

# Indoor Positioning Using the OpenHPS Framework

---

Maxim Van de Wynckel, Beat Signer

*Web & Information Systems Engineering Lab  
Vrije Universiteit Brussel*



# What is OpenHPS?



## An Open Source Hybrid Positioning System

DOCSBLOGGITHUB

Documentation

Introduction

Installation

Modules

Basic Concepts

Data Object

Data Frame

Creating data frames

Creating a custom data frame

Standard Units

Position and Orientation

Reference Space

Positioning Model

Source Node

Processing Node

Sink Node

Services

Advanced Concepts

Remote Service

Threading

Miscellaneous

Examples

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

uidtimestamp

source

CameraObject

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

Image

DataObject

Detected object

DataObject

Detected object

DataObject

Detected object

IMUDataFrame

uidtimestamp

source

DataObject

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

Acceleration

Sensor Frequency

No additional objects

RFDDataFrame

uidtimestamp

source

RFRceiverObject

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

AP1 DataObject

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

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.

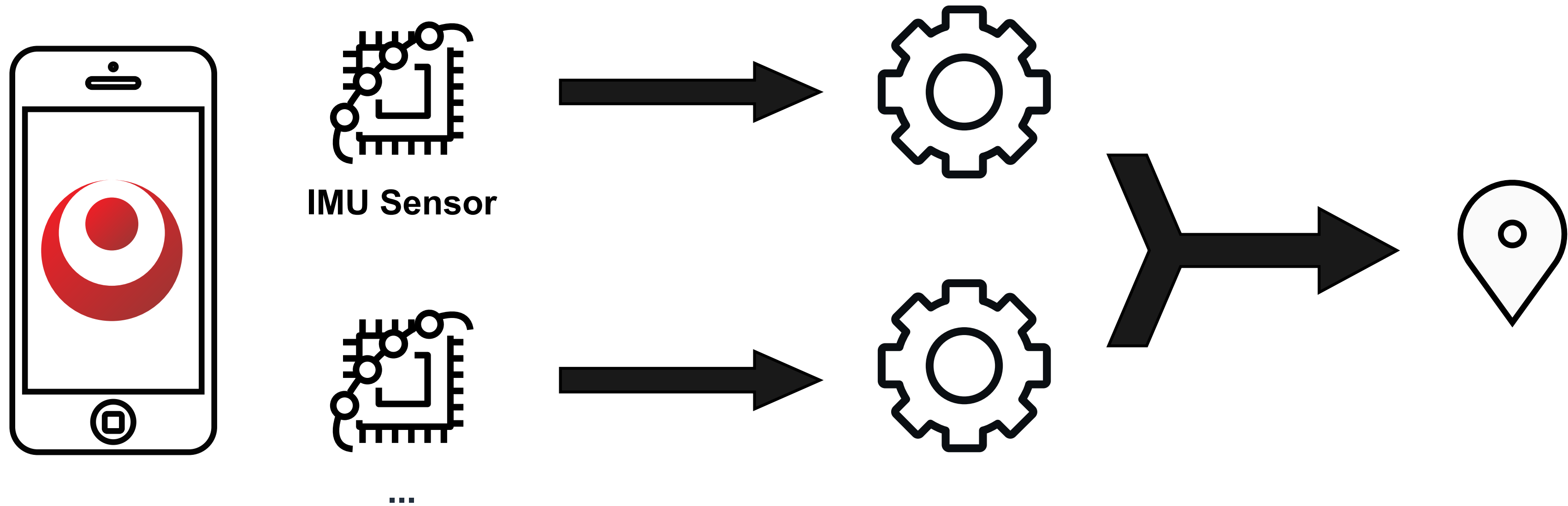
```
import {  
  DataFrame,  
  SerializableObject,  
  SerializableMember  
} from '@openhps/core';  
  
@SerializableObject()  
export class QRDataFrame extends DataFrame {  
  public rawImage: any = undefined;  
}
```

# What is OpenHPS?

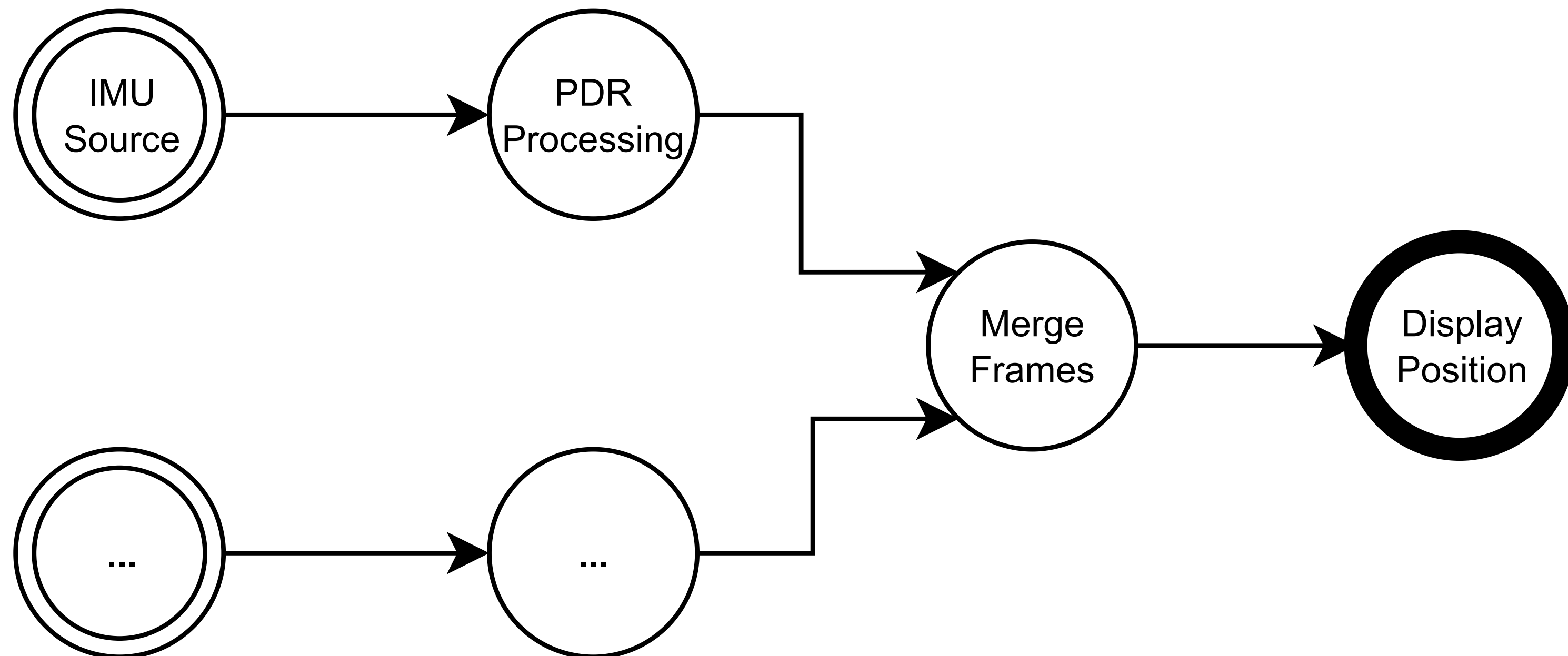
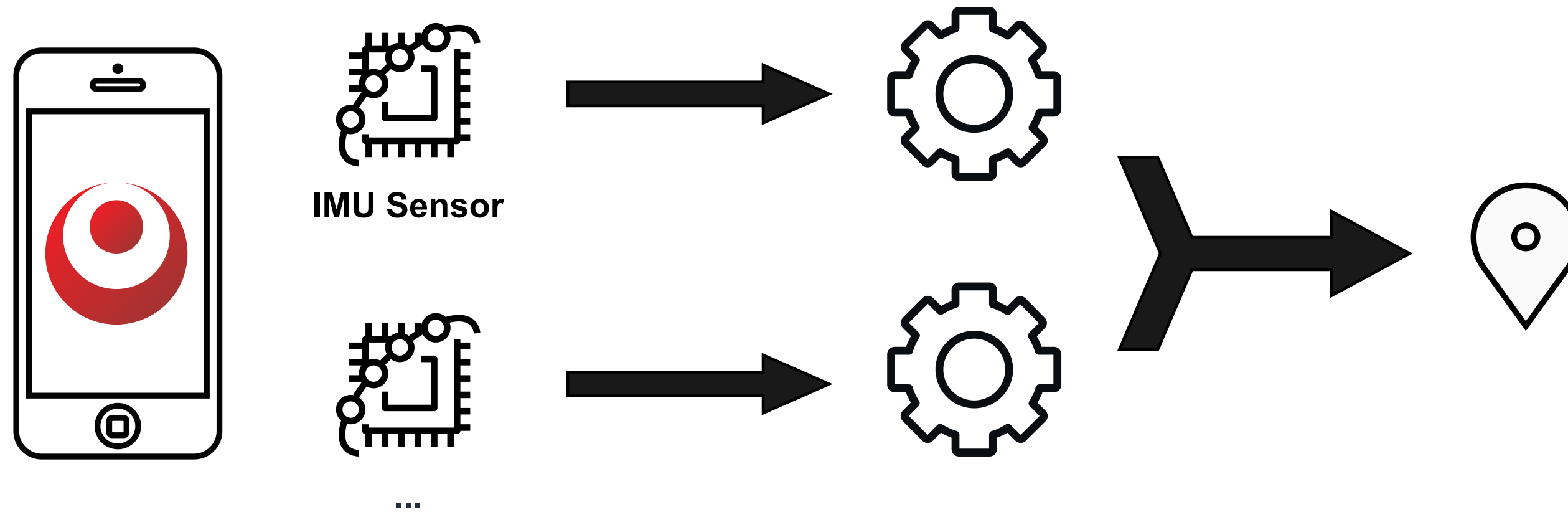
## An Open Source Hybrid Positioning System

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

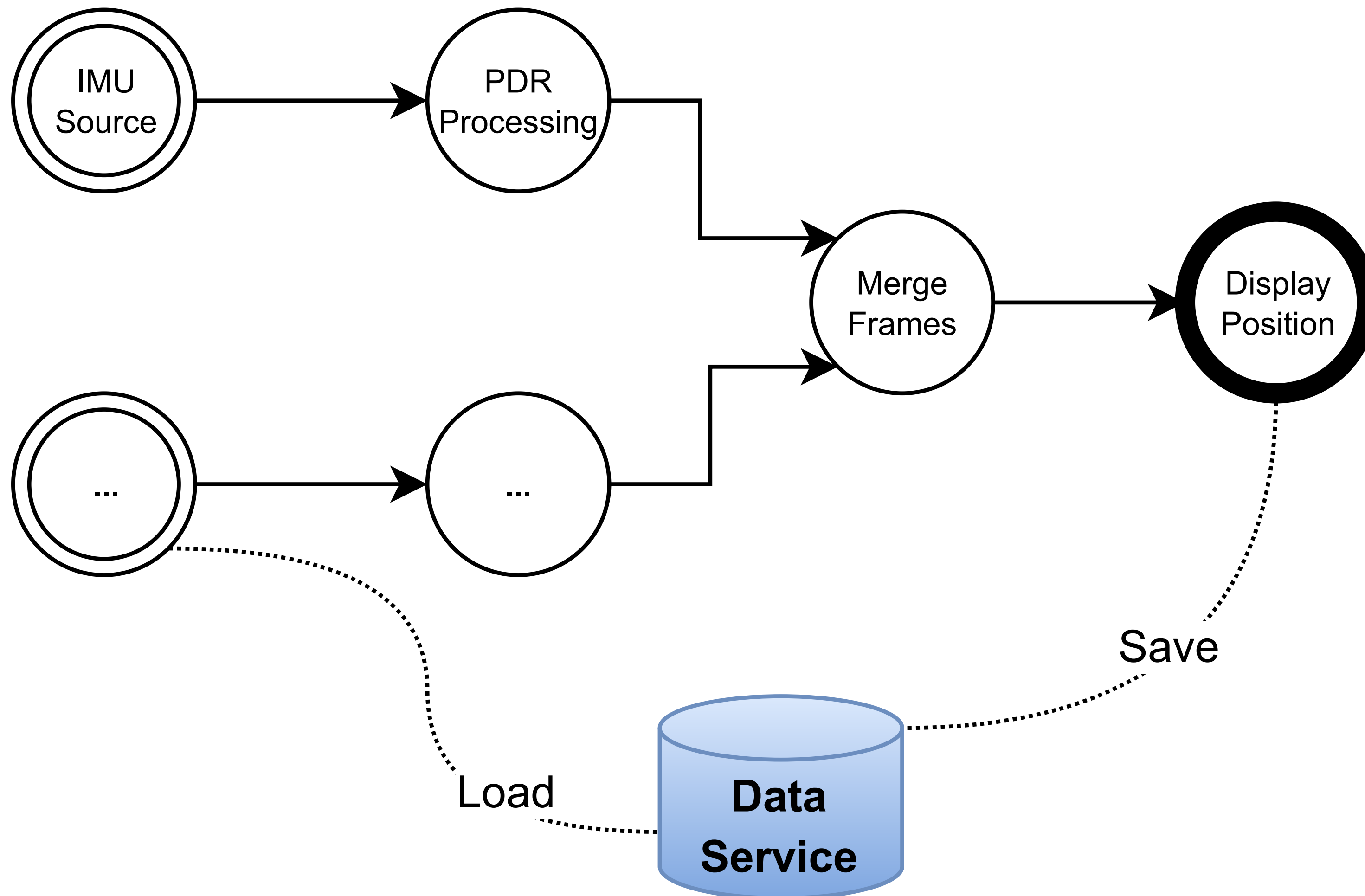
# Process Network Design



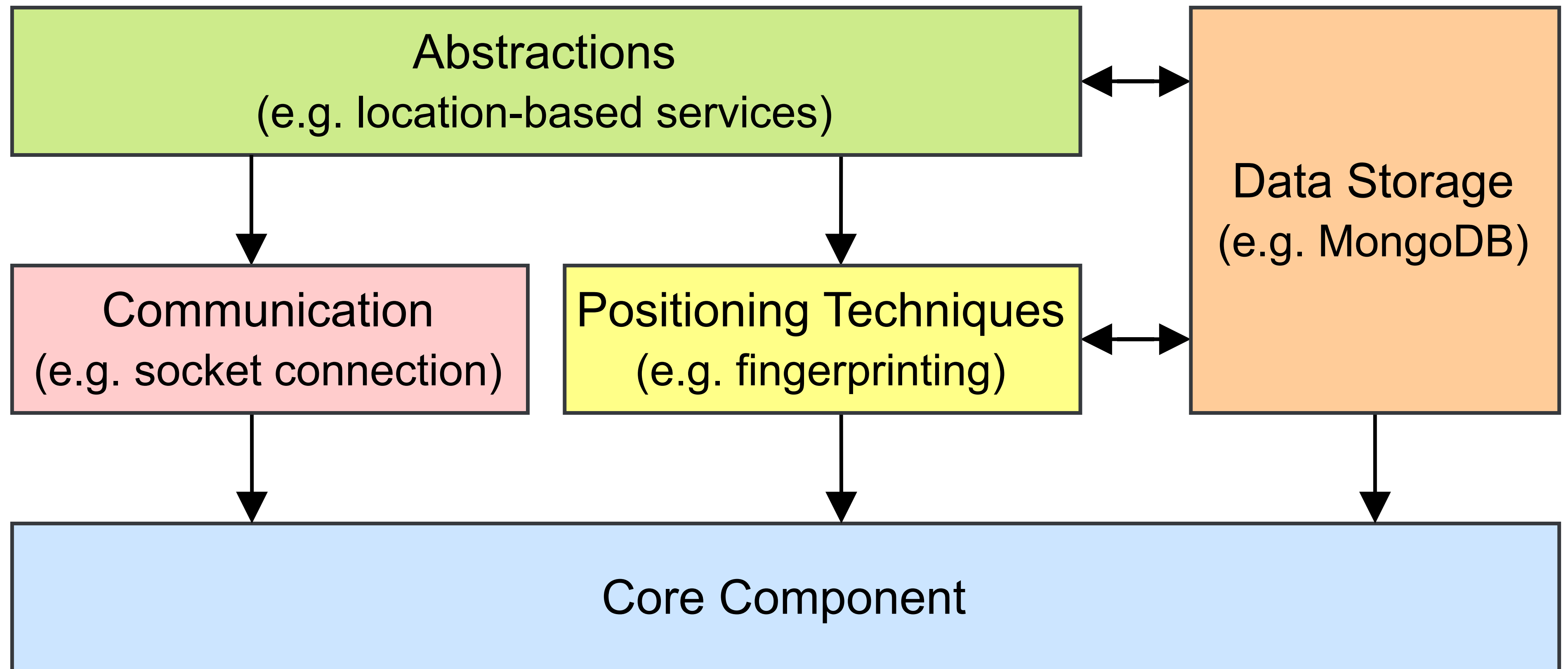
# Process Network Design ...



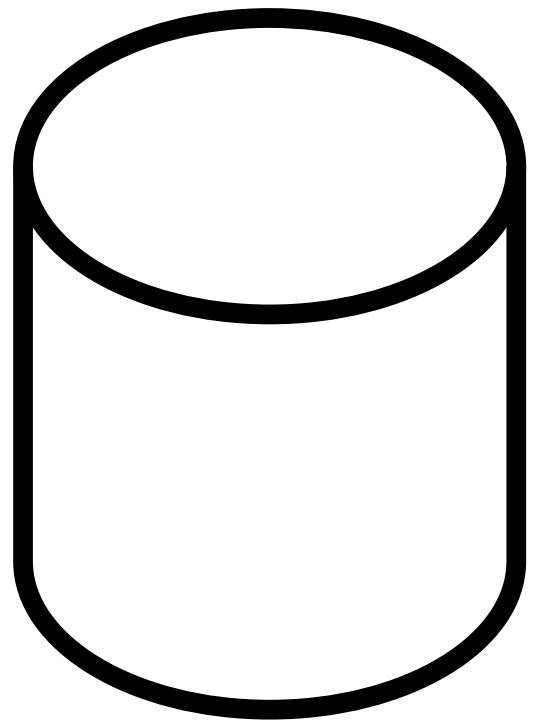
# Process Network Design ...



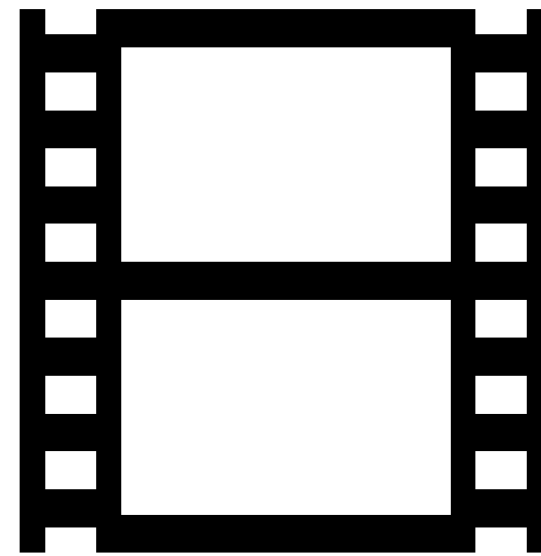
# Modularity



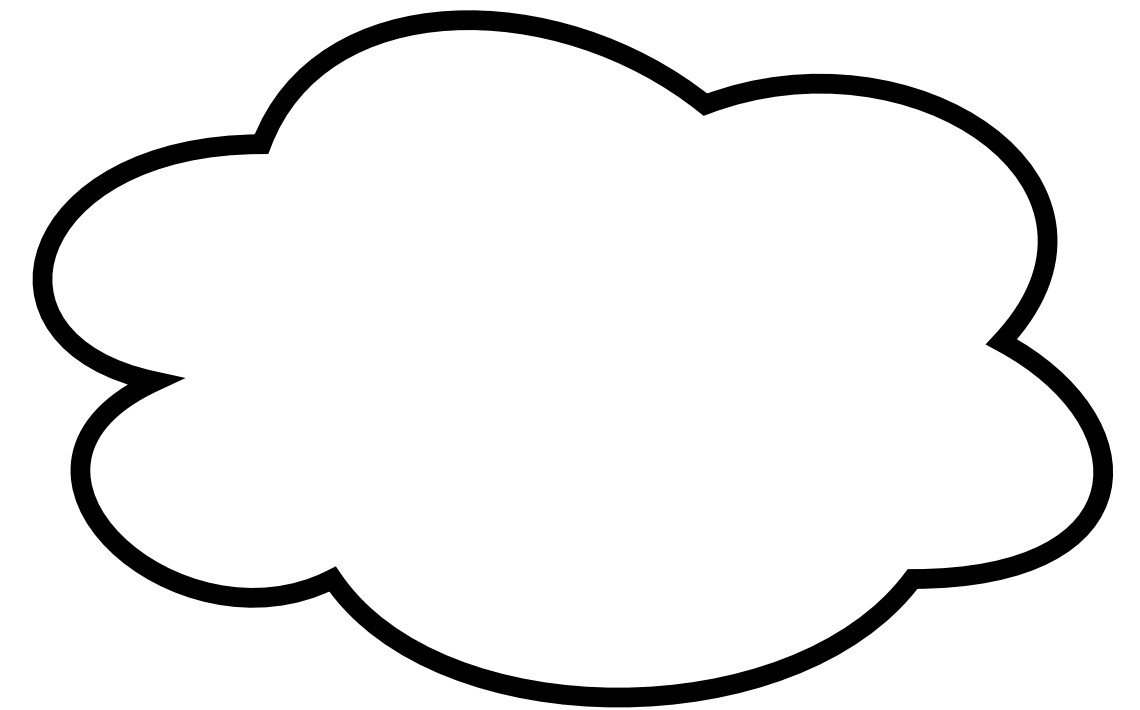
# Data Processing



**Knowledge**



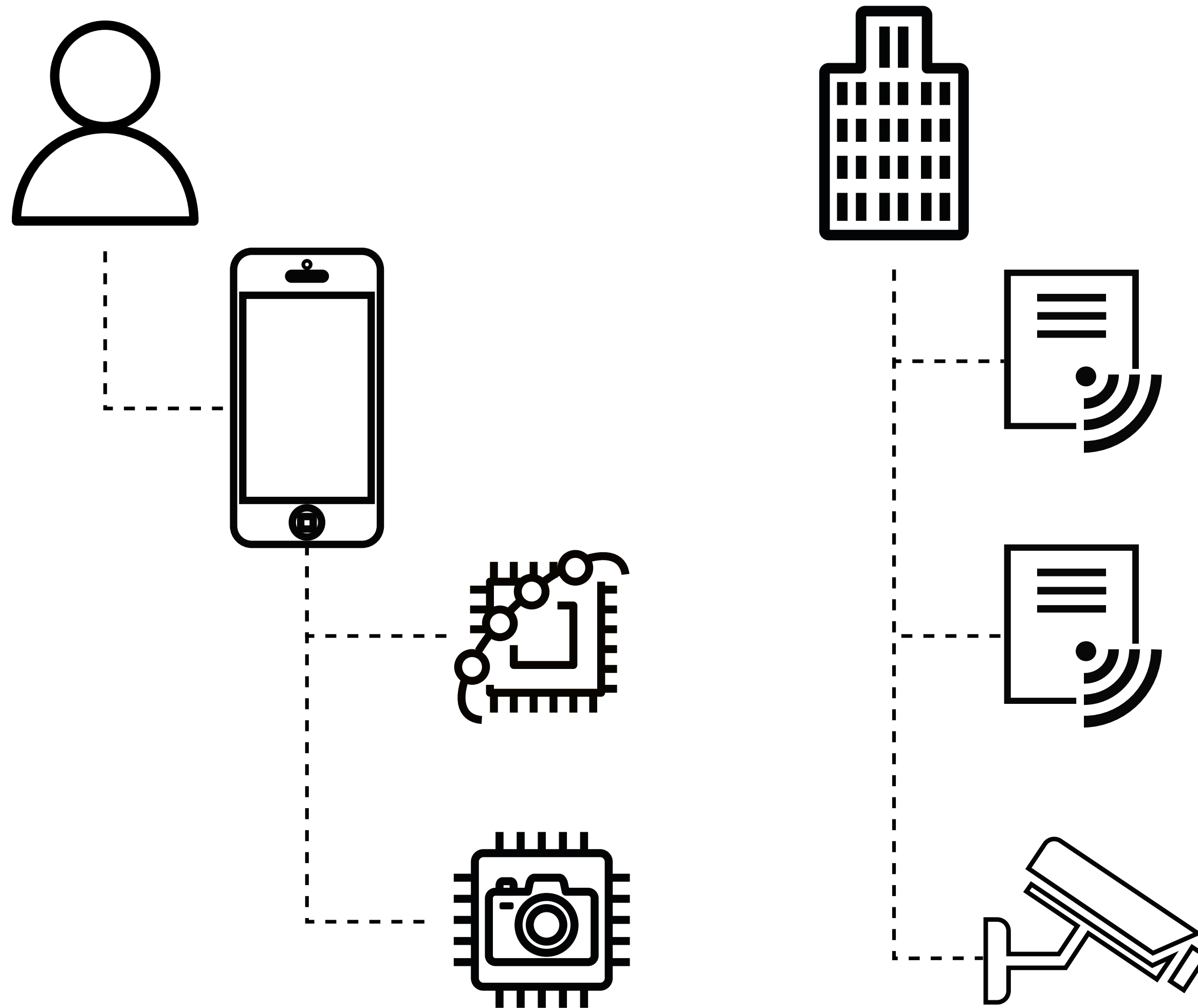
**Raw Data**



**Processed Data**



# DataObject



# Absolute and Relative Positions

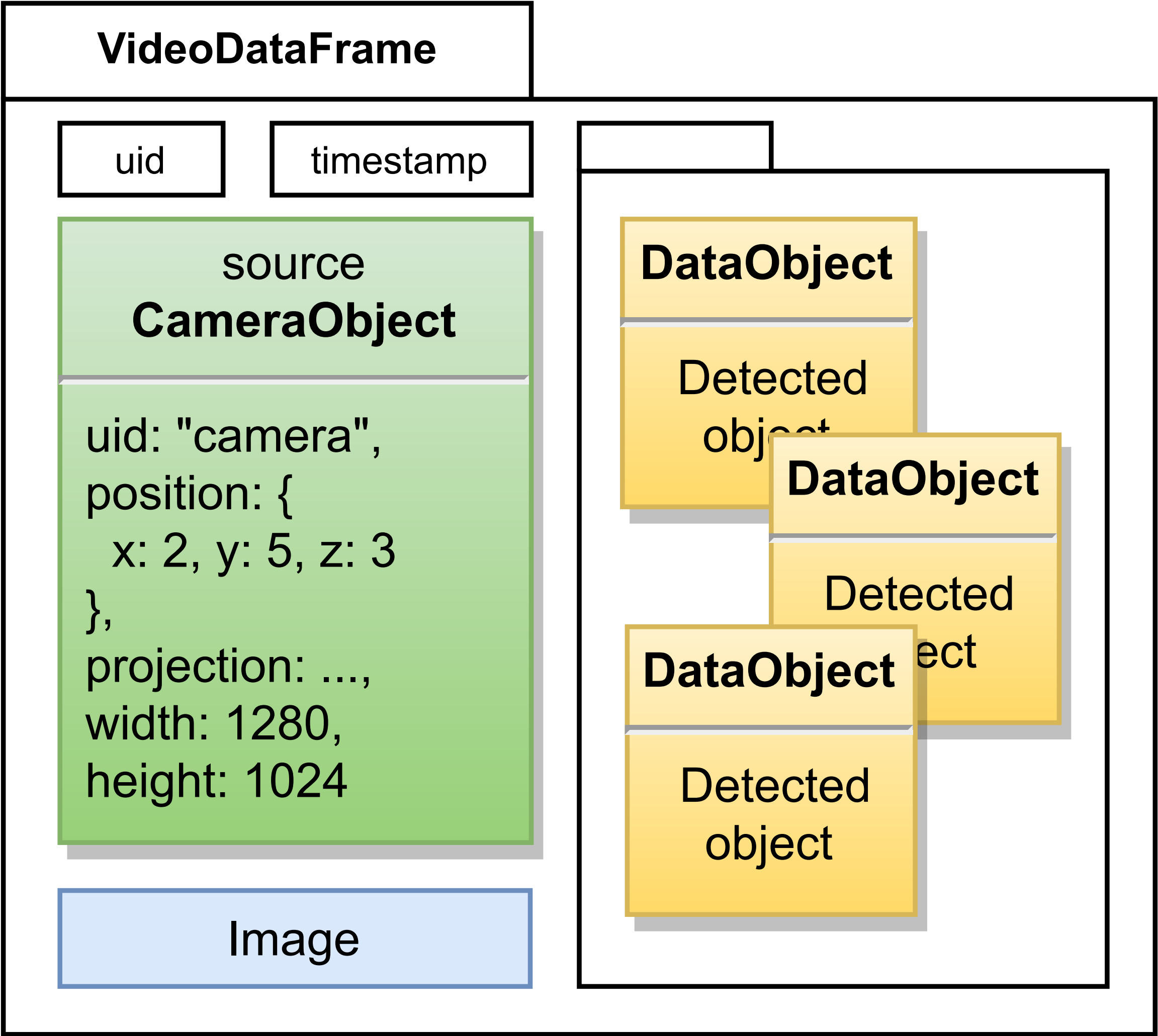
## Absolute

- ▶ 2D, 3D, Geographical, ...

## Relative

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

# DataFrame



# SymbolicSpace

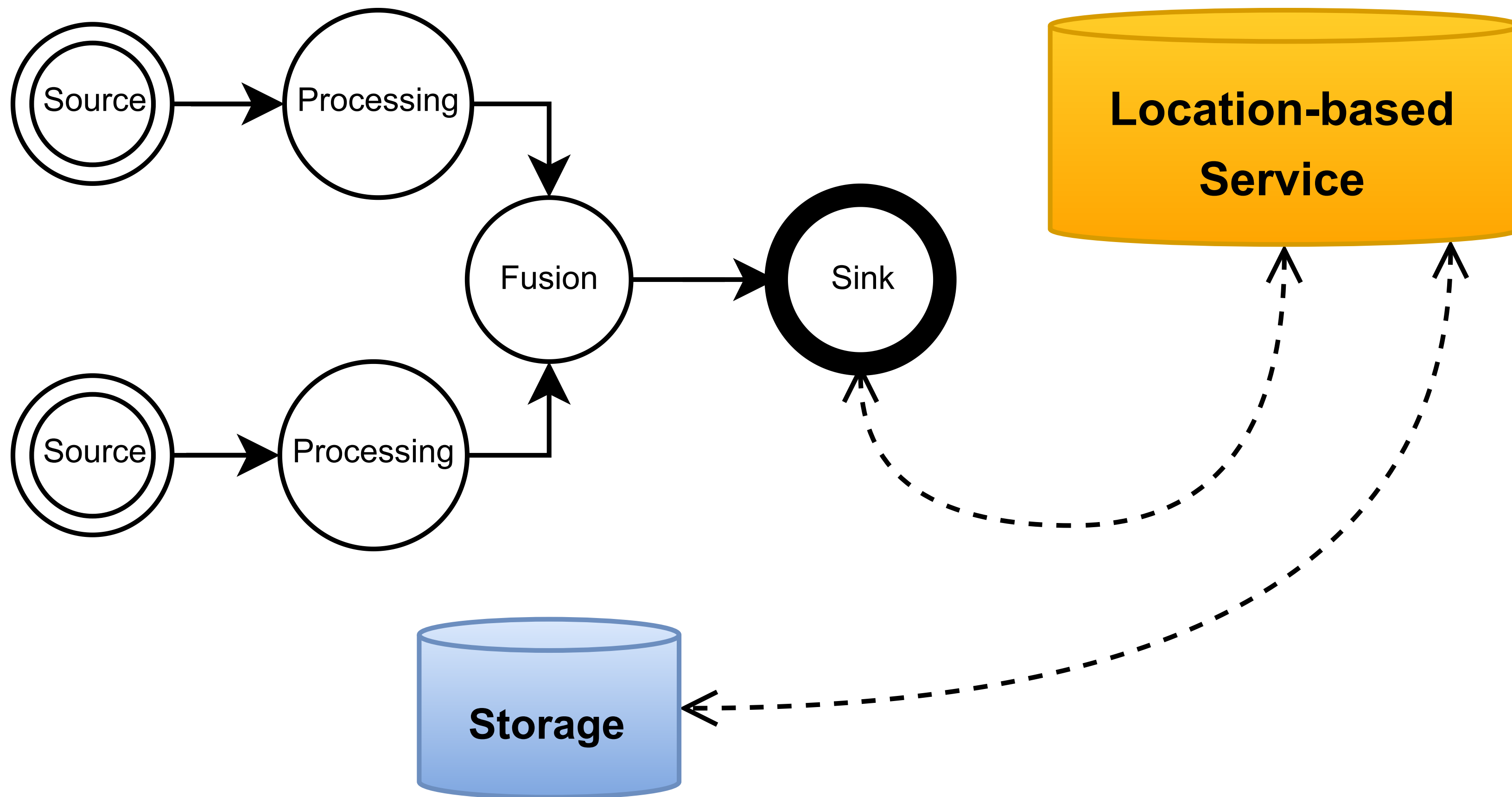
*An object that semantically defines a space*

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



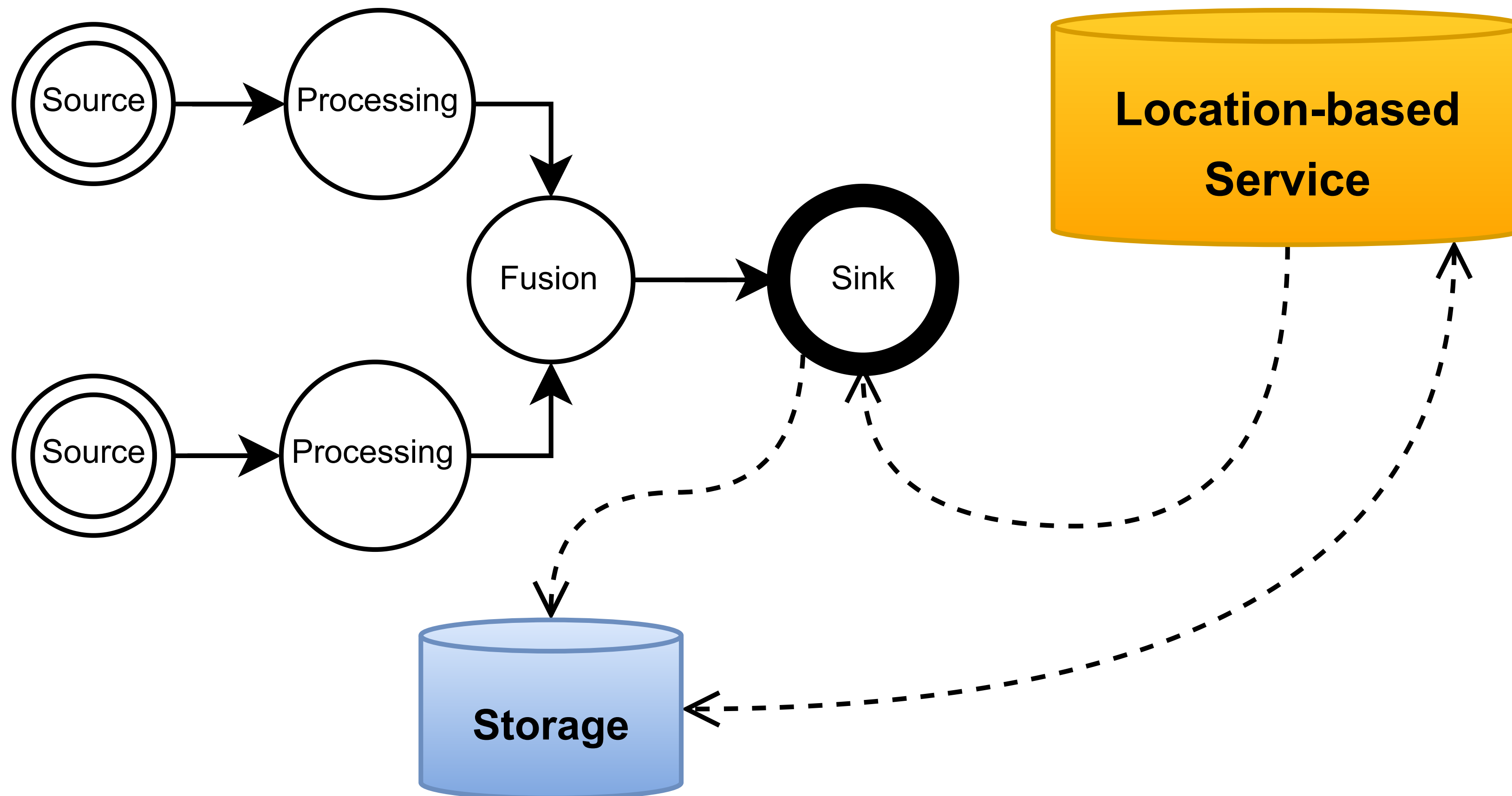
# Location-based Service

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



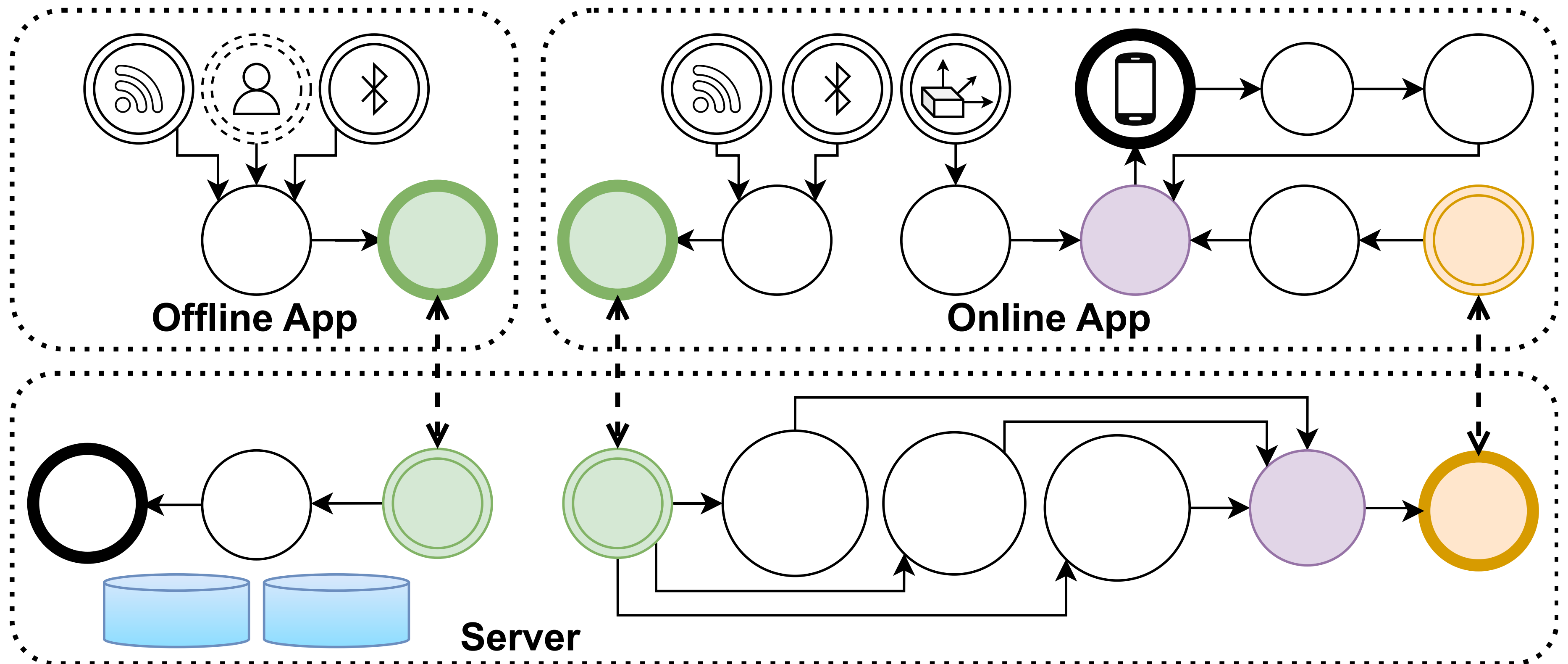
# Location-based Service ...

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



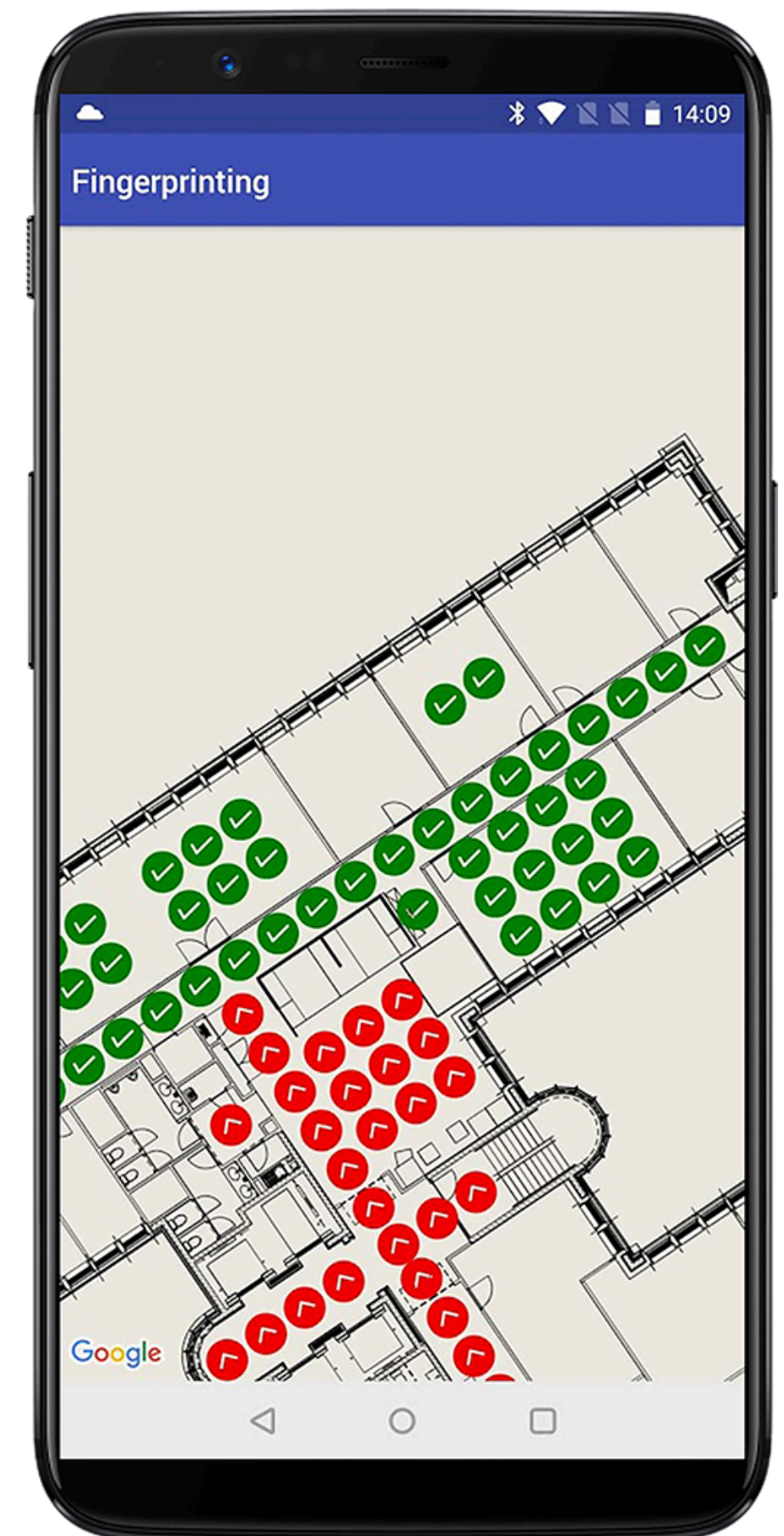
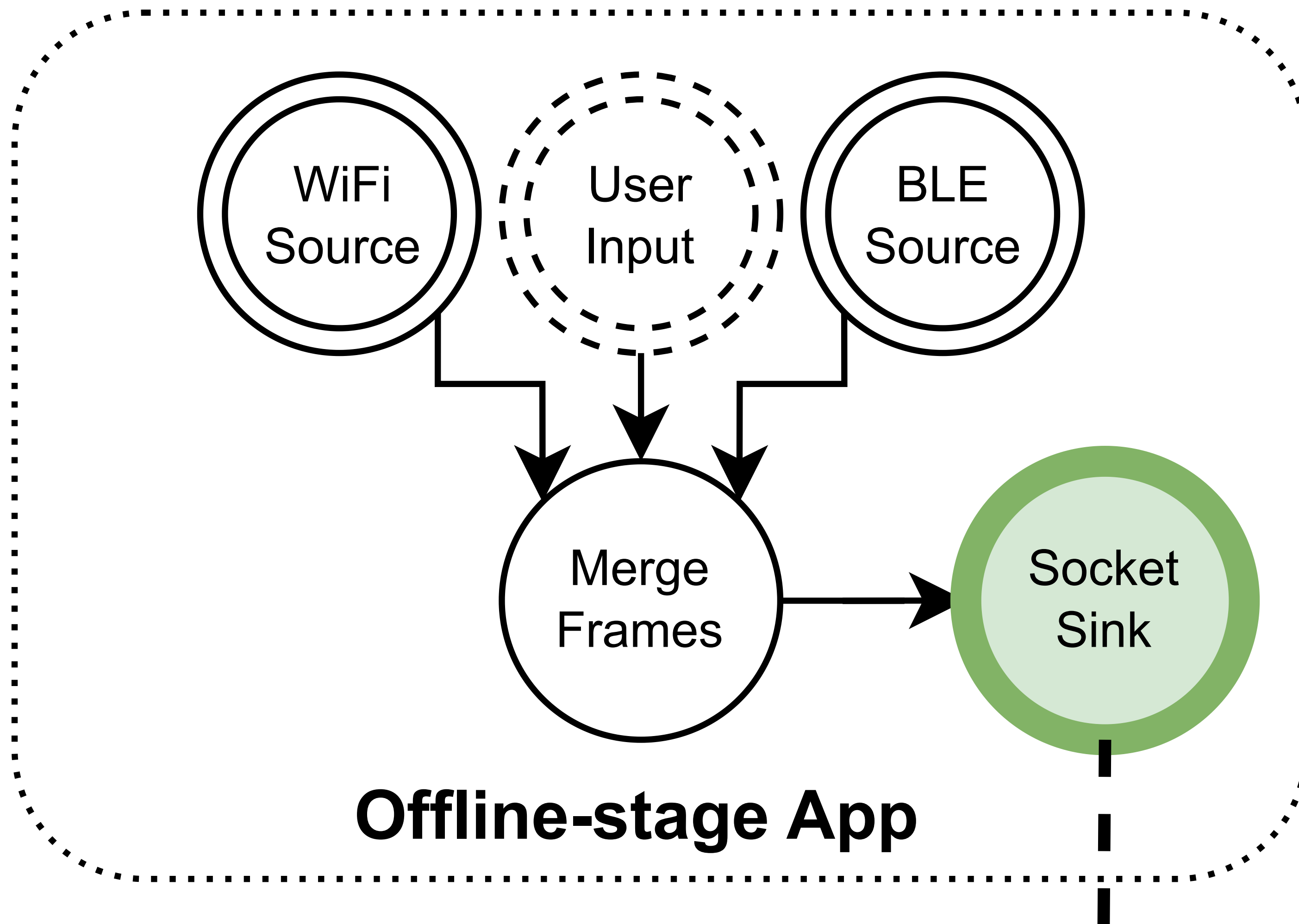
# Demonstration

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



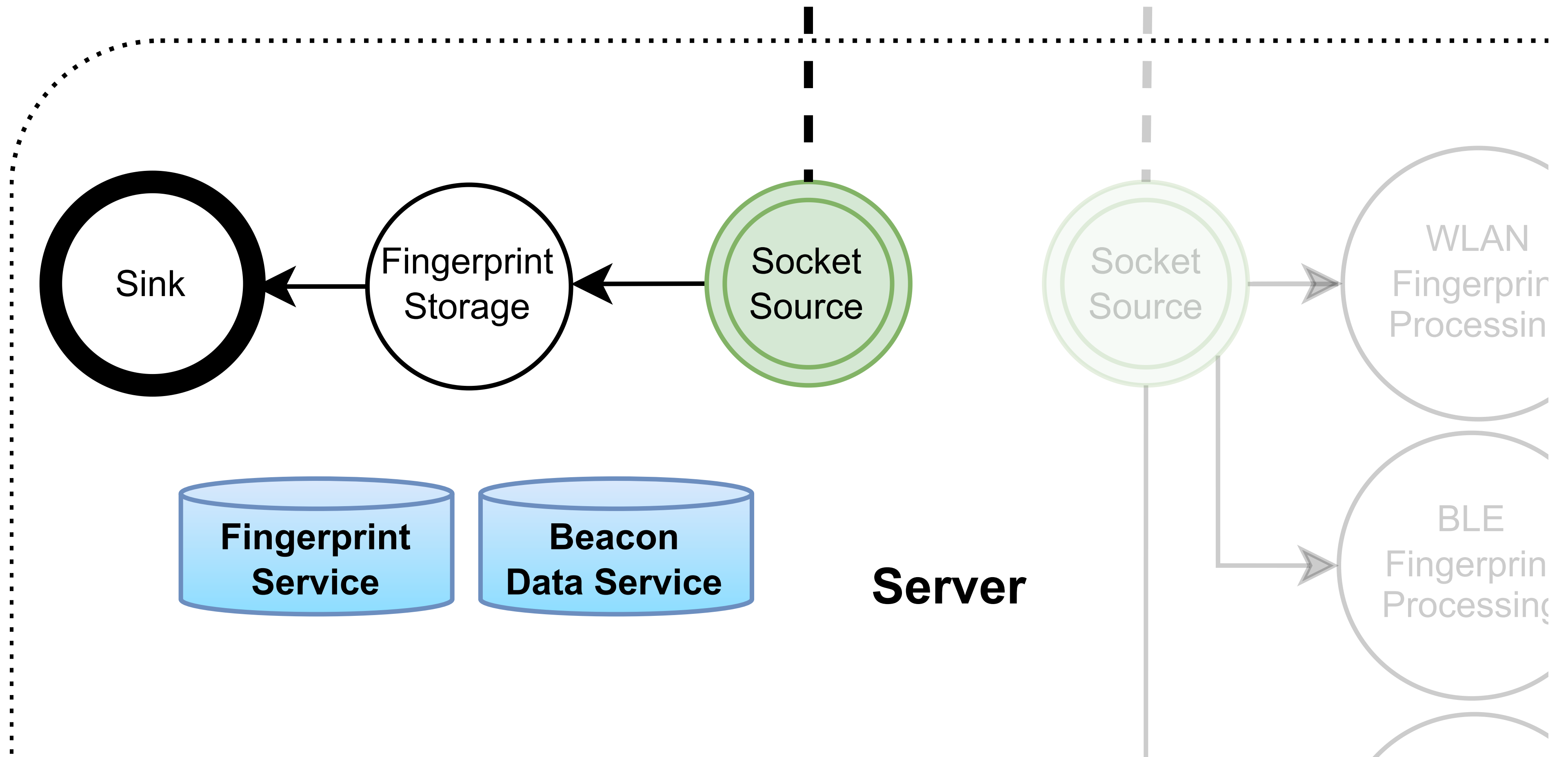


# Positioning Model

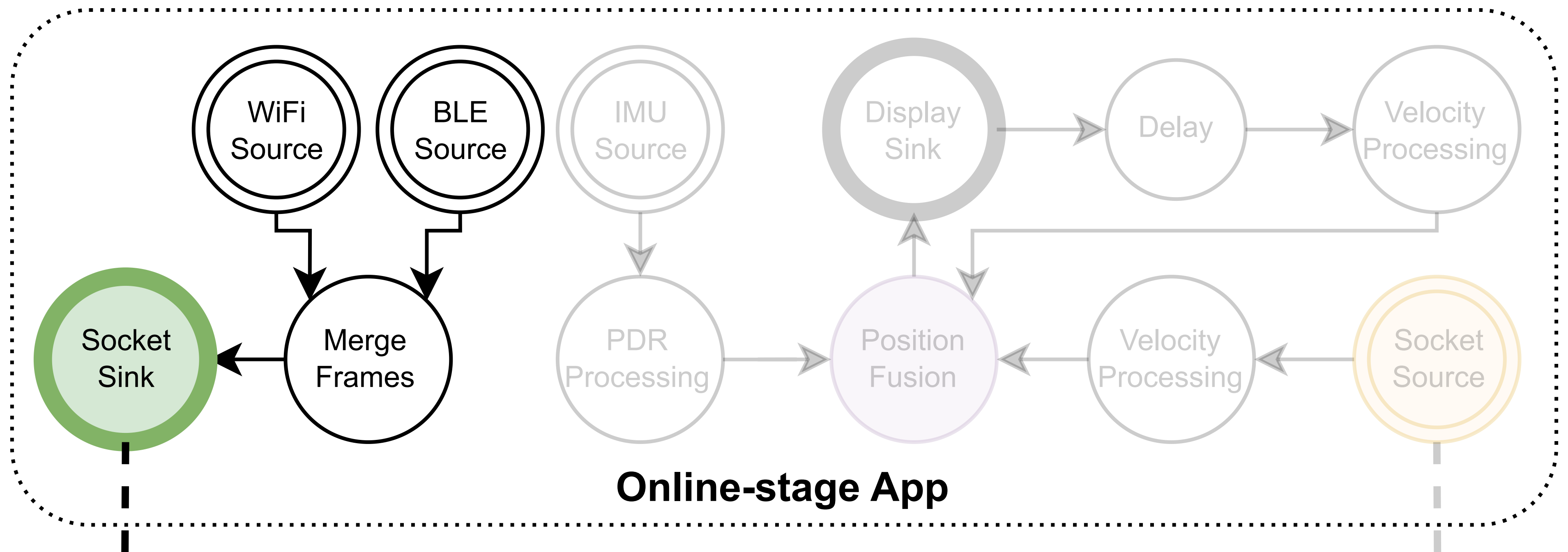




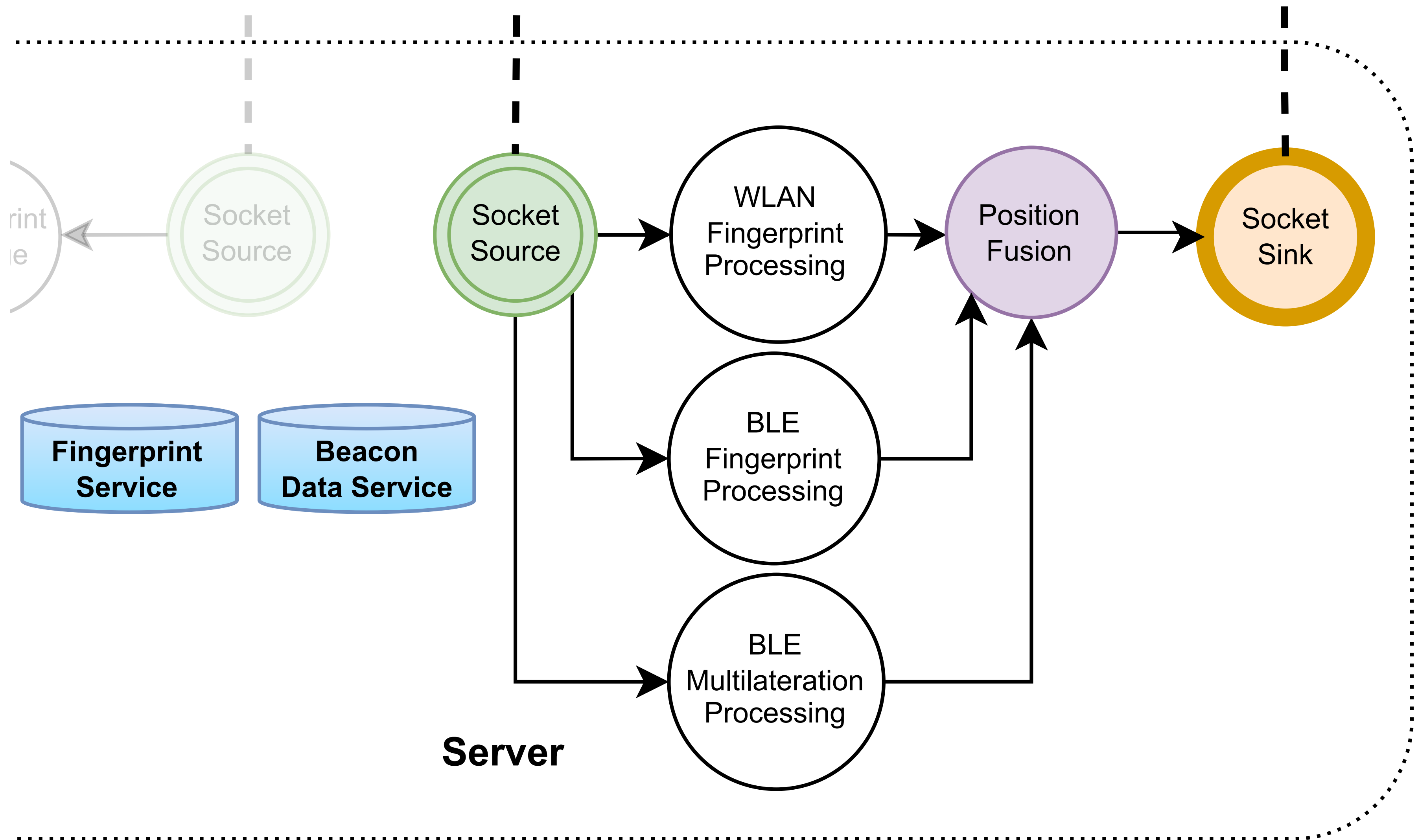
# Positioning Model ...



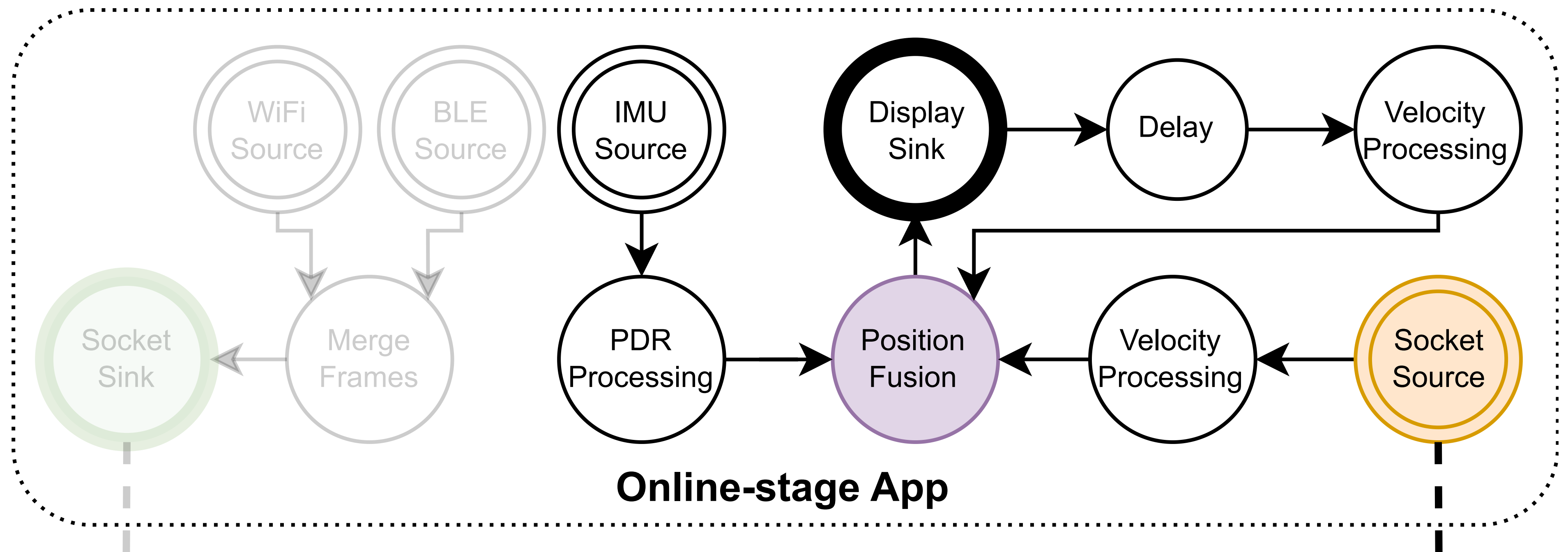
# Positioning Model ...



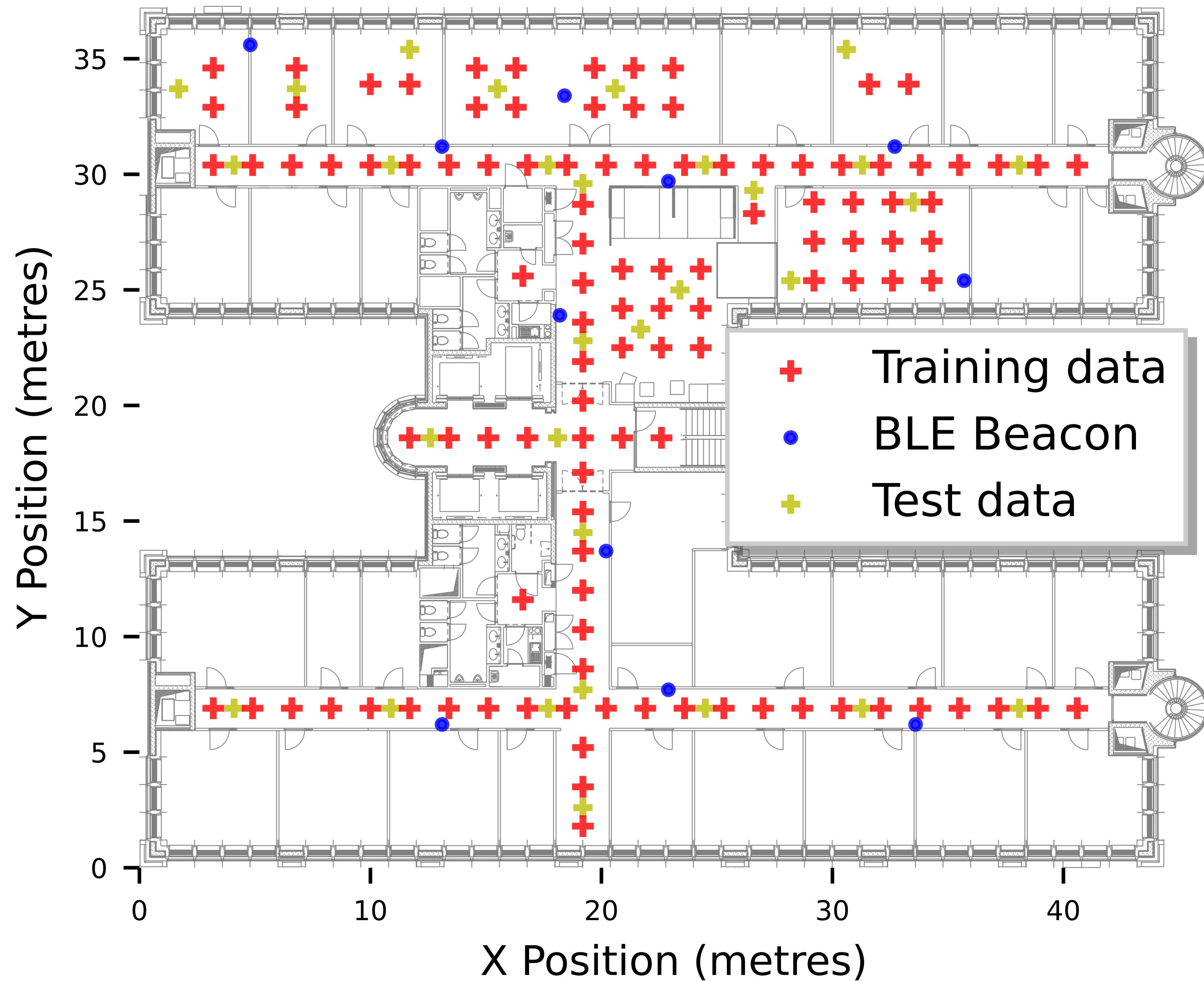
# Positioning Model ...



# Positioning Model ...



# Dataset



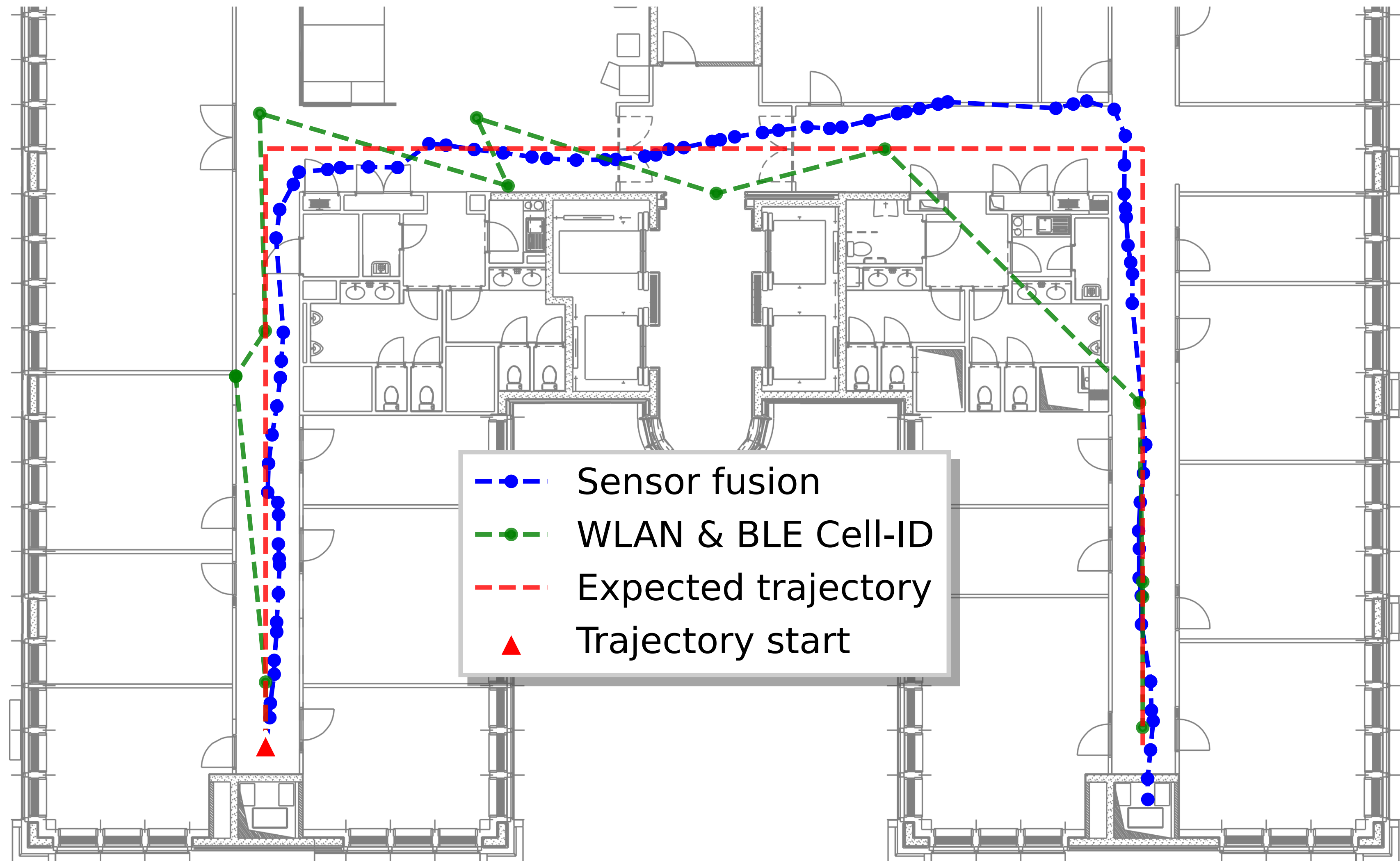
# Validation Results

## 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

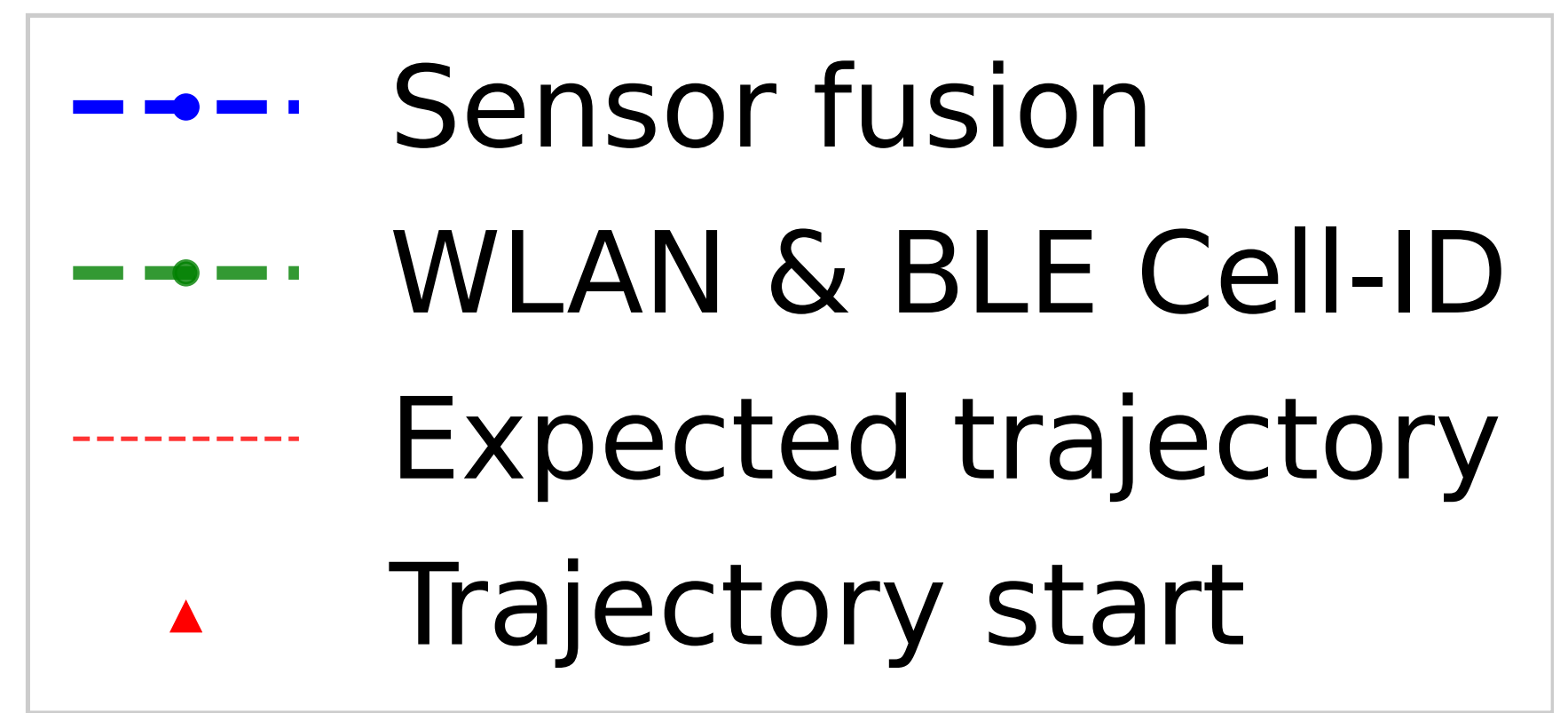
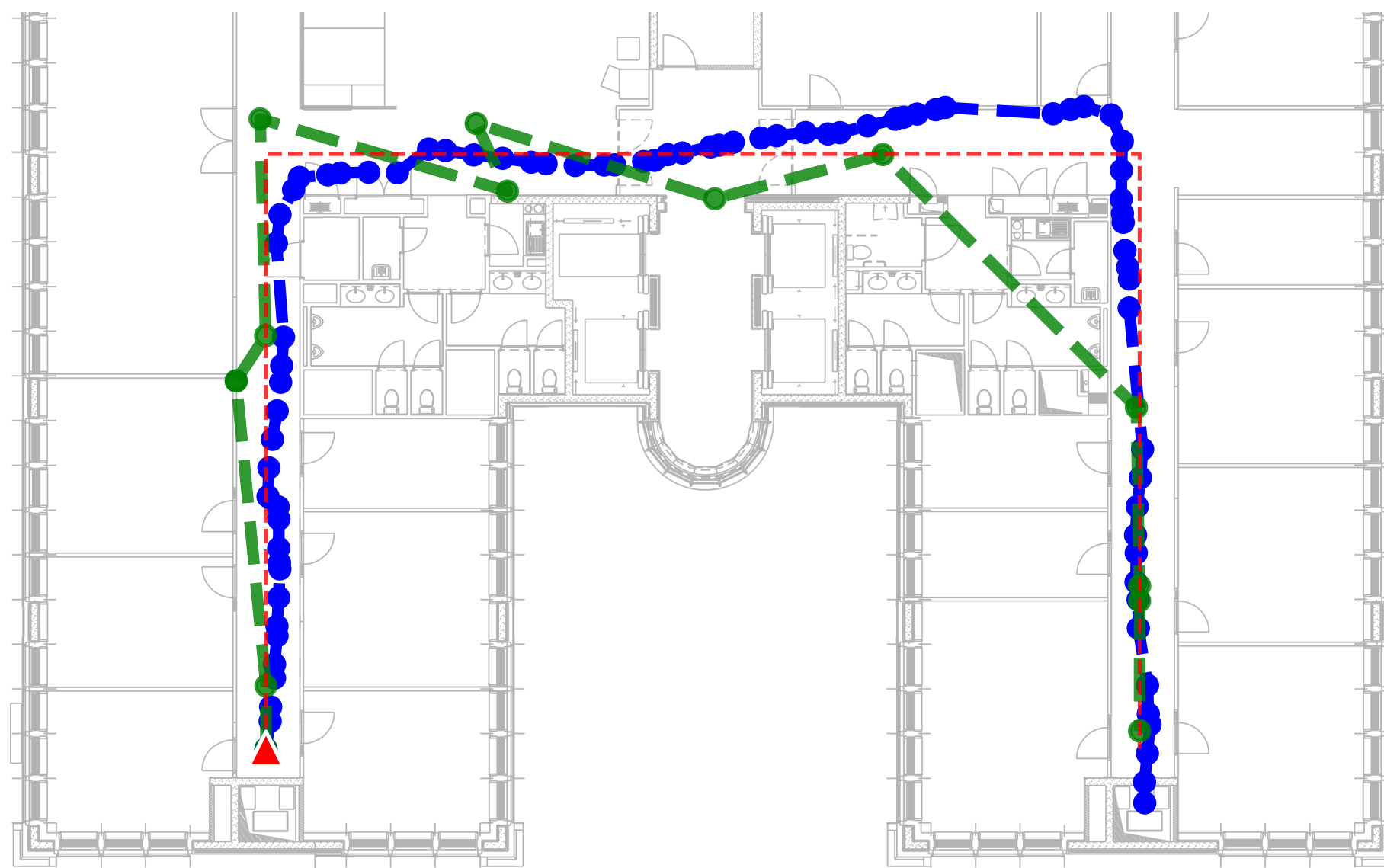




# Validation Results ...

## Trajectories

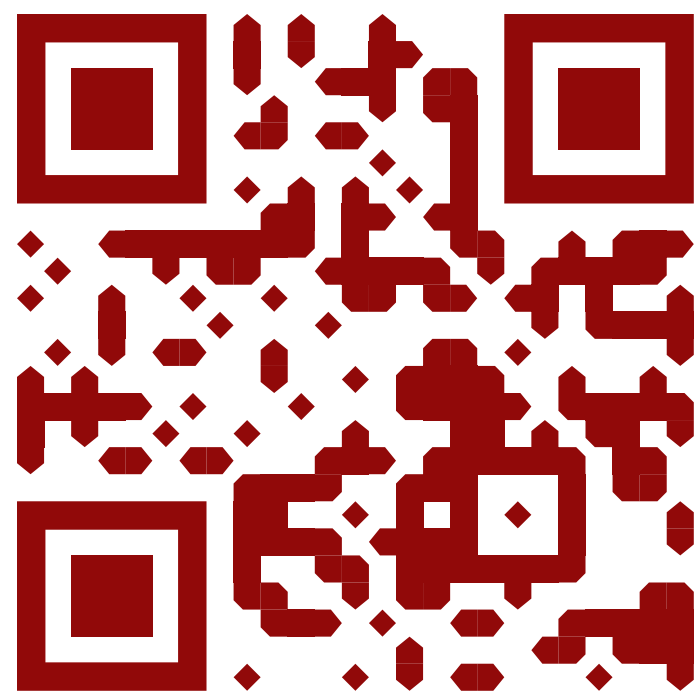
	WLAN + BLE	WLAN + BLE + IMU
<i>average error</i>	3.28 m	1.26 m
<i>maximum error</i>	9.60 m	3.10 m
<i>average update frequency</i>	3.04 s	0.52 s





# 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!