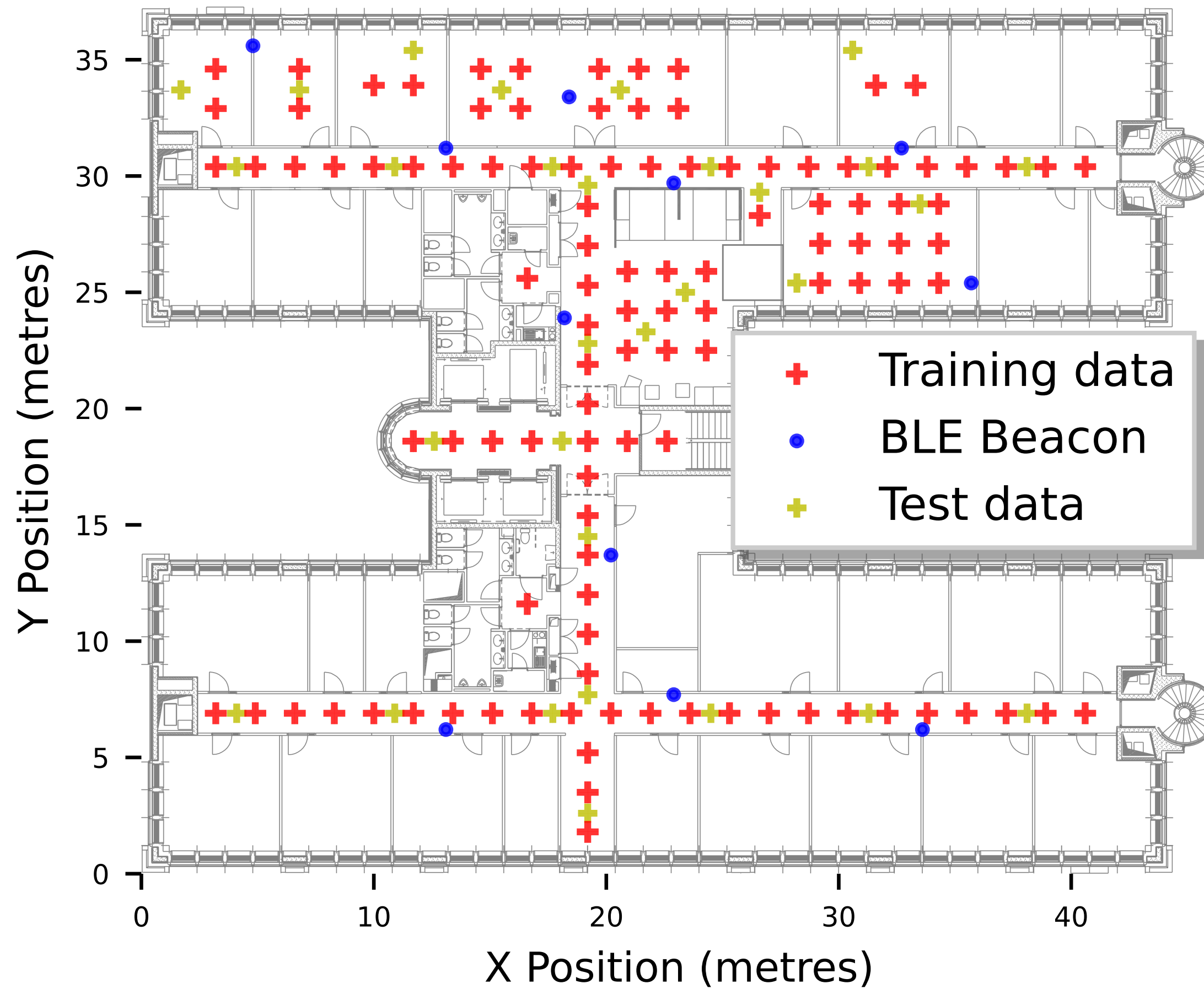
# Positioning Model ...



# Positioning Model ...



# Dataset



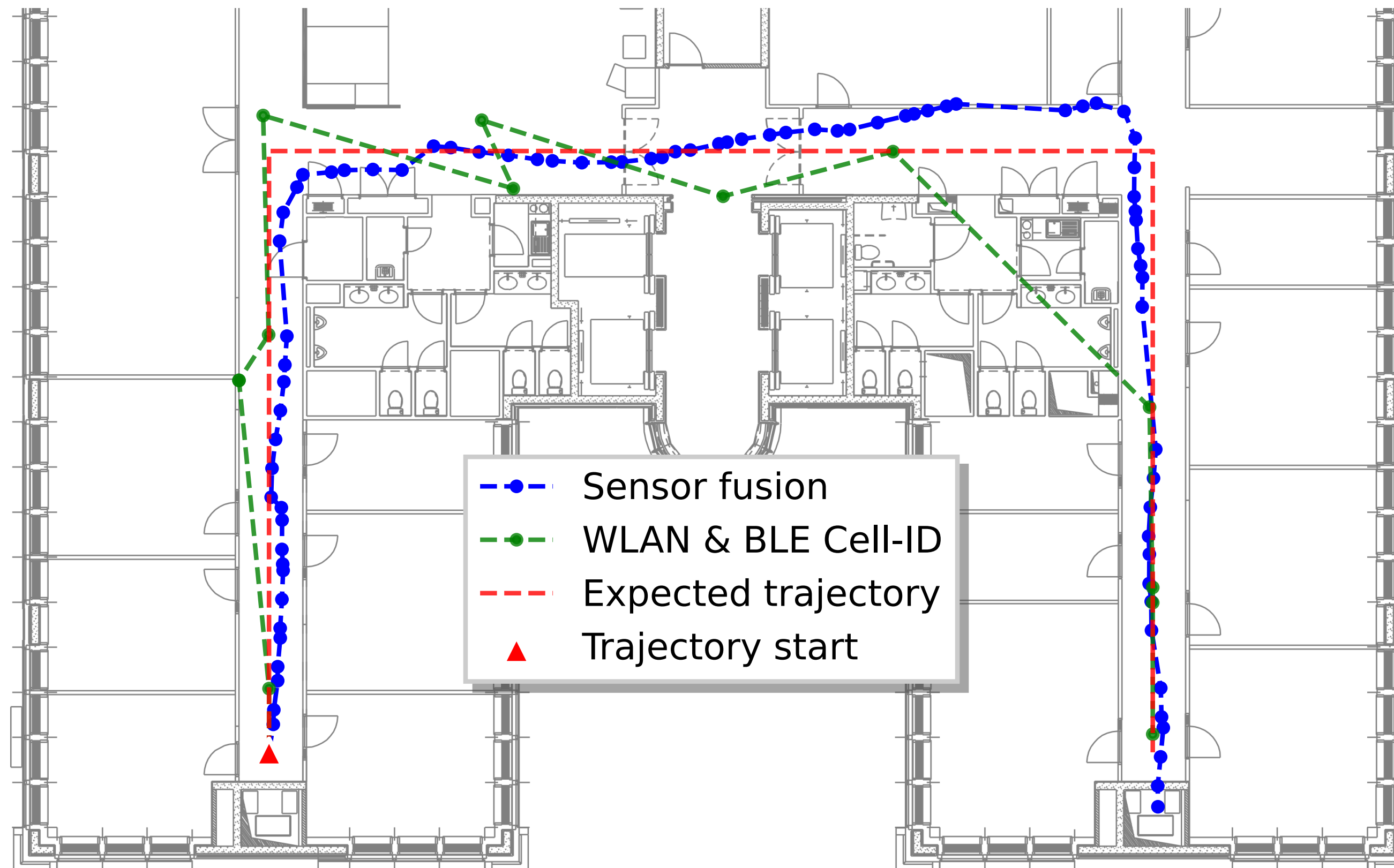
# Validation Results

## Static Positioning

	<b>WLAN</b> fingerprinting	<b>BLE</b> fingerprinting	<b>BLE</b> multilateration	<b>Fusion</b>
<i>failed points</i>	0	6	12	0
<i>average error</i>	1.23 m	3.23 m	4.92 m	1.37 m
<i>minimum error</i>	0.01 m	0.17 m	0.74 m	0.01 m
<i>maximum error</i>	4.77 m	15.39 m	19.26 m	9.75 m
<i>hit rate</i>	95.82 %	80.83 %	52.50 %	<b>96.67 %</b>

# Validation Results ...

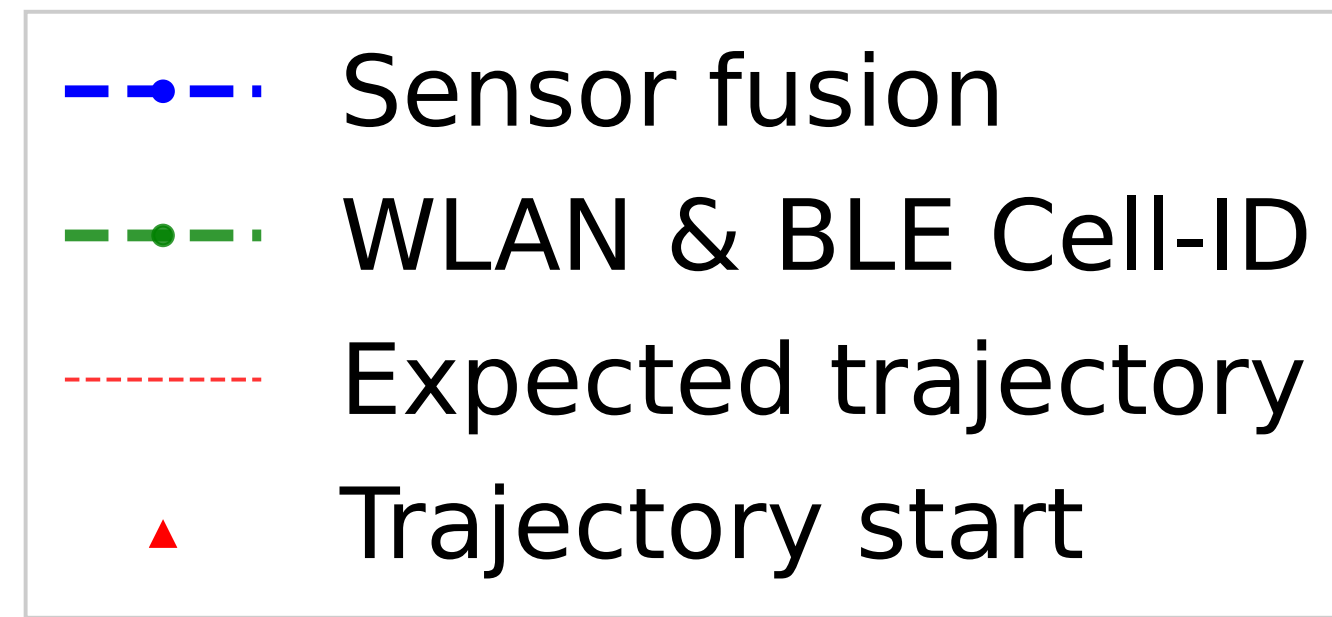
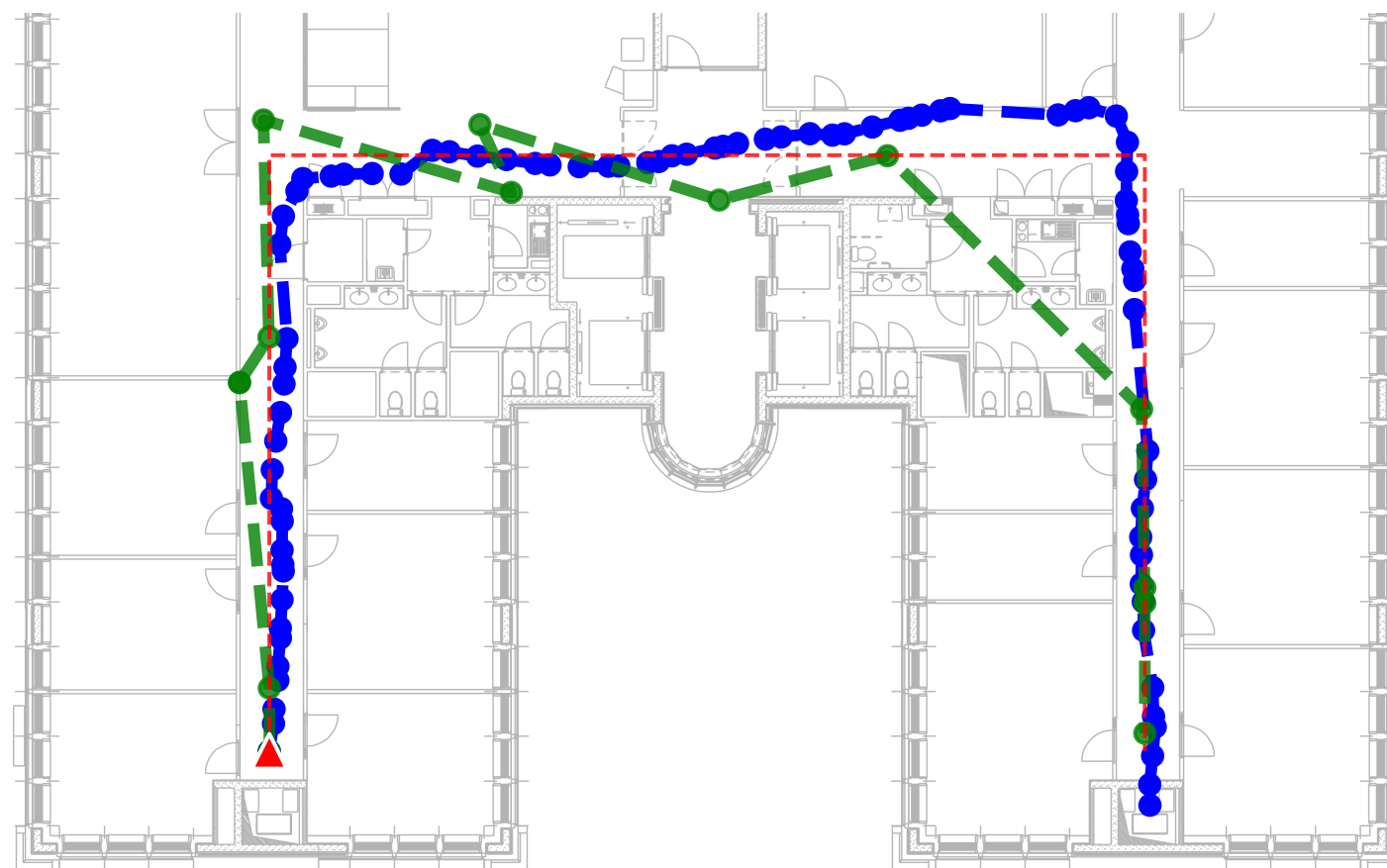
## Trajectories



# Validation Results ...

## Trajectories

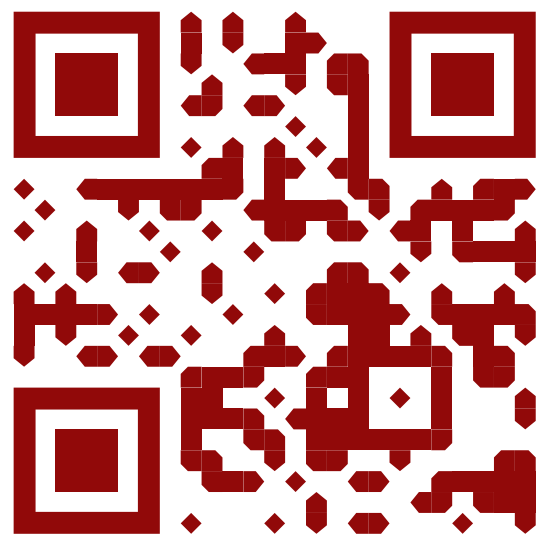
	WLAN + BLE	WLAN + BLE + IMU
<i>average error</i>	3.28 m	1.26 m
<i>maximum error</i>	9.60 m	3.10 m
<i>average update frequency</i>	3.04 s	0.52 s





# Contributions and Conclusions

- ▶ OpenHPS: **open source** framework for hybrid positioning
  - Aimed towards **developers** and **researchers**
- ▶ **Abstractions** such as location-based services and spaces
- ▶ Validation of an indoor positioning use case
- ▶ Configurable and interchangeable **nodes** and **services**
- ▶ **Public dataset** with multiple orientations



Visit <https://openhps.org> for additional resources, documentation, source code and more!