

# Indoor Positioning Using the OpenHPS Framework


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# An Open Source Hybrid Positioning System





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Standard Units

Position and Orientation

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Positioning Model

Source Node

Processing Node

Sink Node

Services

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

IMUDDataFrame

uidtimestamp

source

DataObject

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

Acceleration

Sensor Frequency

No additional objects

RFDDataFrame

uidtimestamp

source

RFReceiverObject

uid: "wificscanner",  
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;
}
```

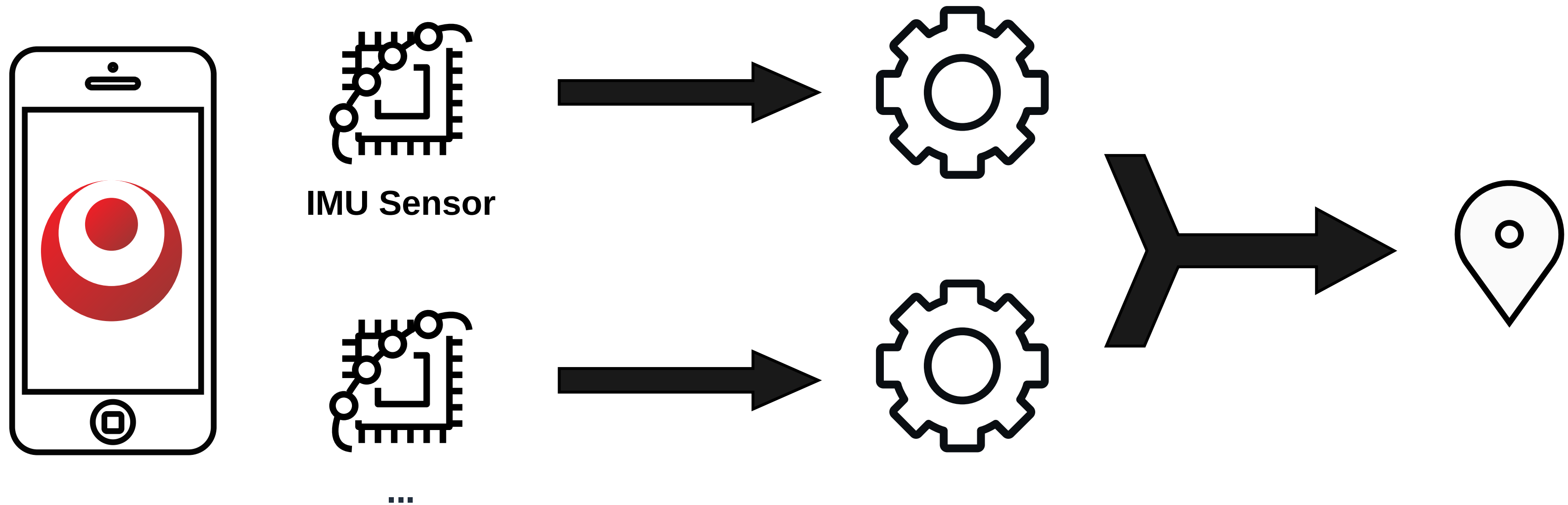
# What is OpenHPS?



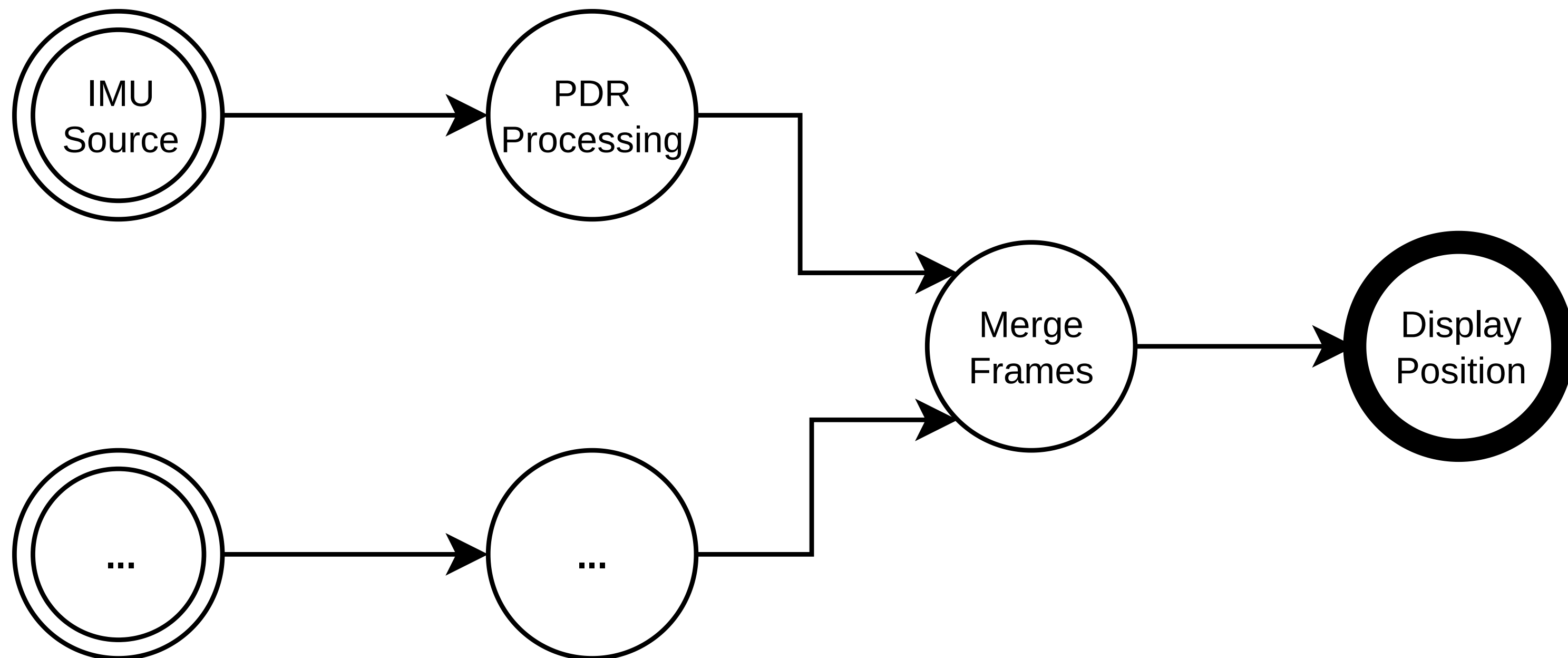
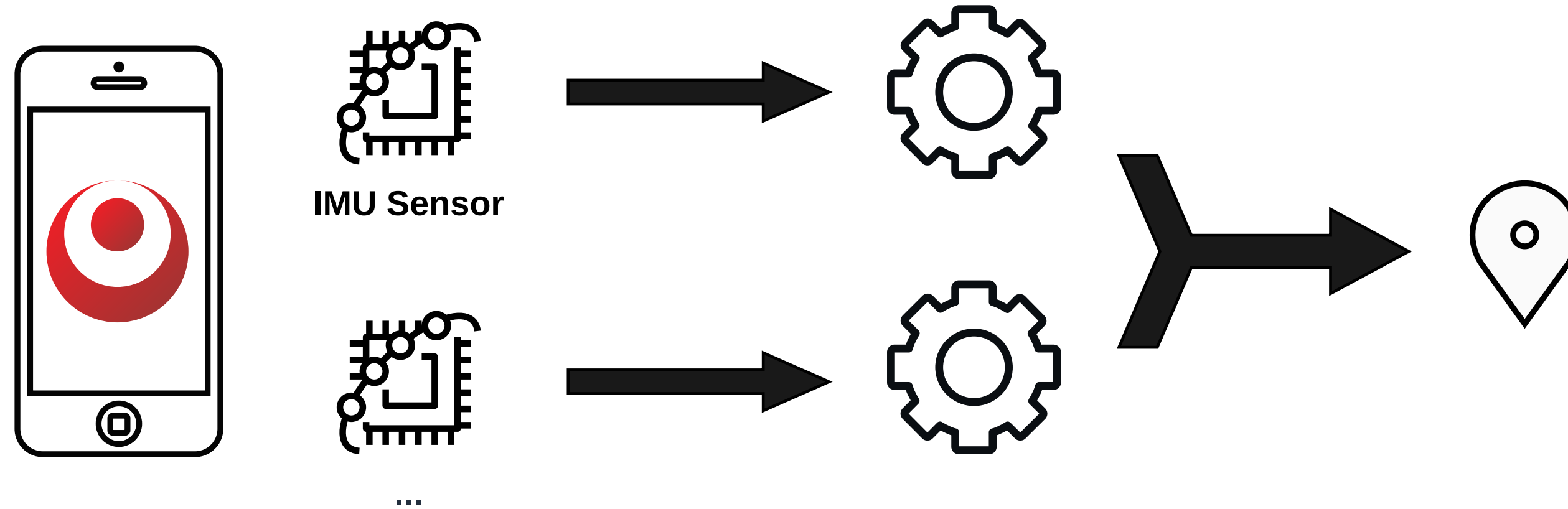
## An Open Source Hybrid Positioning System

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

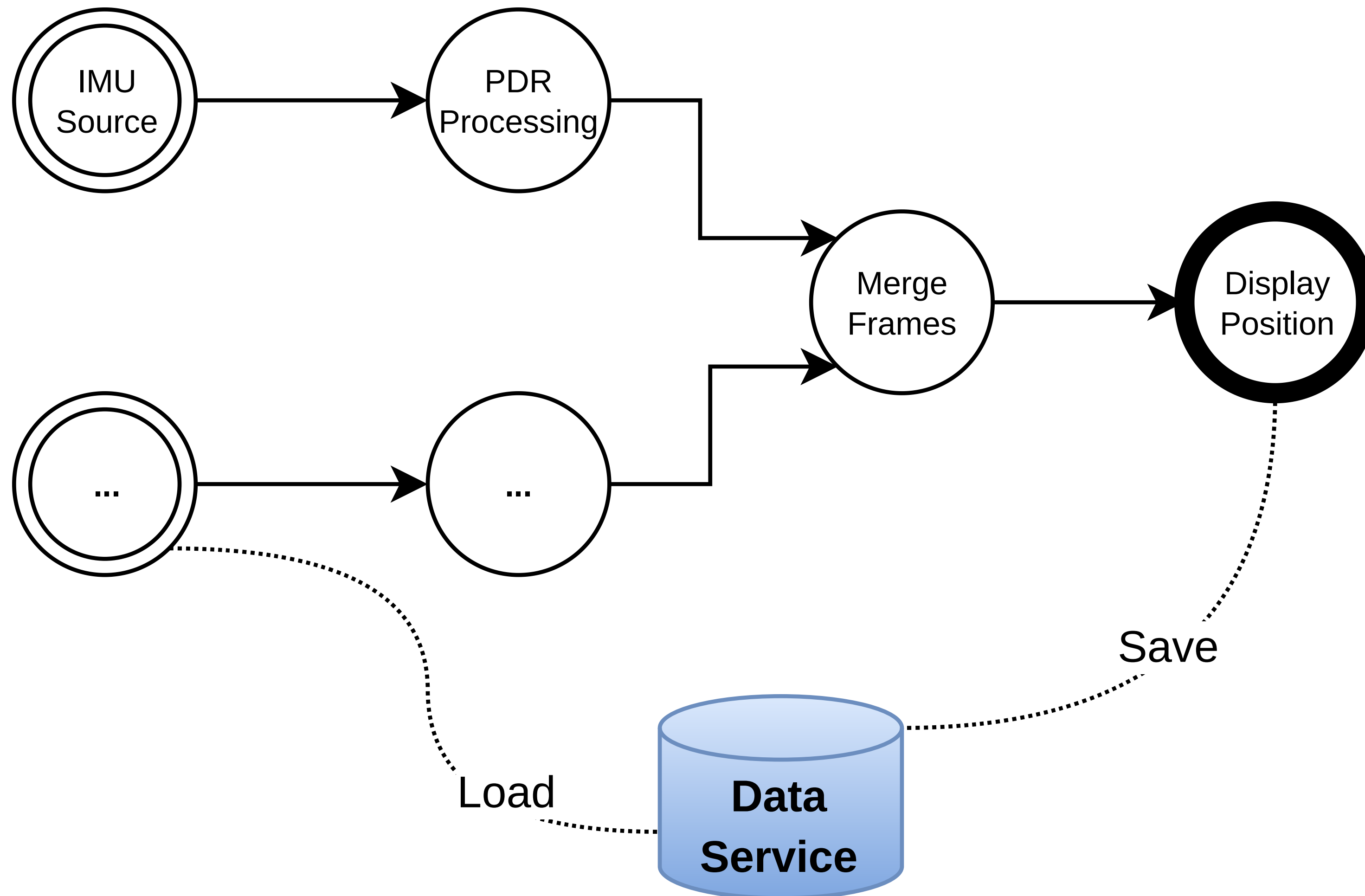
# Process Network Design



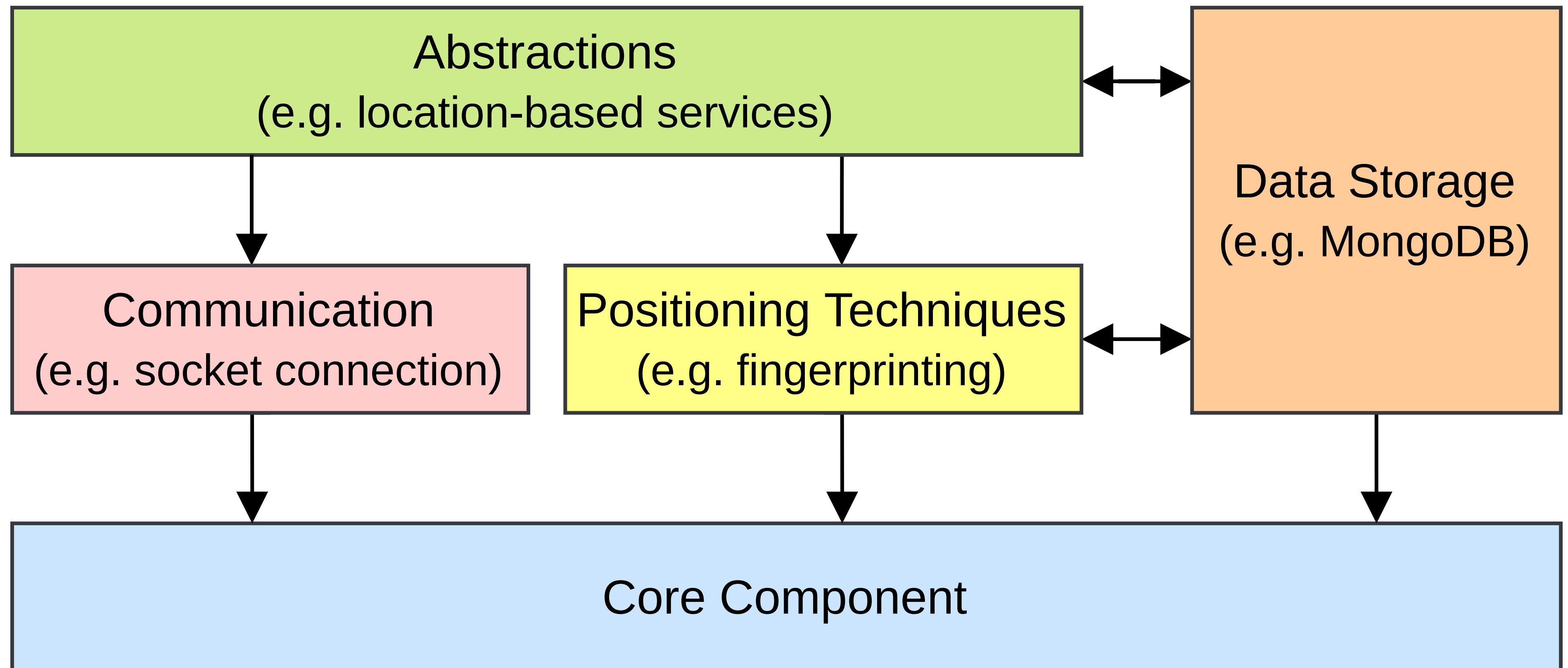
# Process Network Design ...



# Process Network Design ...



# Modularity



# Modularity ...

## **Communication**

Socket, MQTT, REST API, ...

## **Data Storage**

MongoDB, LocalStorage, RDF, ...

## **Positioning Algorithms**

IMU, fingerprinting, OpenVSLAM, ...

## **Abstractions**

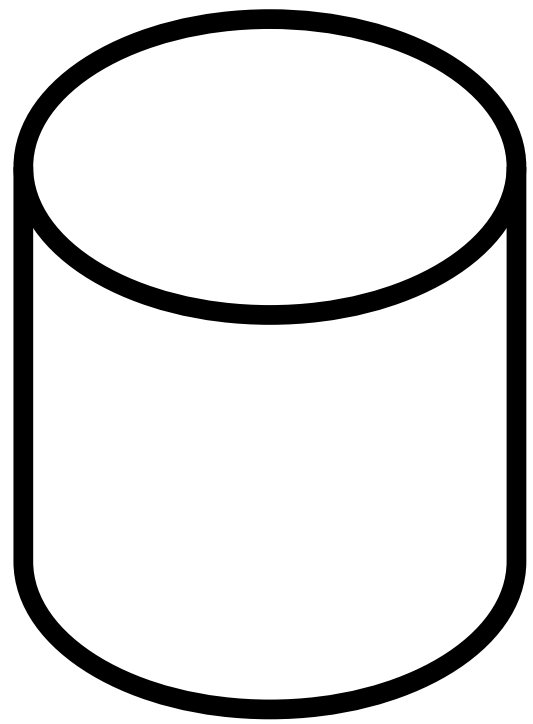
Geospatial, location-based services, geojson, ...

## **Other**

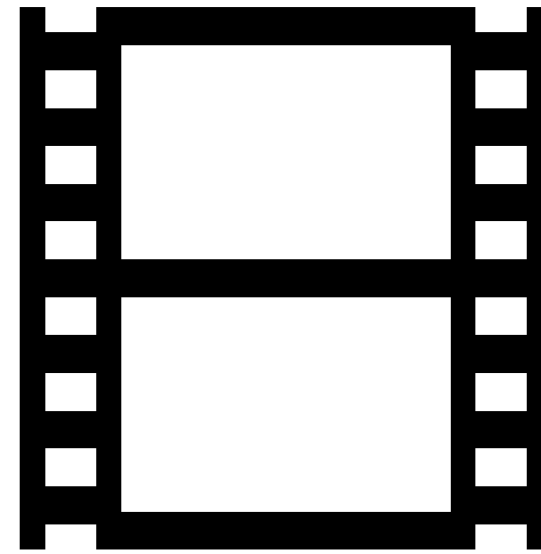
React-Native, NativeScript, Sphero, ...



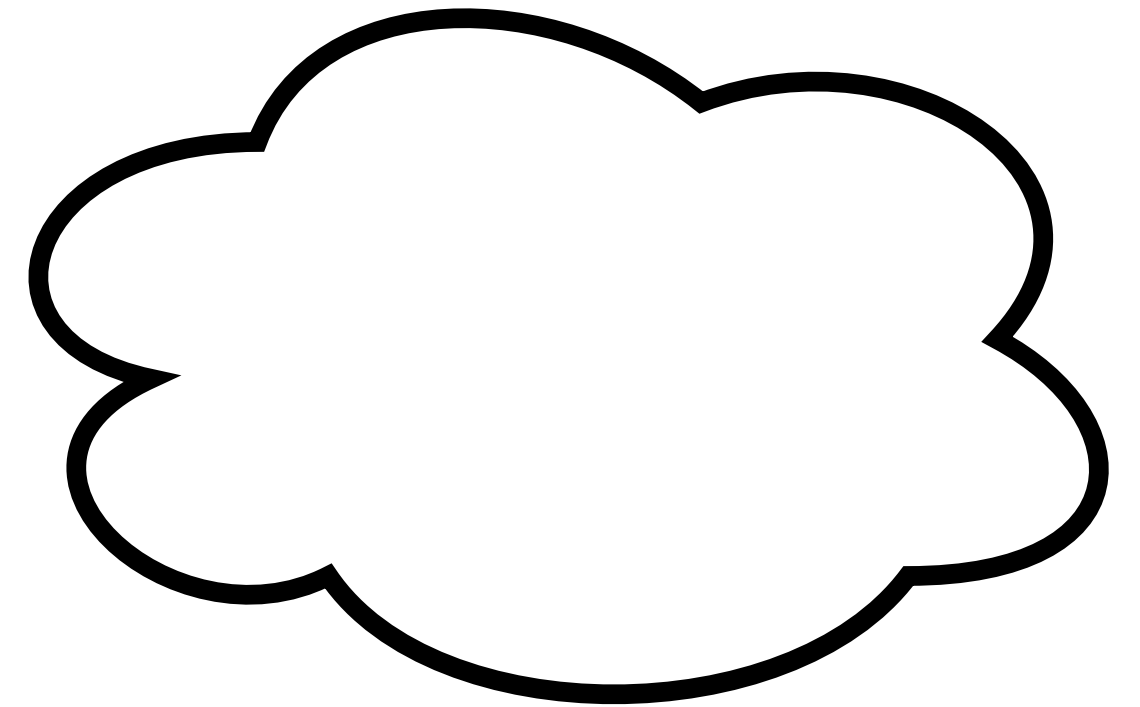
# Data Processing



**Knowledge**

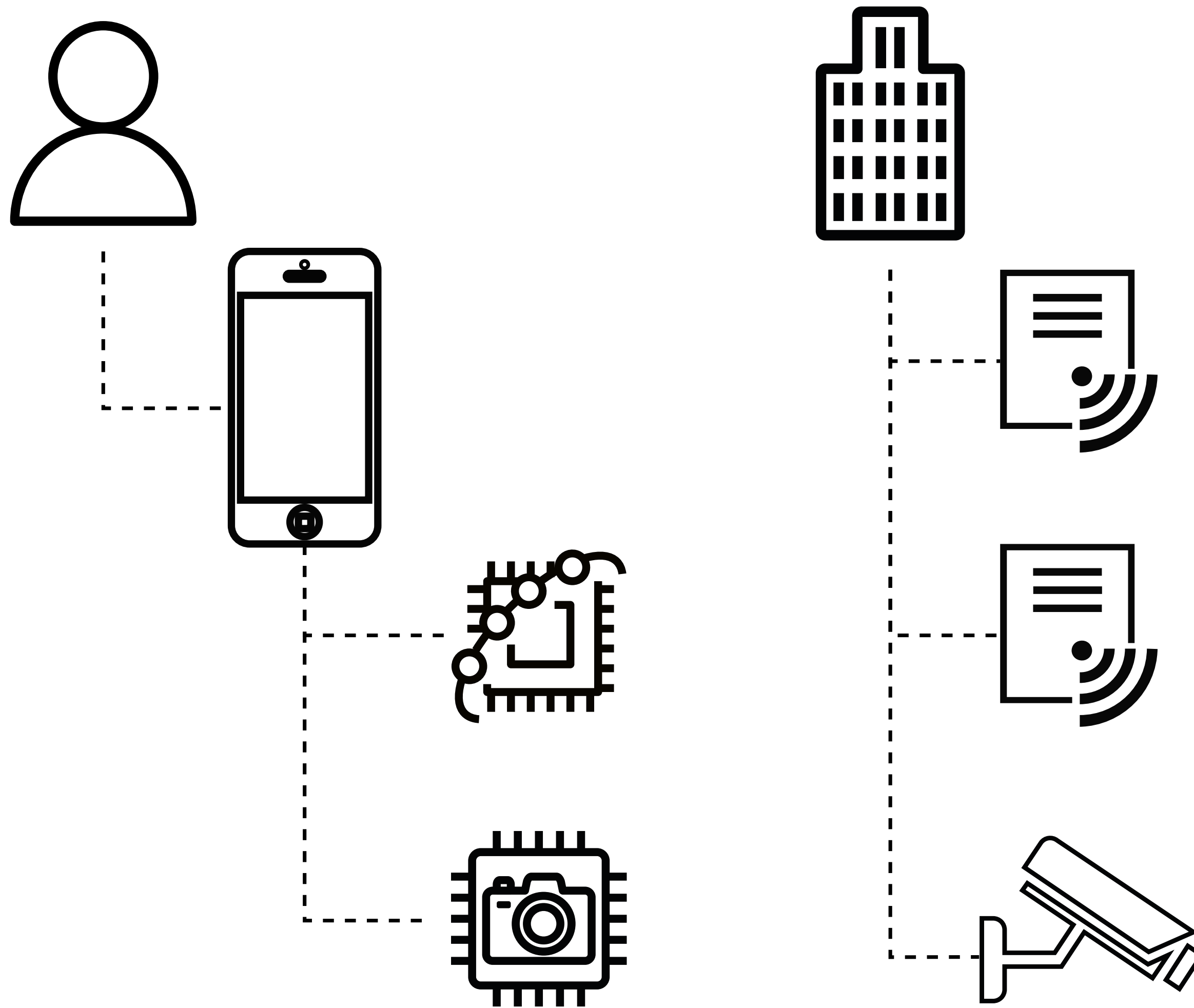


**Raw Data**



**Processed Data**

# DataObject



# Absolute and Relative Positions

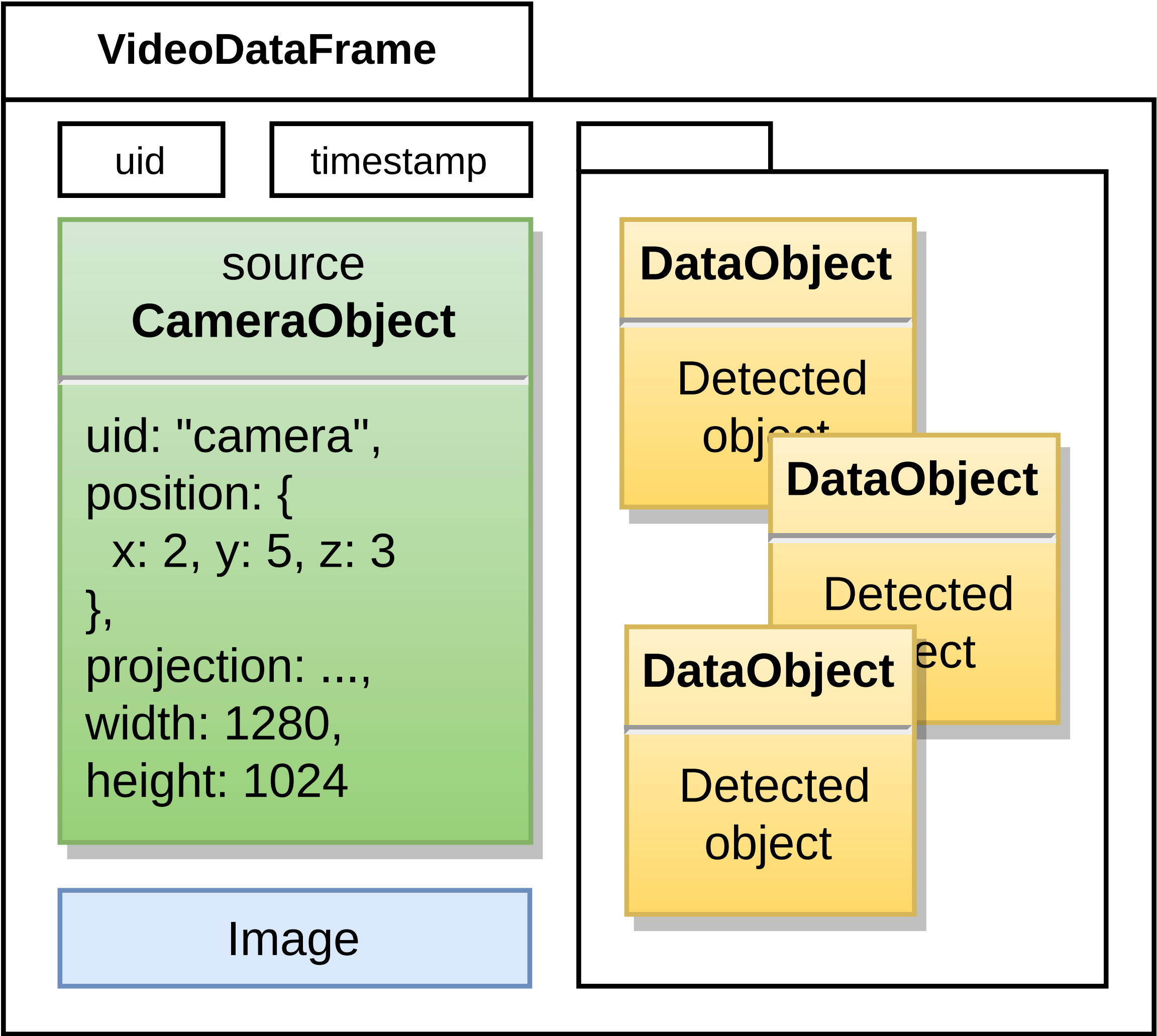
## Absolute

- ▶ 2D, 3D, Geographical, ...

## Relative

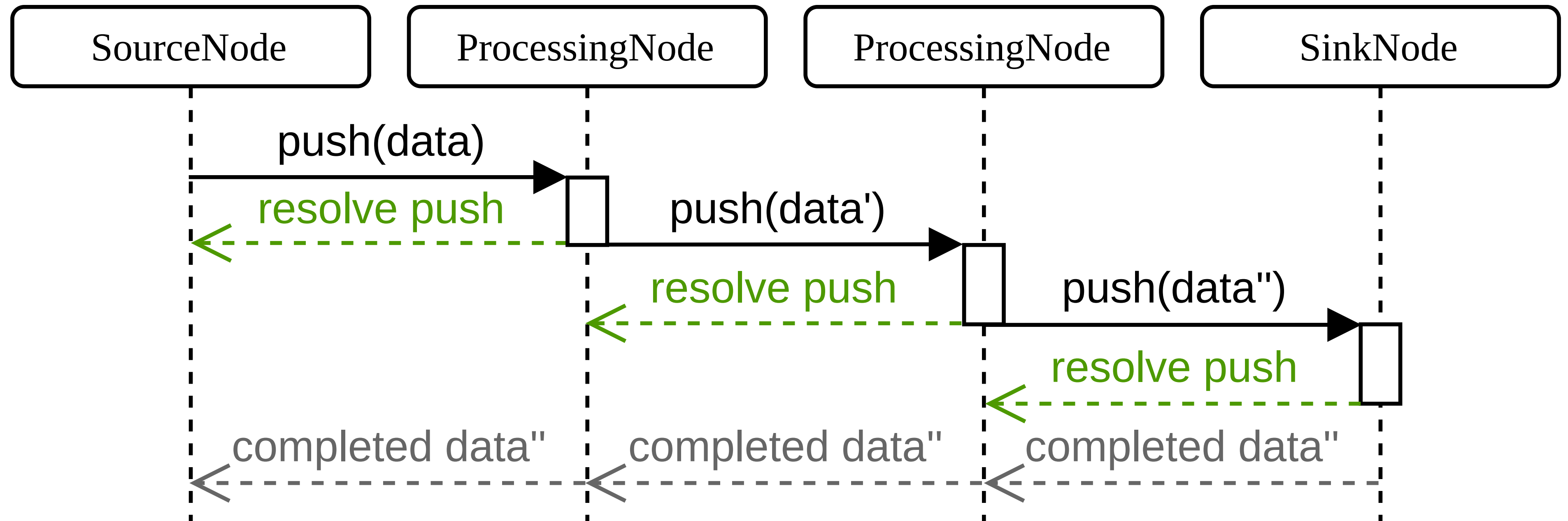
- ▶ Distance, angle, velocity, ...
- ▶ Relative to another *object*

# DataFrame



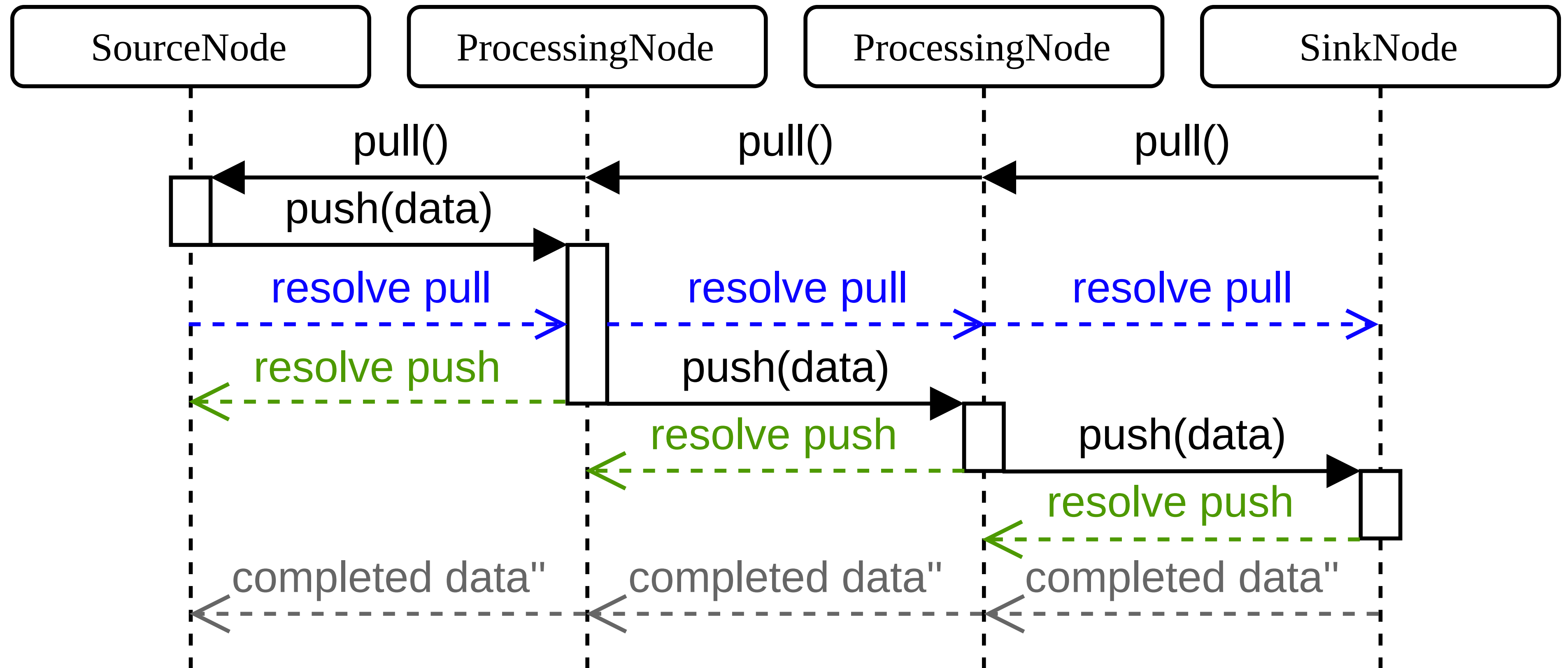
# DataFrame ...

## Pushing Data



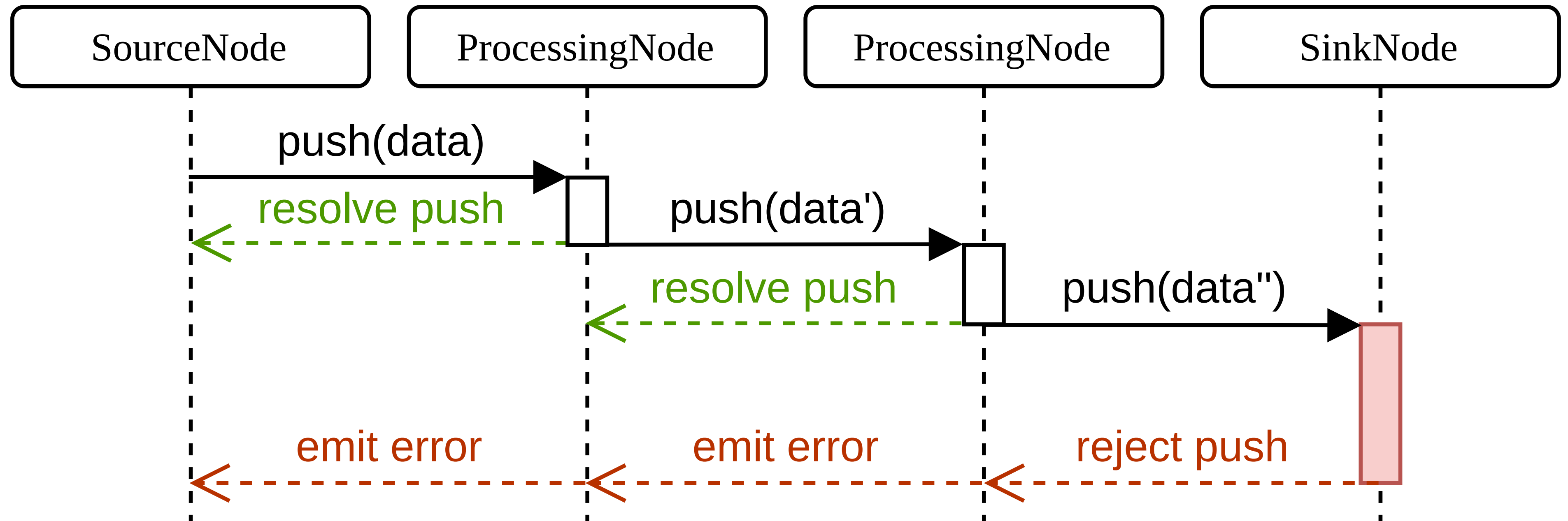
# DataFrame ...

## Pulling Data



# DataFrame ...

## Pushing Error



# SymbolicSpace

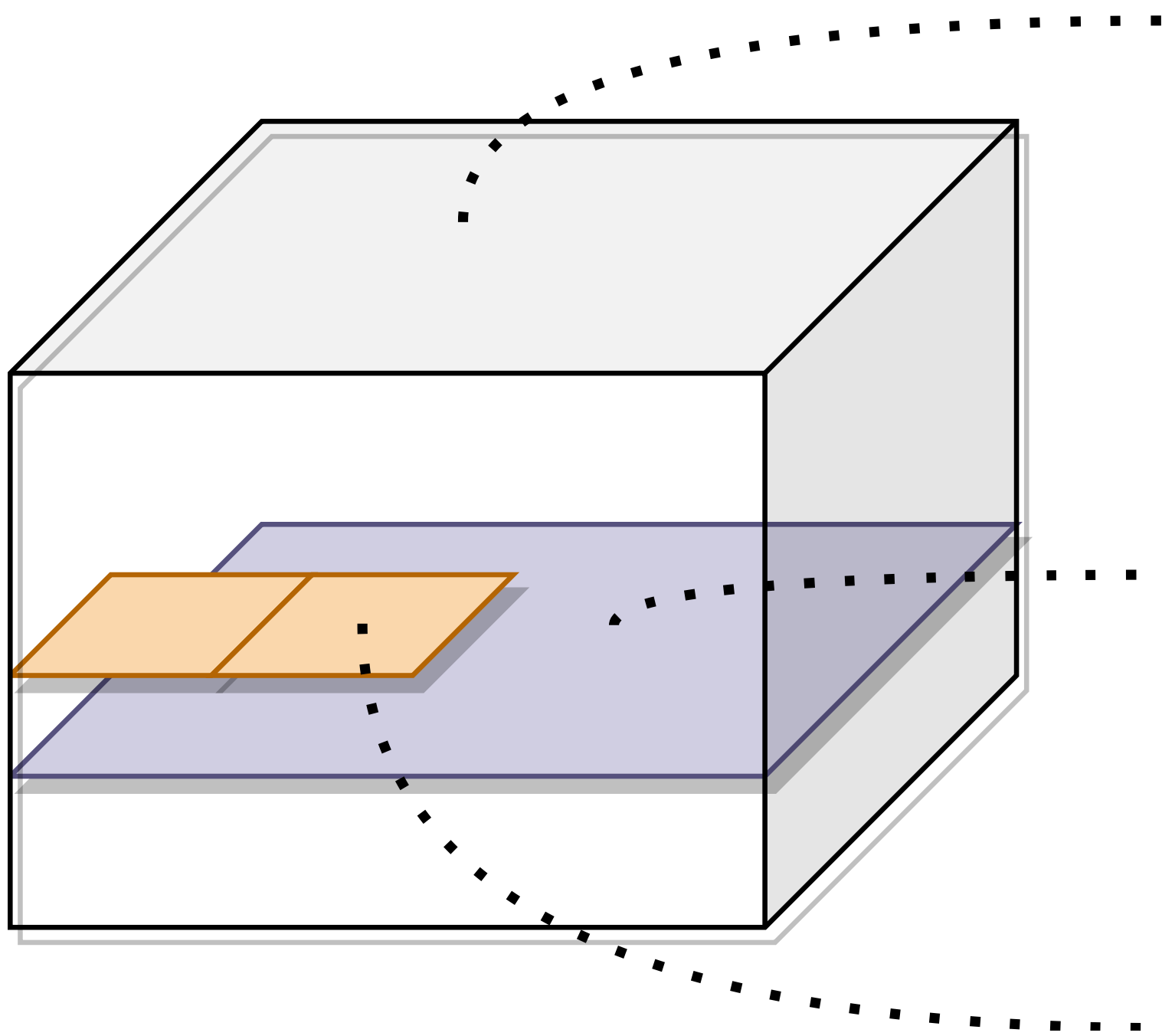
*An object that semantically defines a space*

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





# SymbolicSpace ...



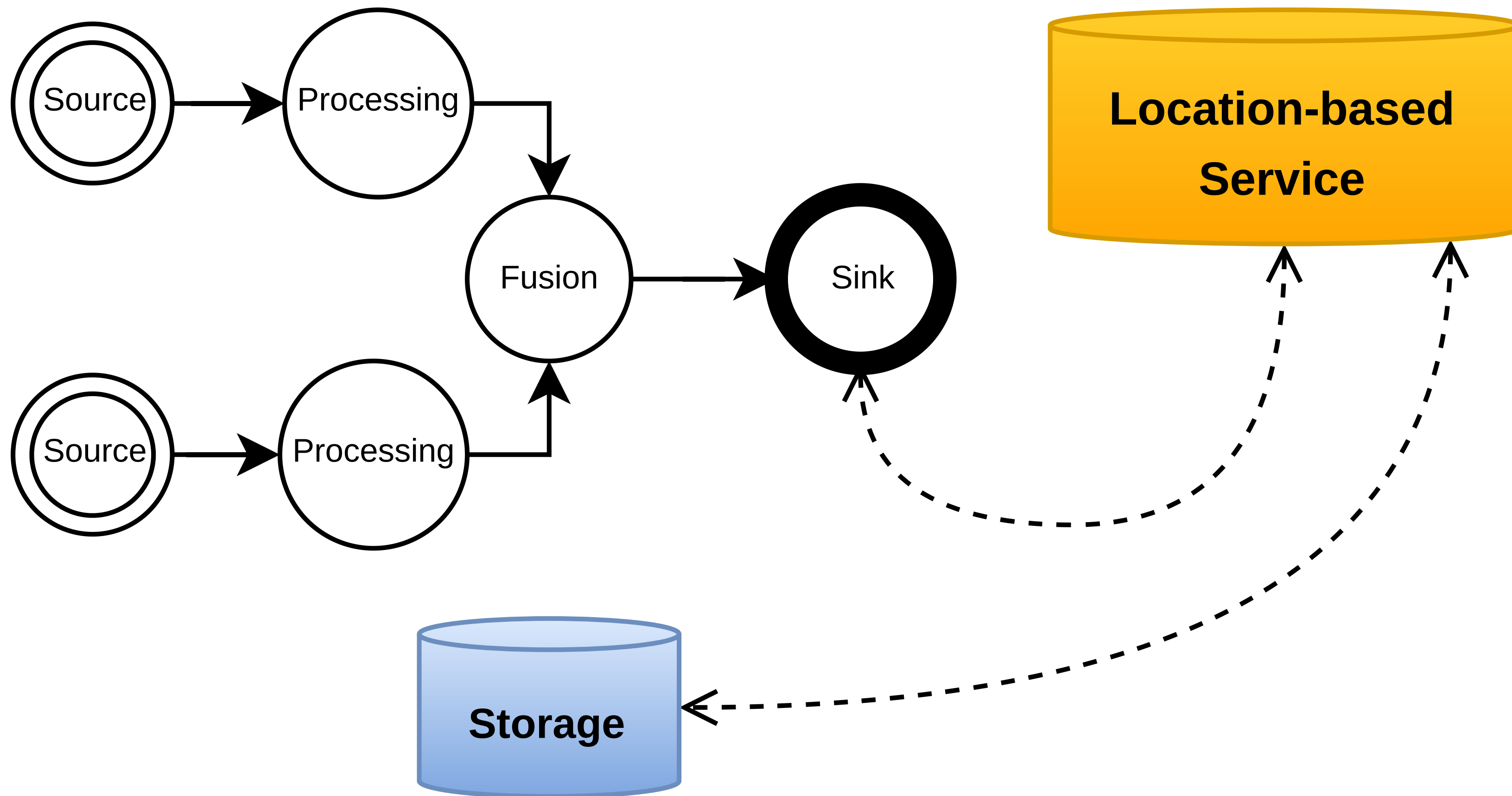
```
const building = new Building("PL9")
  .setBounds({
    topLeft: new GeographicalPosition(
      50.8203,
      4.3922),
    width: 46.275,
    height: 37.27,
    rotation: -34.04
  });

const floor = new Floor("PL9.3")
  .setBuilding(building)
  .setFloorNumber(3);

const office = new Room("PL9.3.58")
  .setFloor(floor)
  .setBounds([
    new Absolute2DPosition(4.75, 31.25),
    new Absolute2DPosition(8.35, 37.02),
  ]);
```

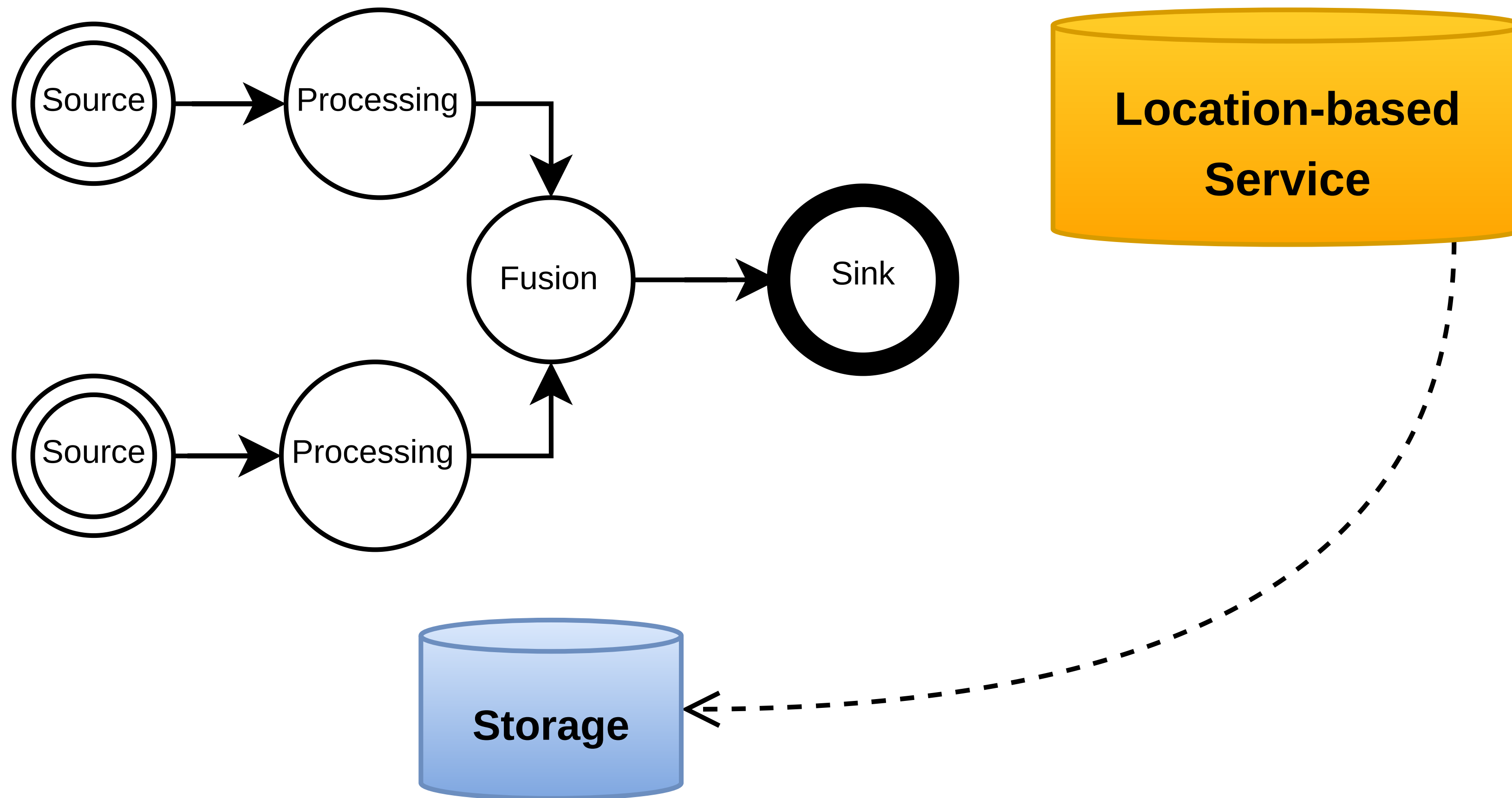
# Location-based Service

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



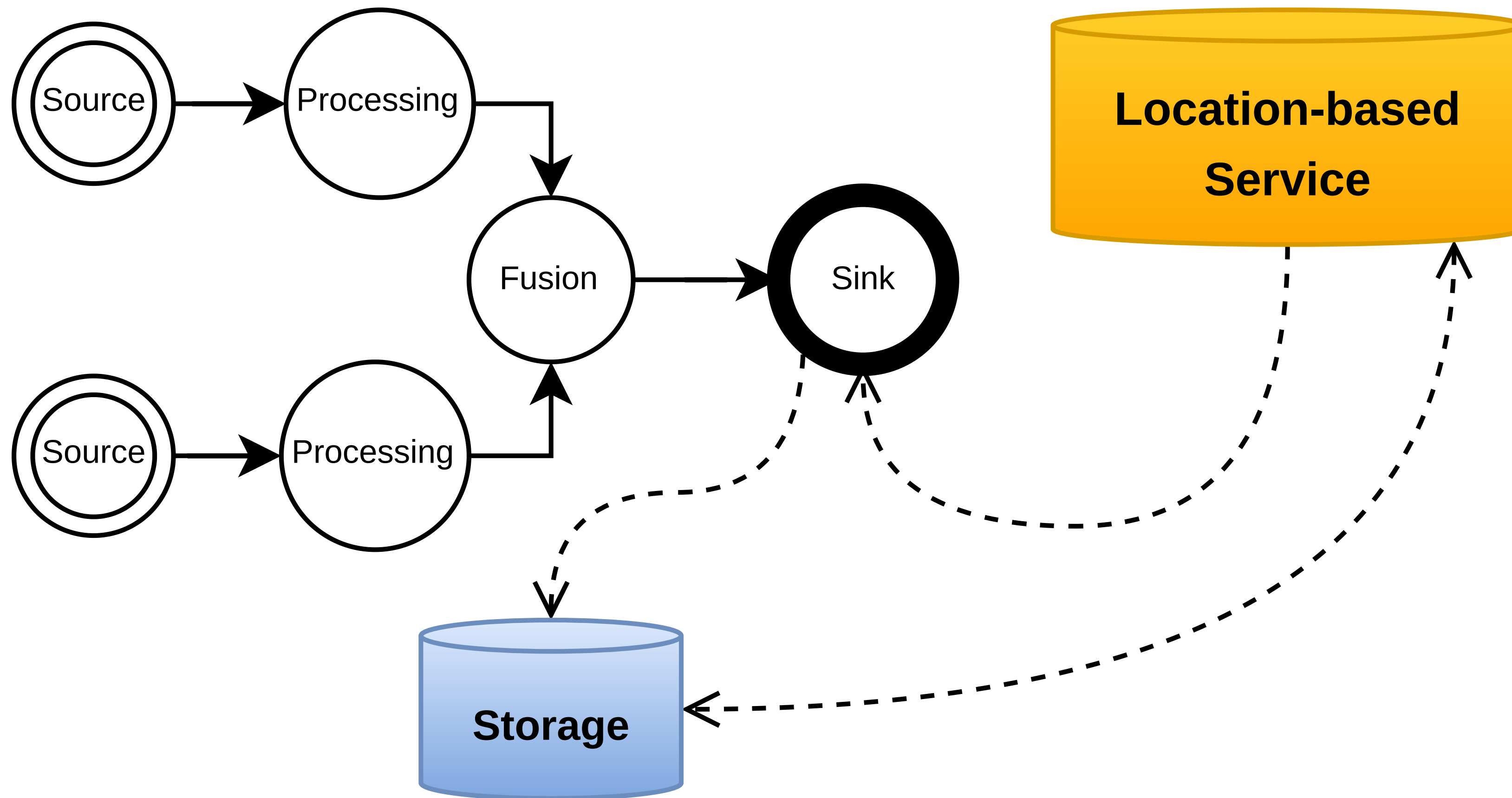
# Location-based Service ...

`setCurrentPosition("me", ...)`



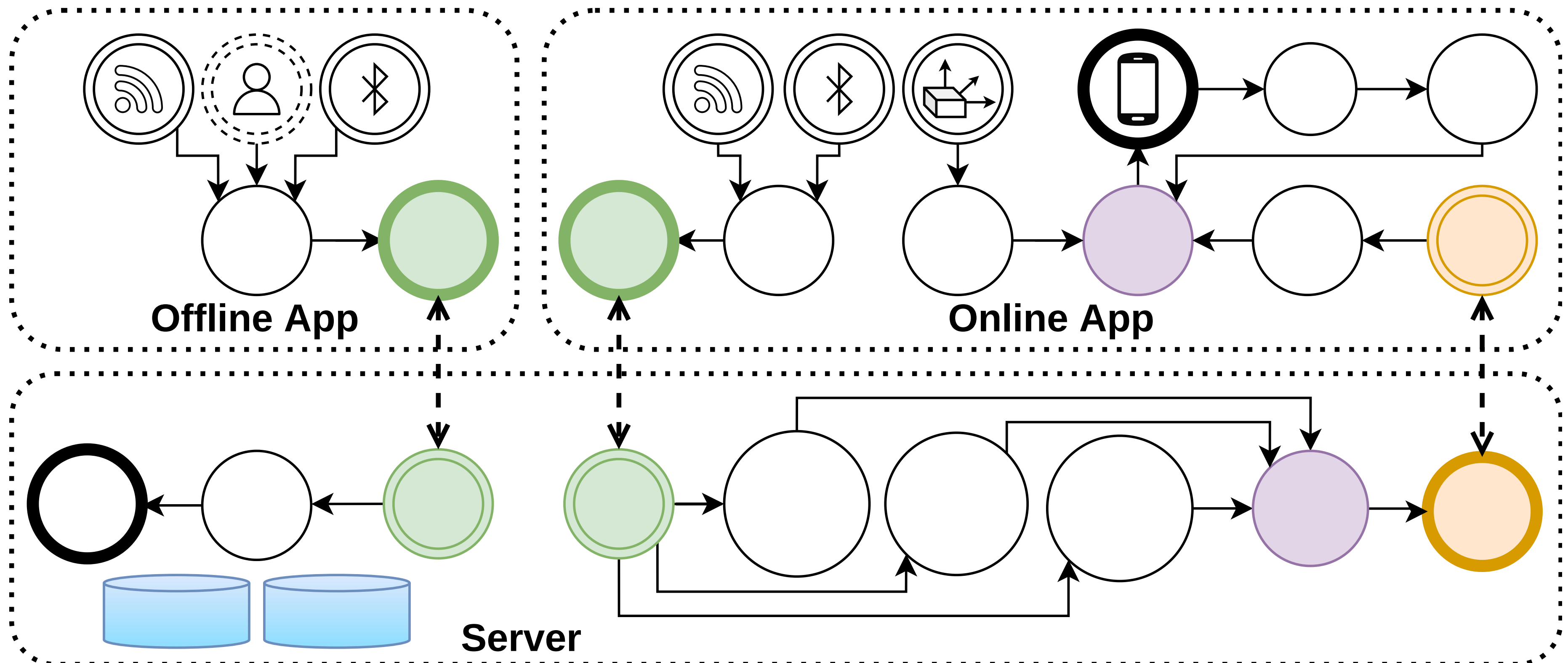
# Location-based Service ...

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

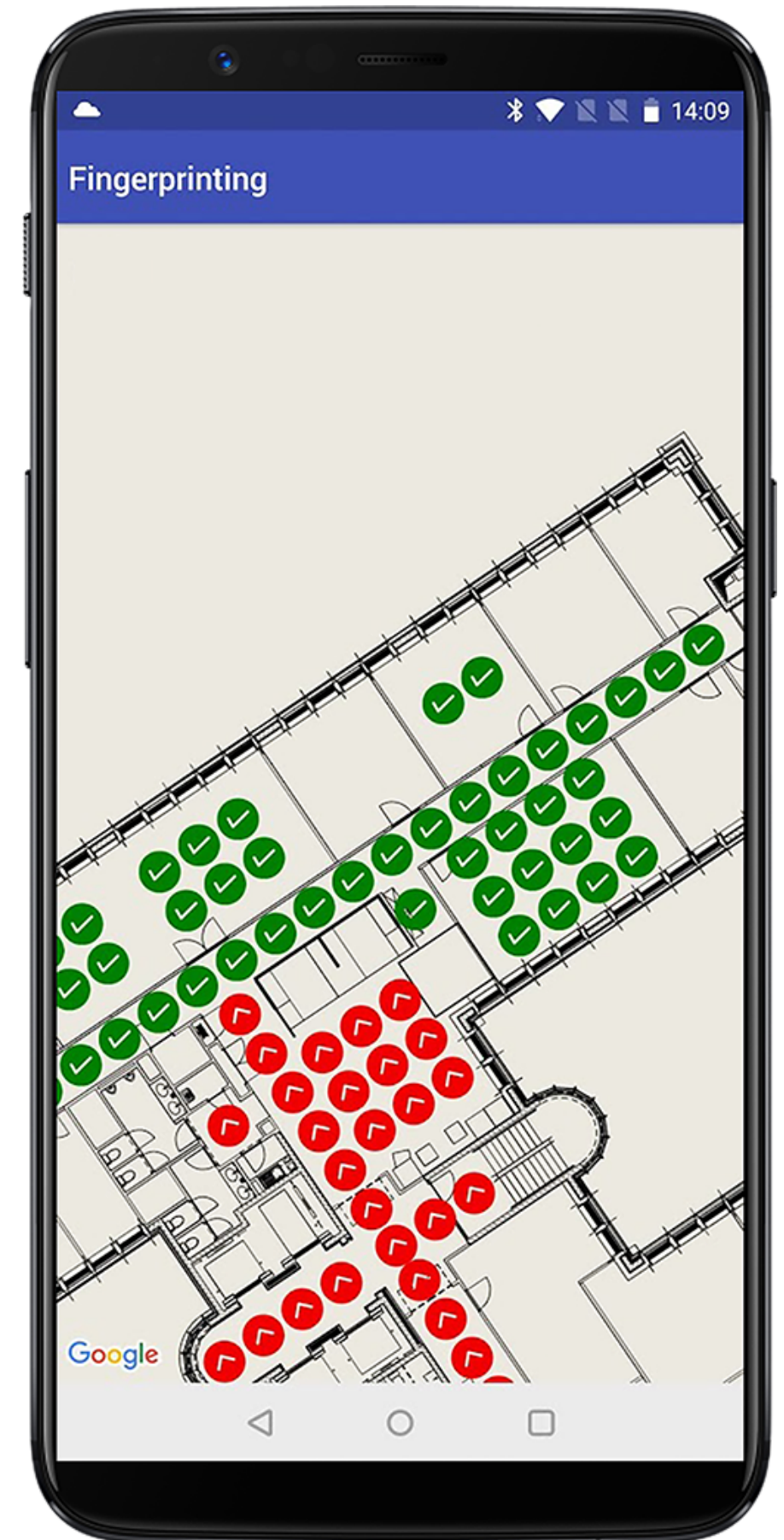
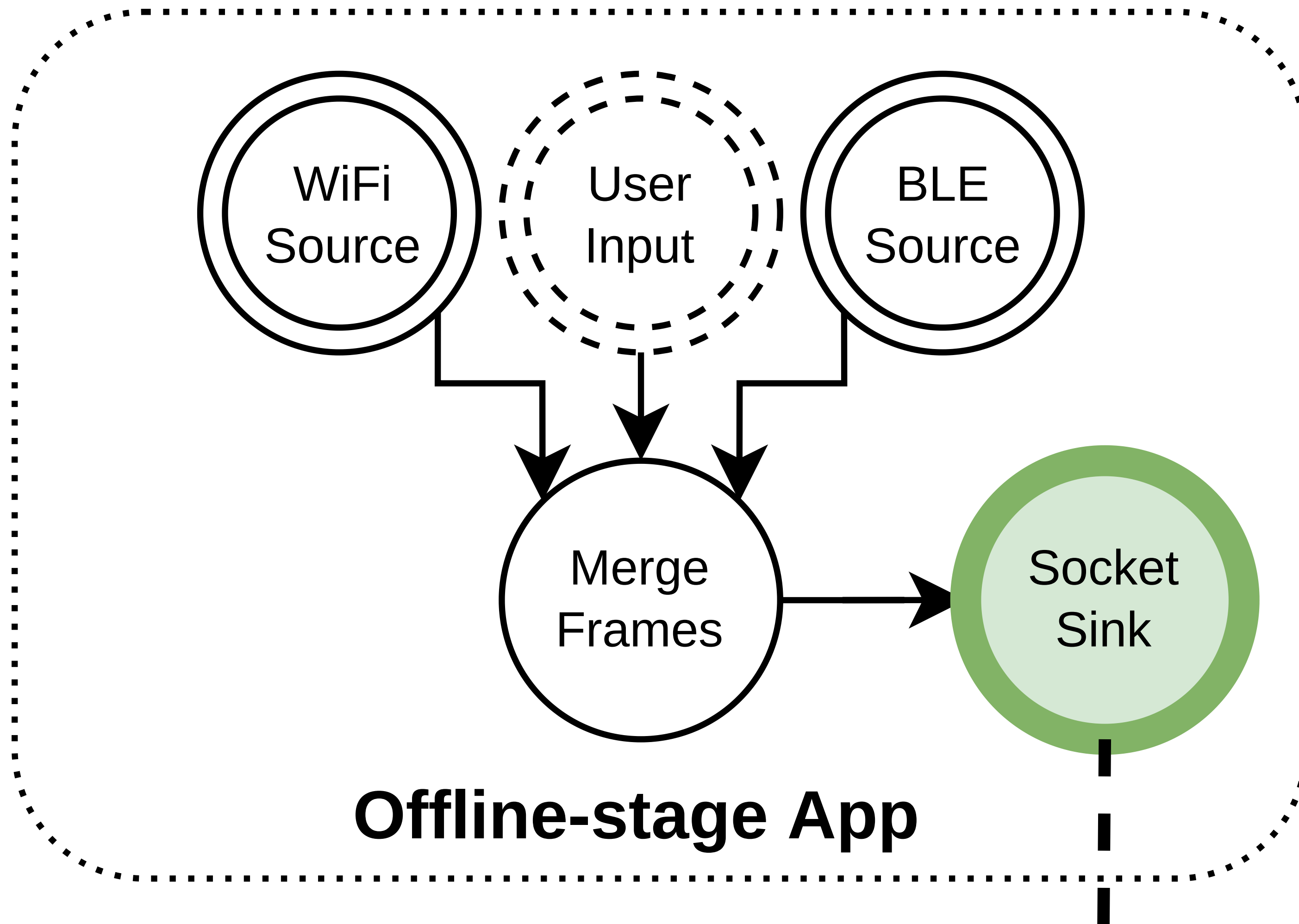


# Demonstration

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

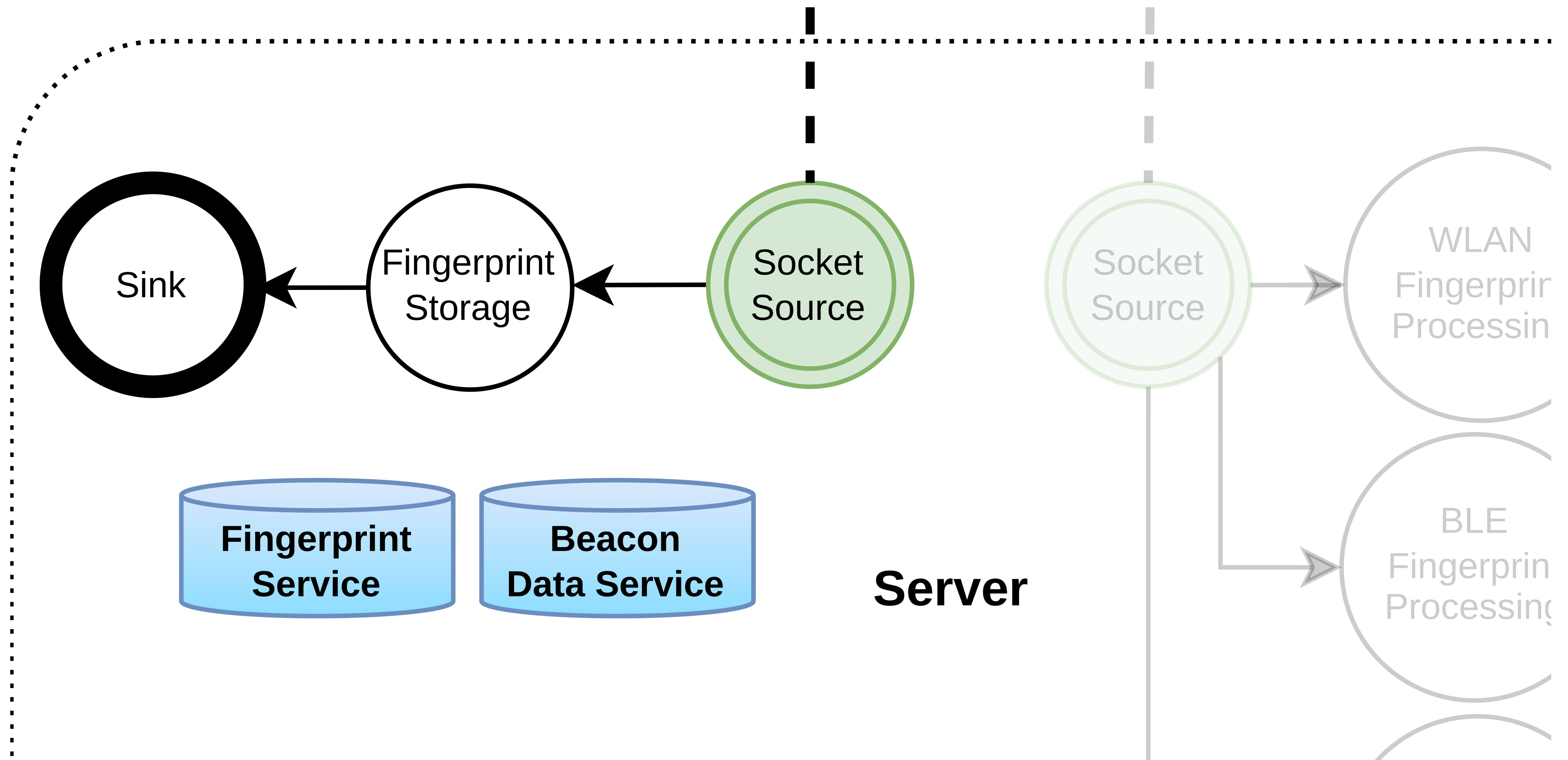


# Positioning Model

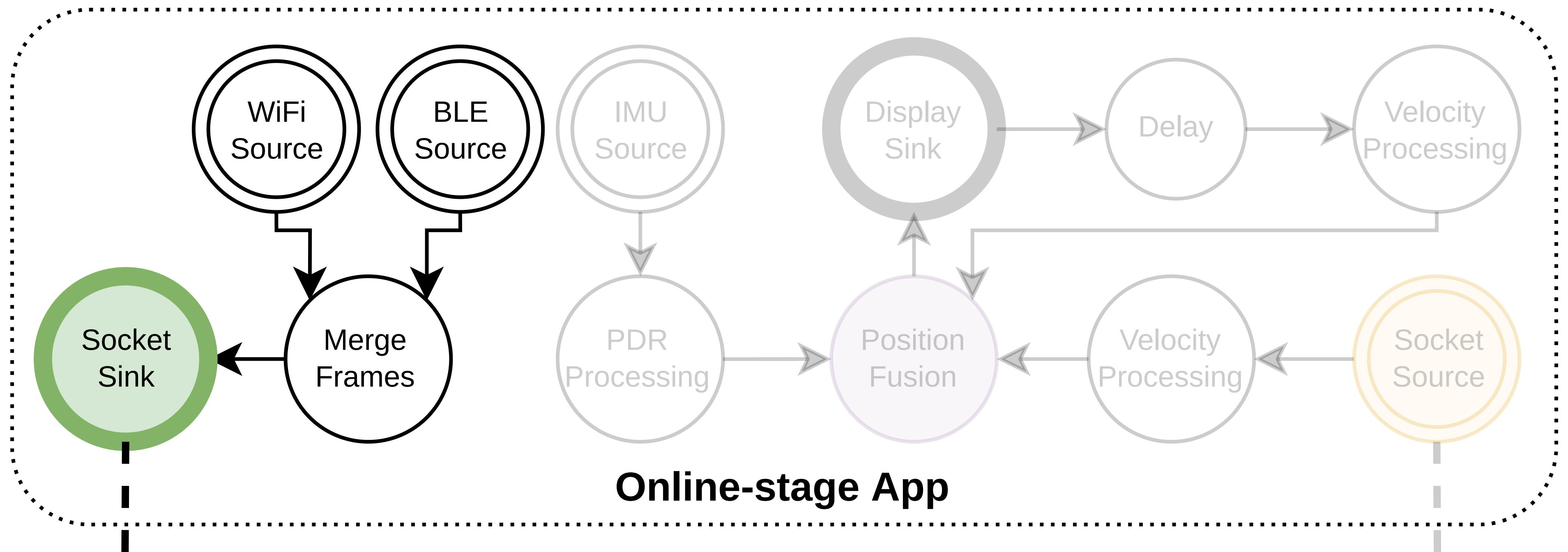




# Positioning Model ...

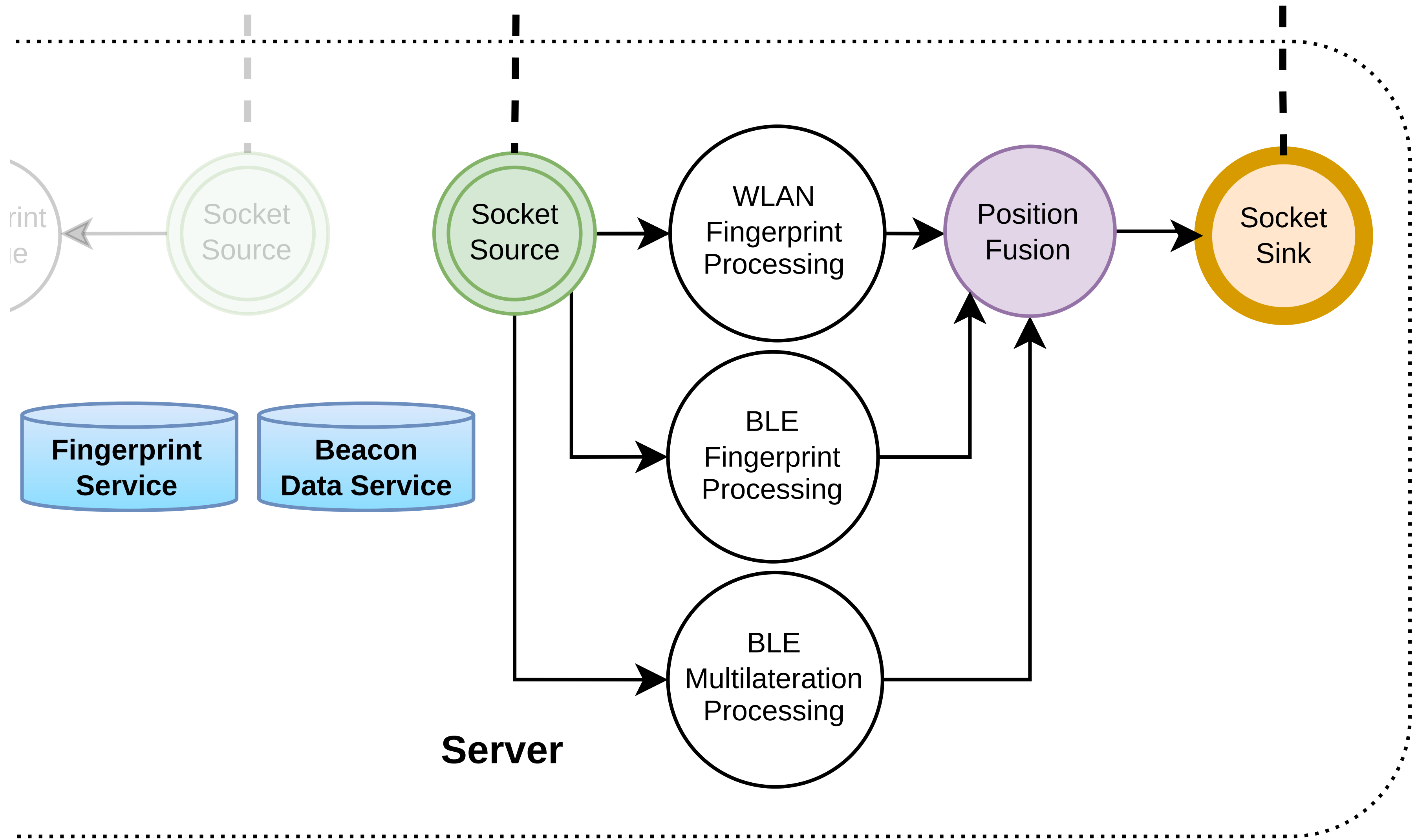


# Positioning Model ...

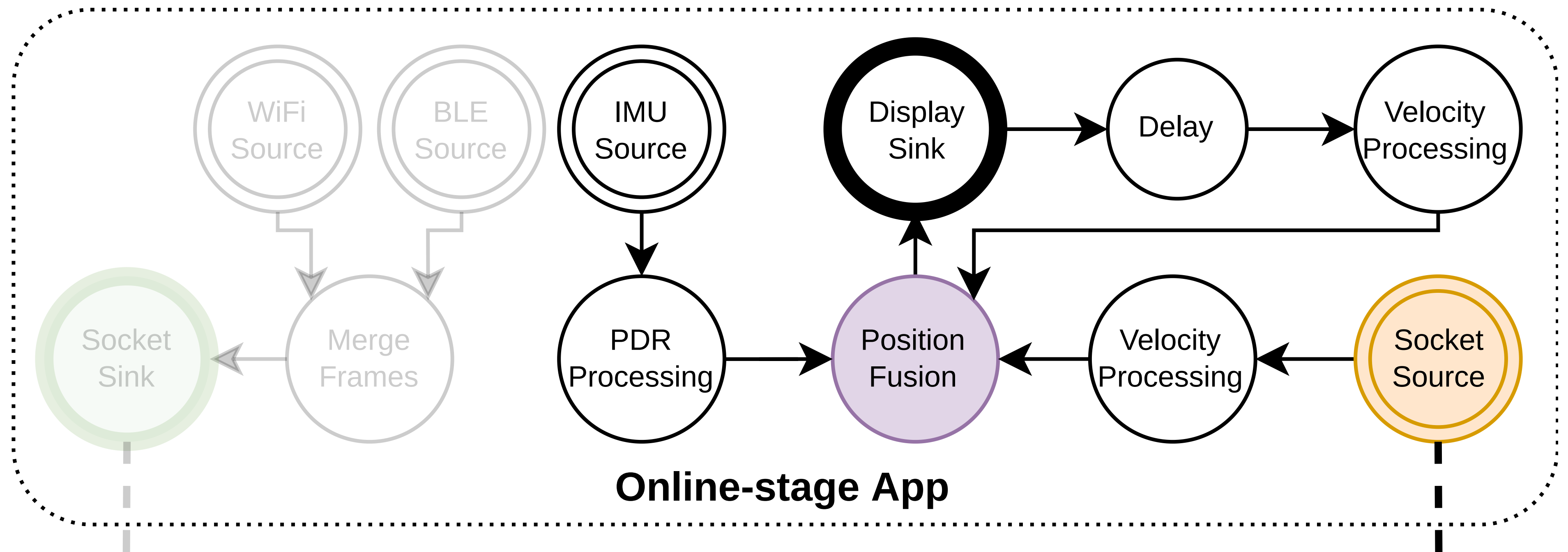




# Positioning Model ...

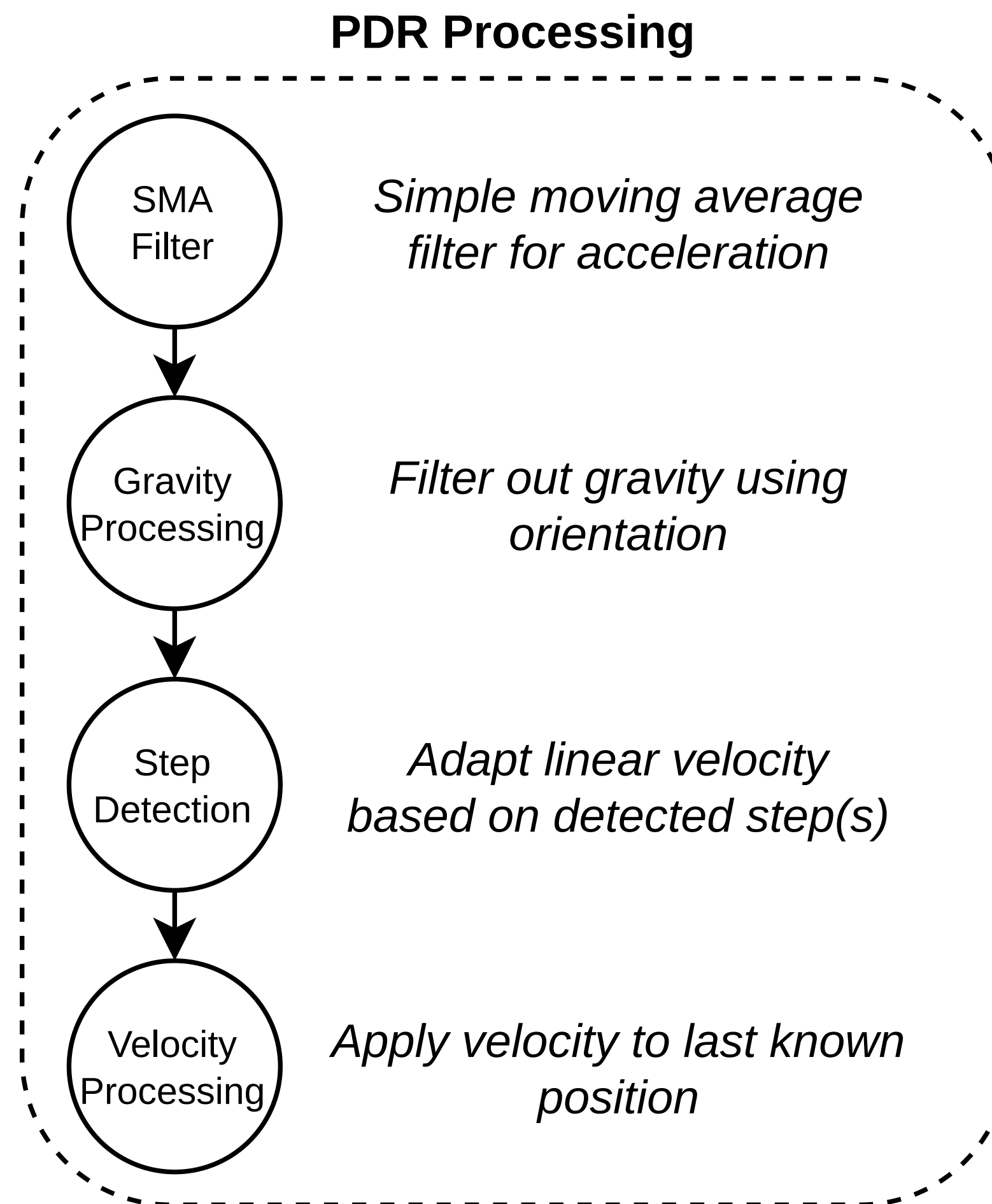


# Positioning Model ...



# Positioning Model

## Online App

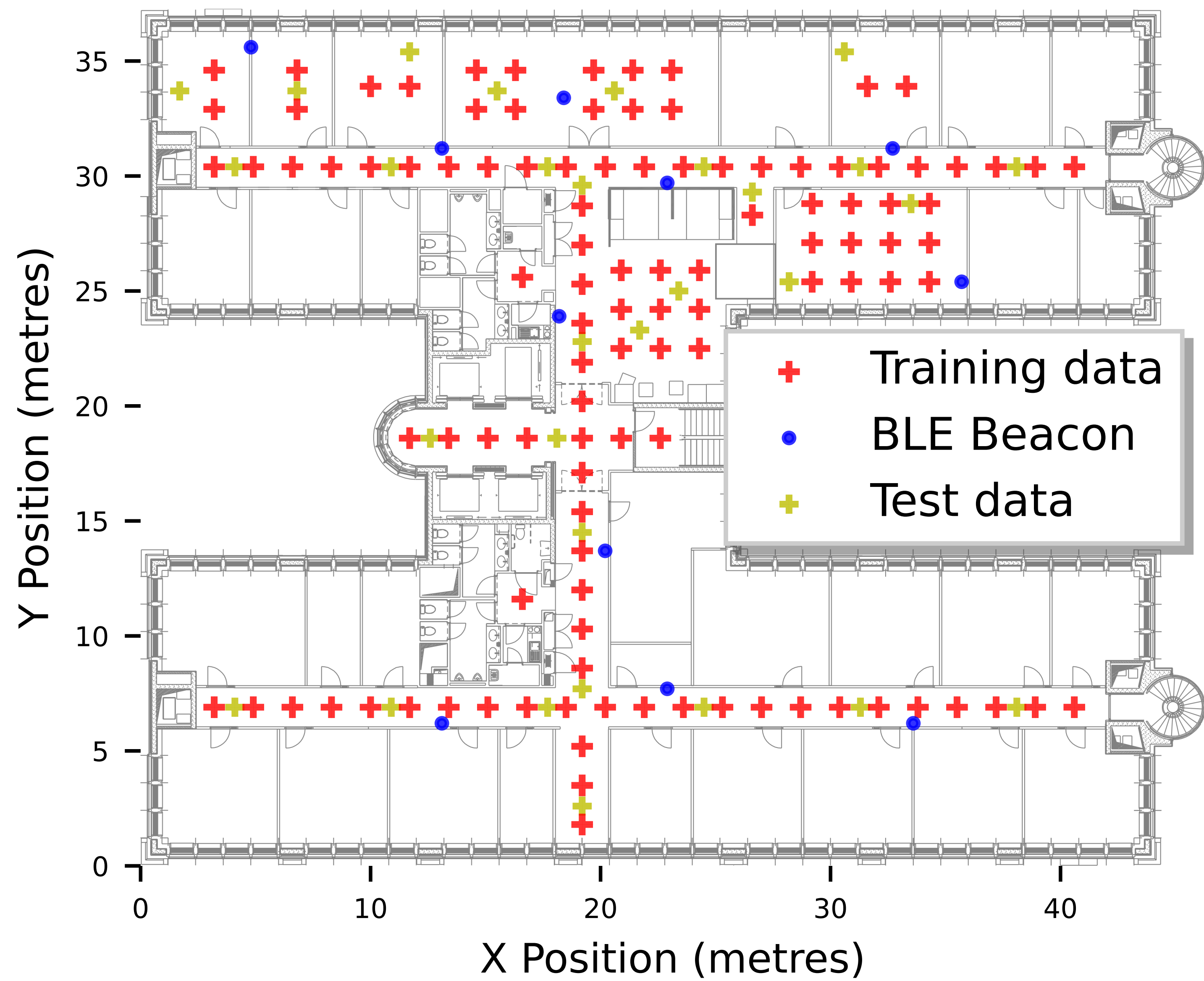


# Positioning Model

## Online App

```
ModelBuilder.create()
  .addShape(GraphBuilder.create()
    .from(new IMUSourceNode({
      source: new DataObject(phoneUID),
      interval: 20,
      sensors: [
        SensorType.ACCELEROMETER,
        SensorType.ORIENTATION
      ]
    })))
  .via(new SMAFilterNode(
    frame => [frame, "acceleration"],
    { taps: 10 }
  ))
  .via(new GravityProcessingNode({
    method: GravityProcessingMethod.ABSOLUTE_ORIENTATION
  })))
```

# Dataset



# Dataset ...

**Total BLE Beacons: 11**

**Total detected WLAN access points: 220**

**Total stable WLAN access points: 199**

	Training	Test
Datapoints	110	30
Total fingerprints	440	120
Duration (per orientation)	20s	20s
Avg. WLAN Scans (per fingerprint)	6	6
Avg. BLE Advertisements (per fingerprint)	16	15

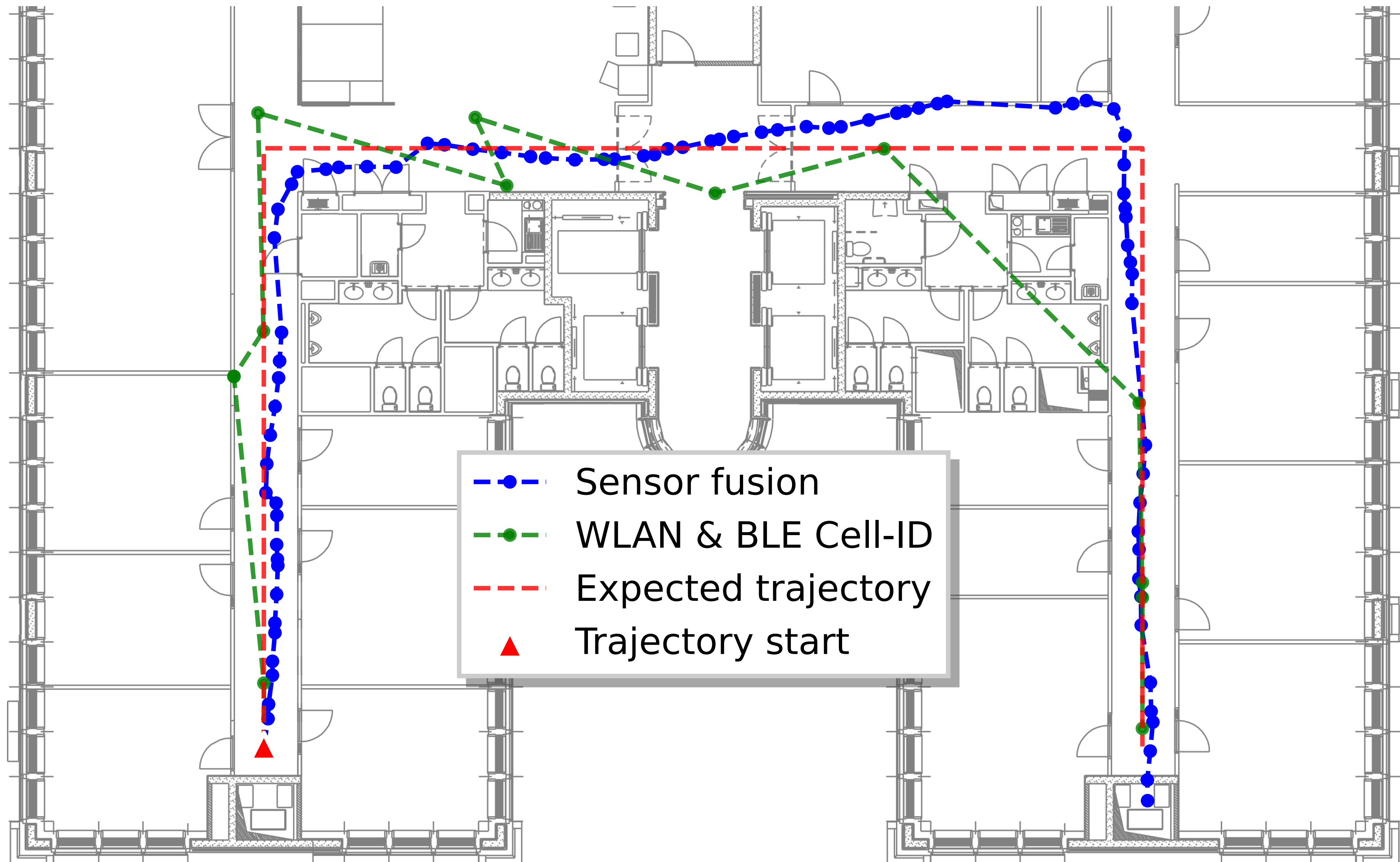
# Validation Results

## 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

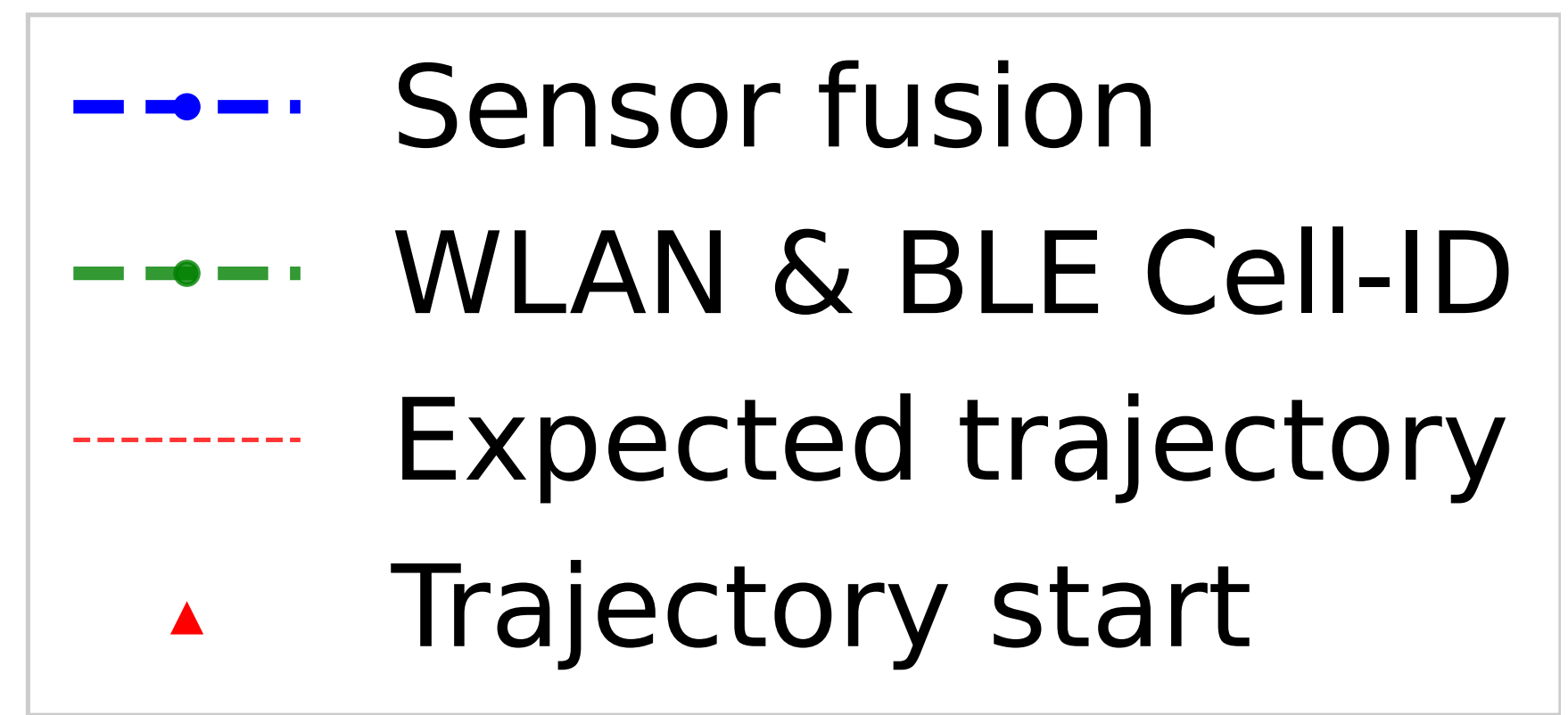




# Validation Results ...

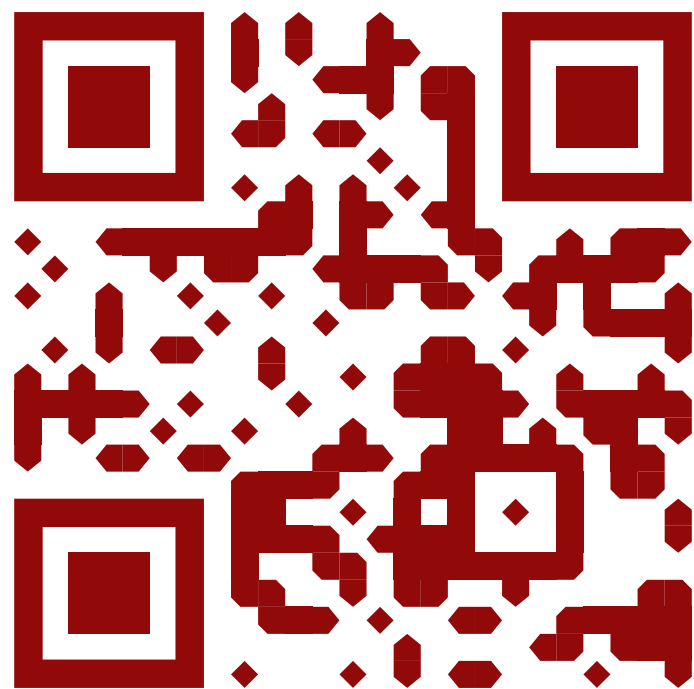
## Trajectories

	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!