


Indoor Positioning Using the OpenHPS Framework

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An Open Source Hybrid Positioning System





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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

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

No additional objects

Sensor Frequency

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;
}

```

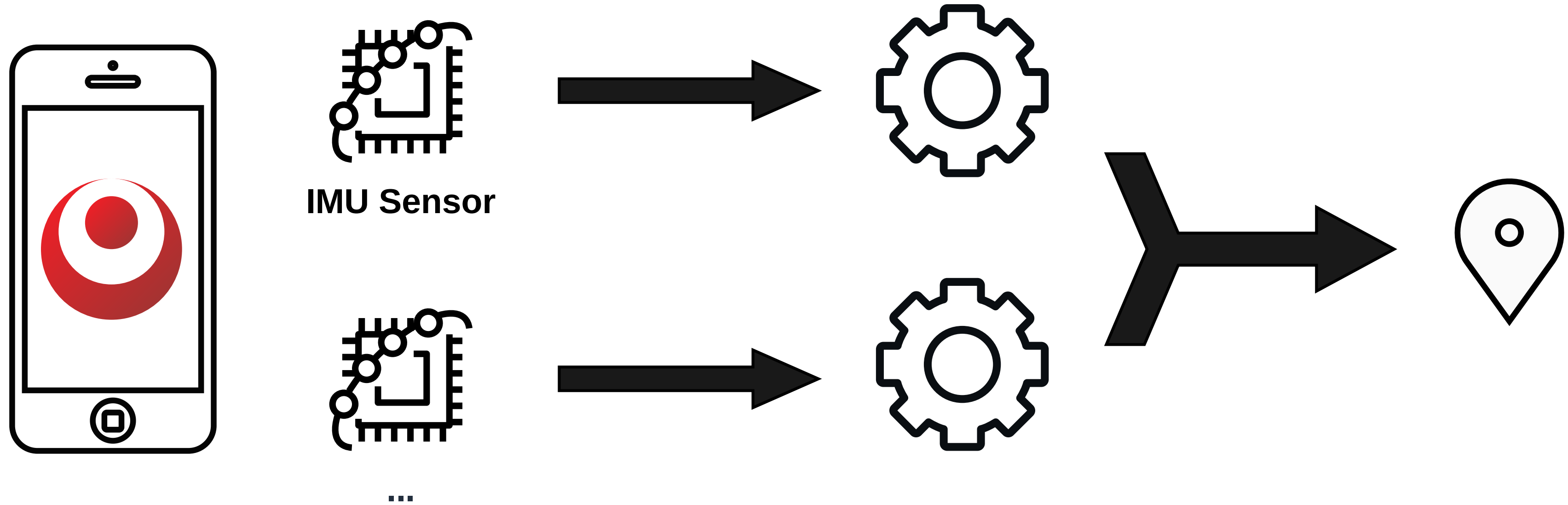
What is OpenHPS?



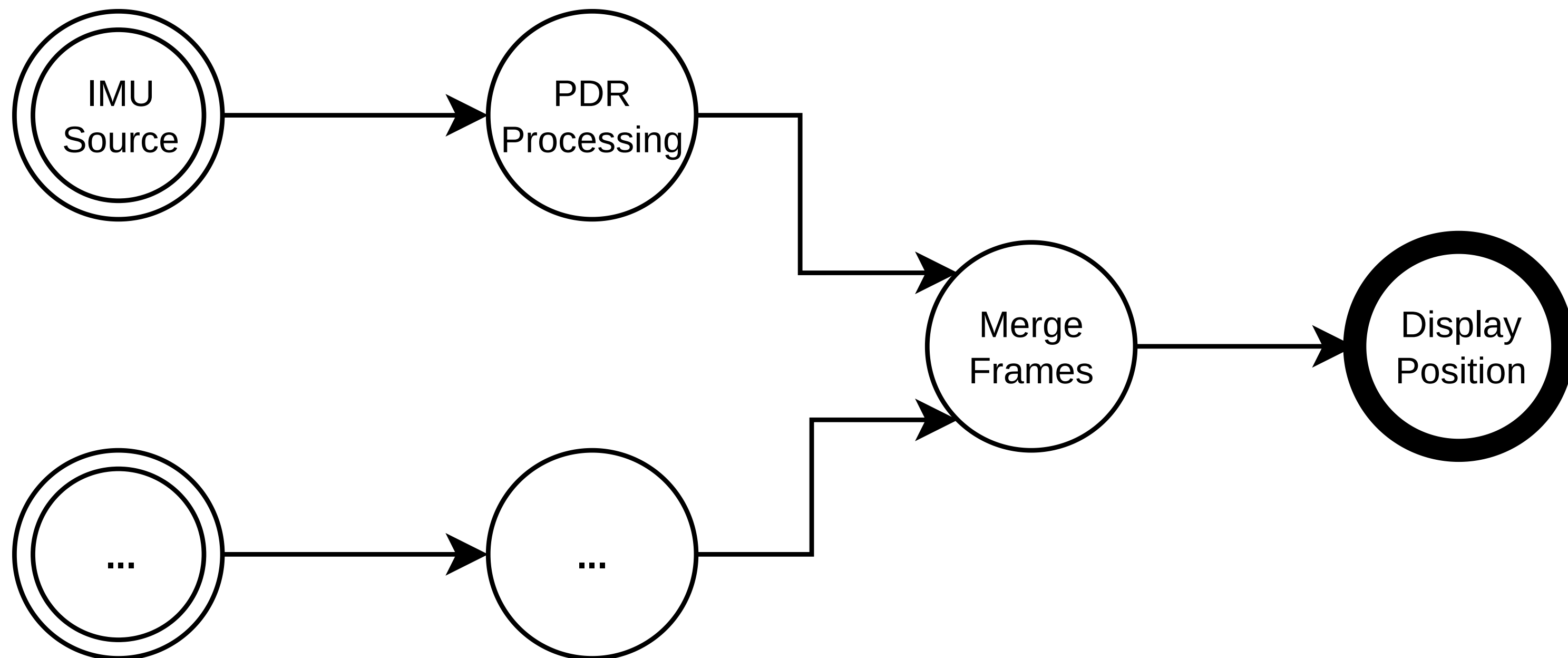
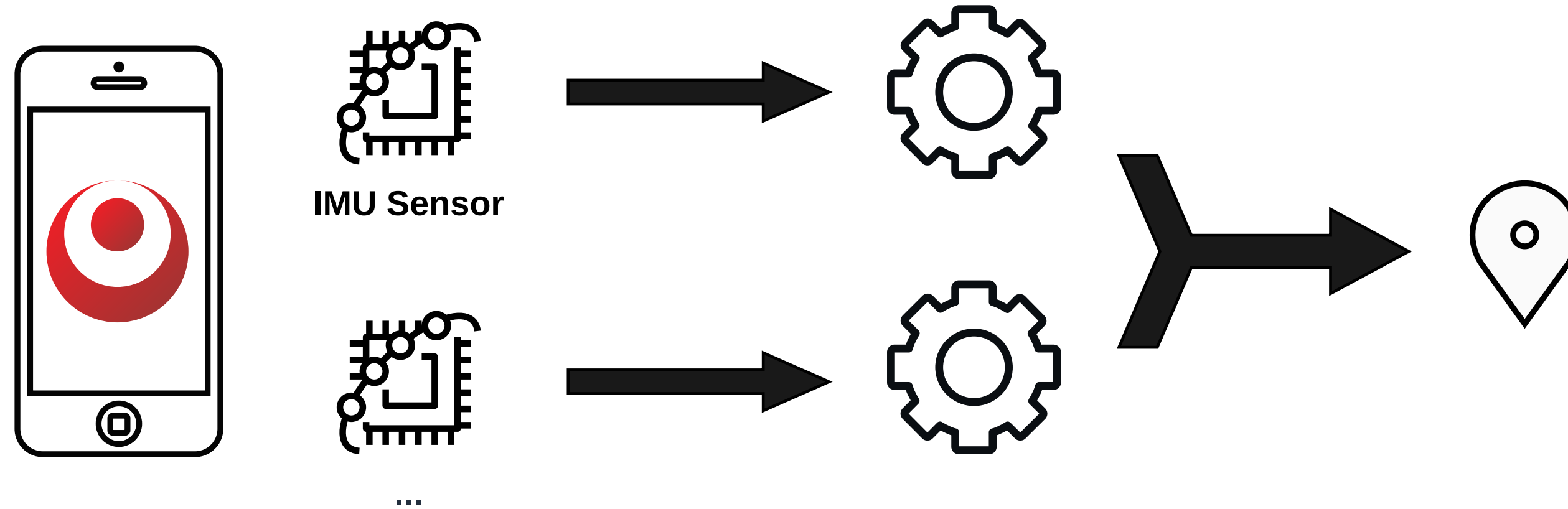
An Open Source Hybrid Positioning System

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

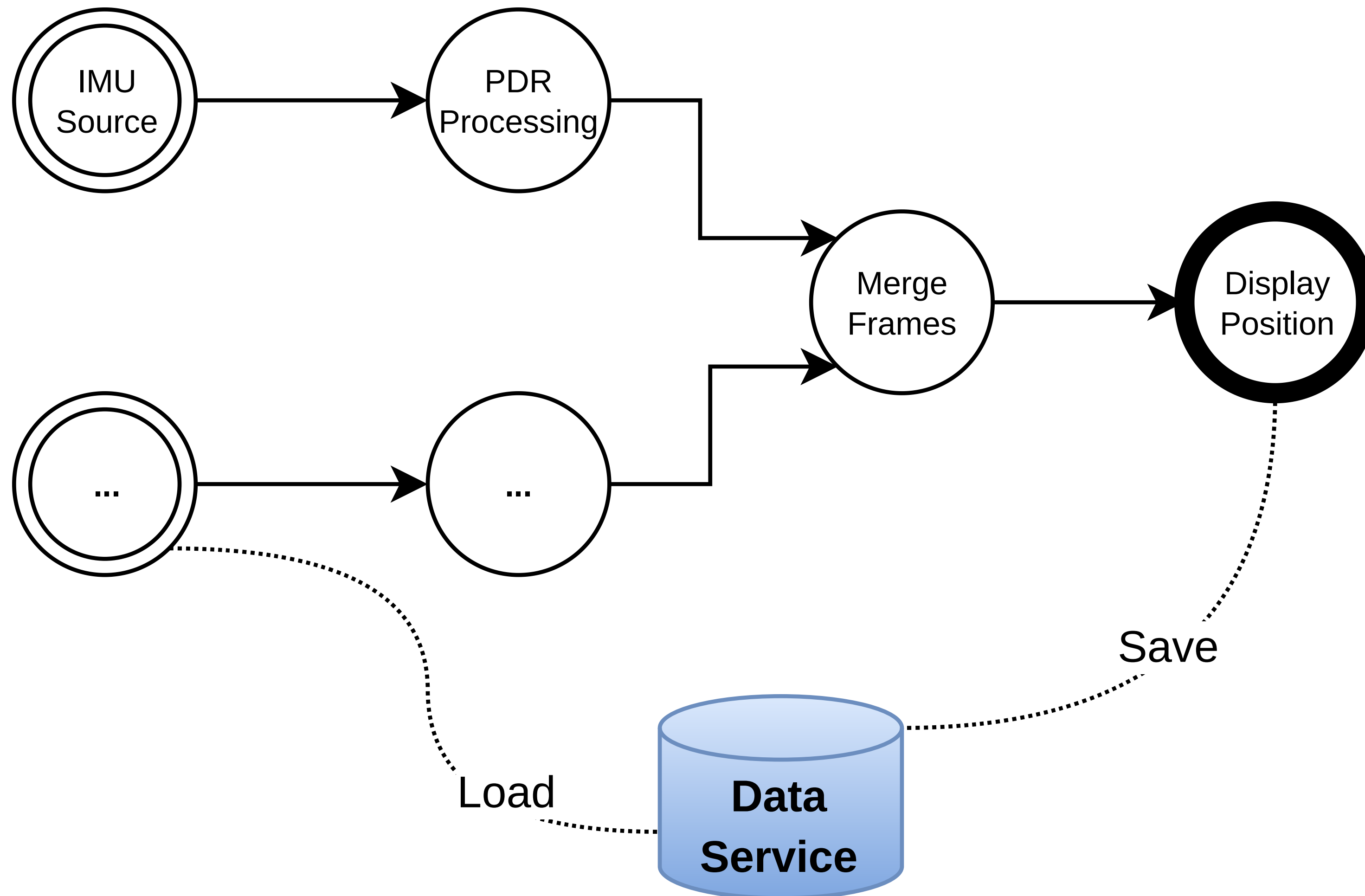
Process Network Design



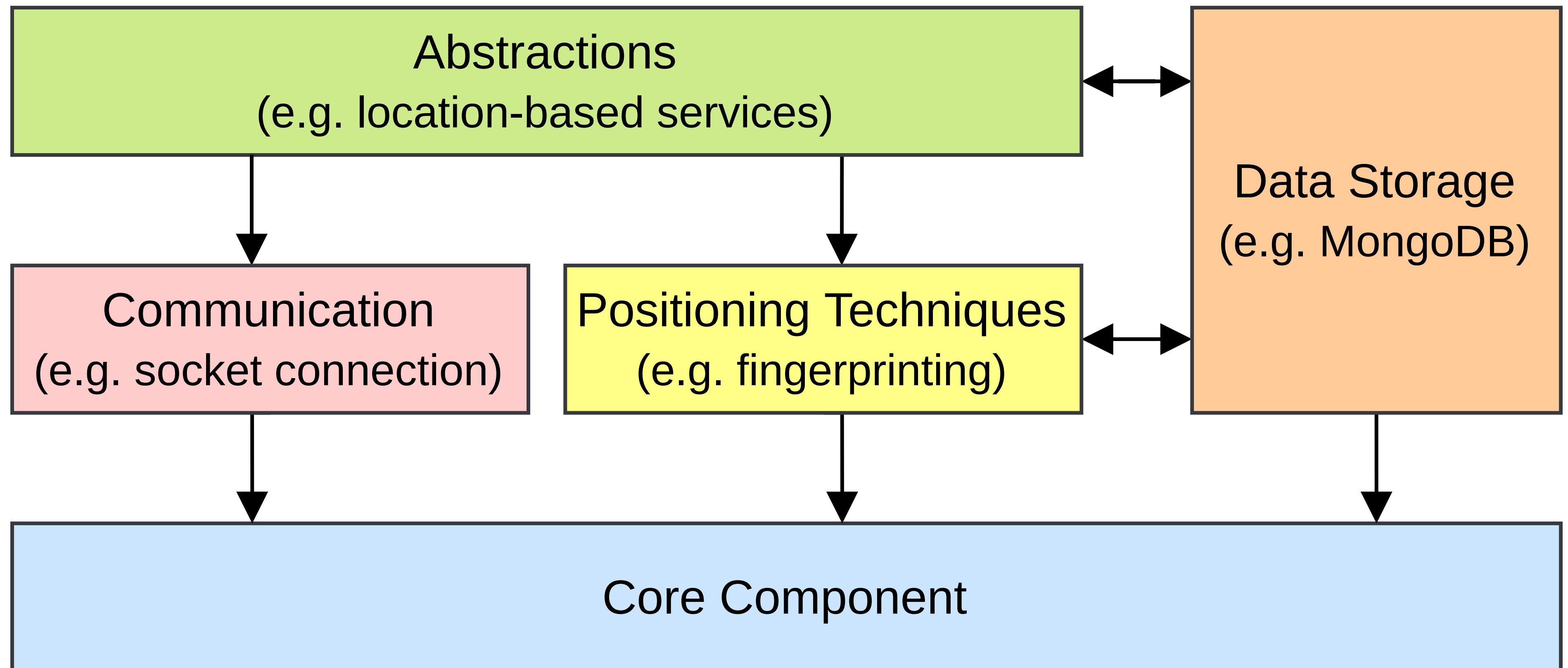
Process Network Design ...



Process Network Design ...



Modularity



Modularity ...

Communication

Socket, MQTT, REST API, ...

Data Storage

MongoDB, LocalStorage, RDF, ...

Positioning Algorithms

IMU, fingerprinting, OpenVSLAM, ...

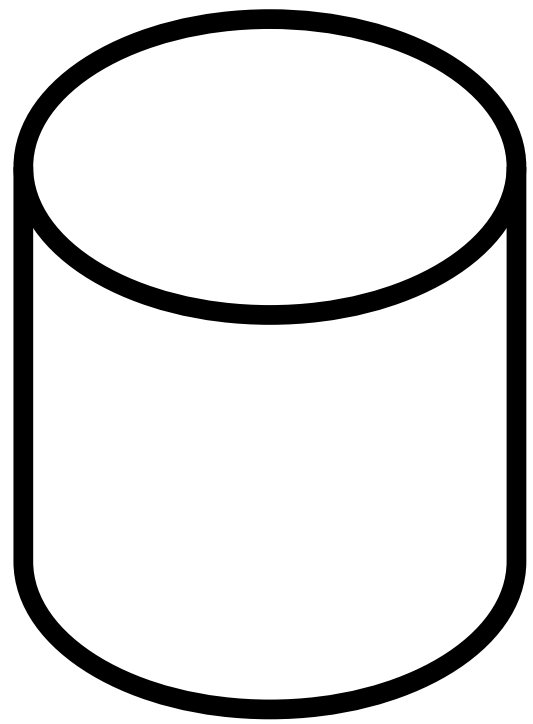
Abstractions

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

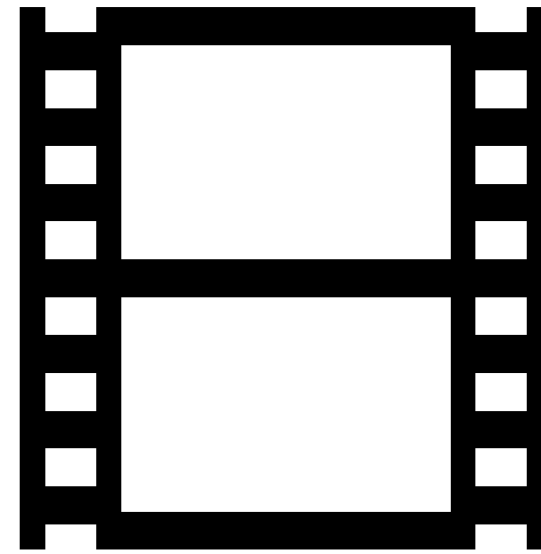
Other

React-Native, NativeScript, Sphero, ...

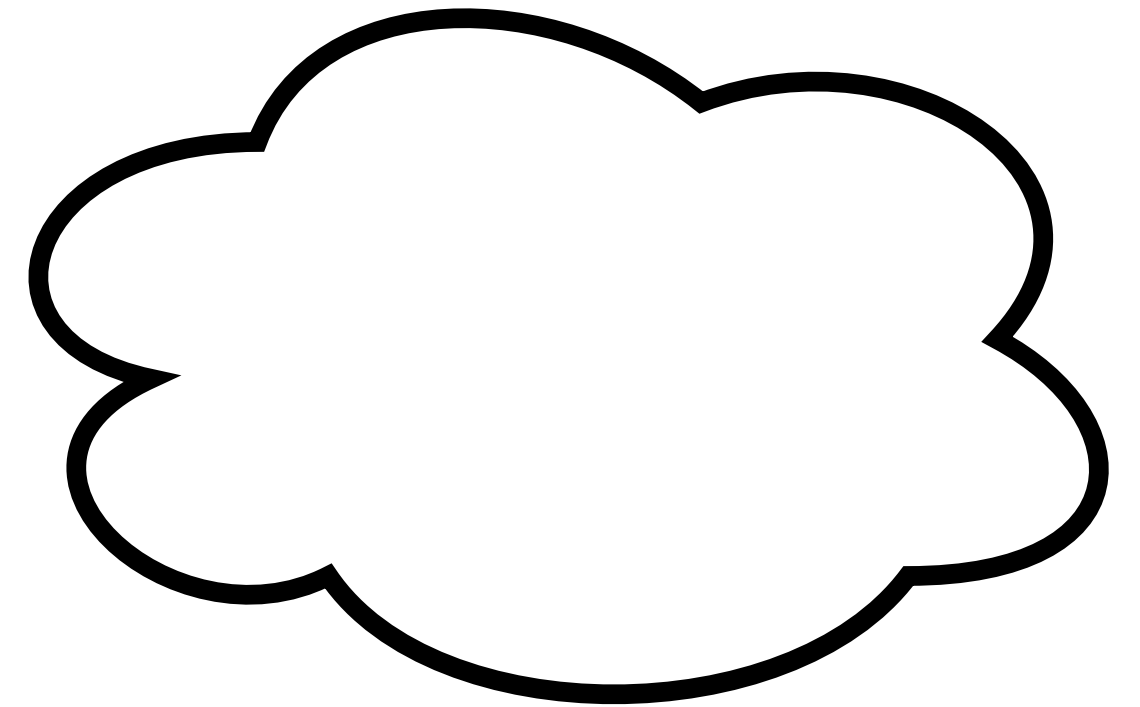
Data Processing



Knowledge

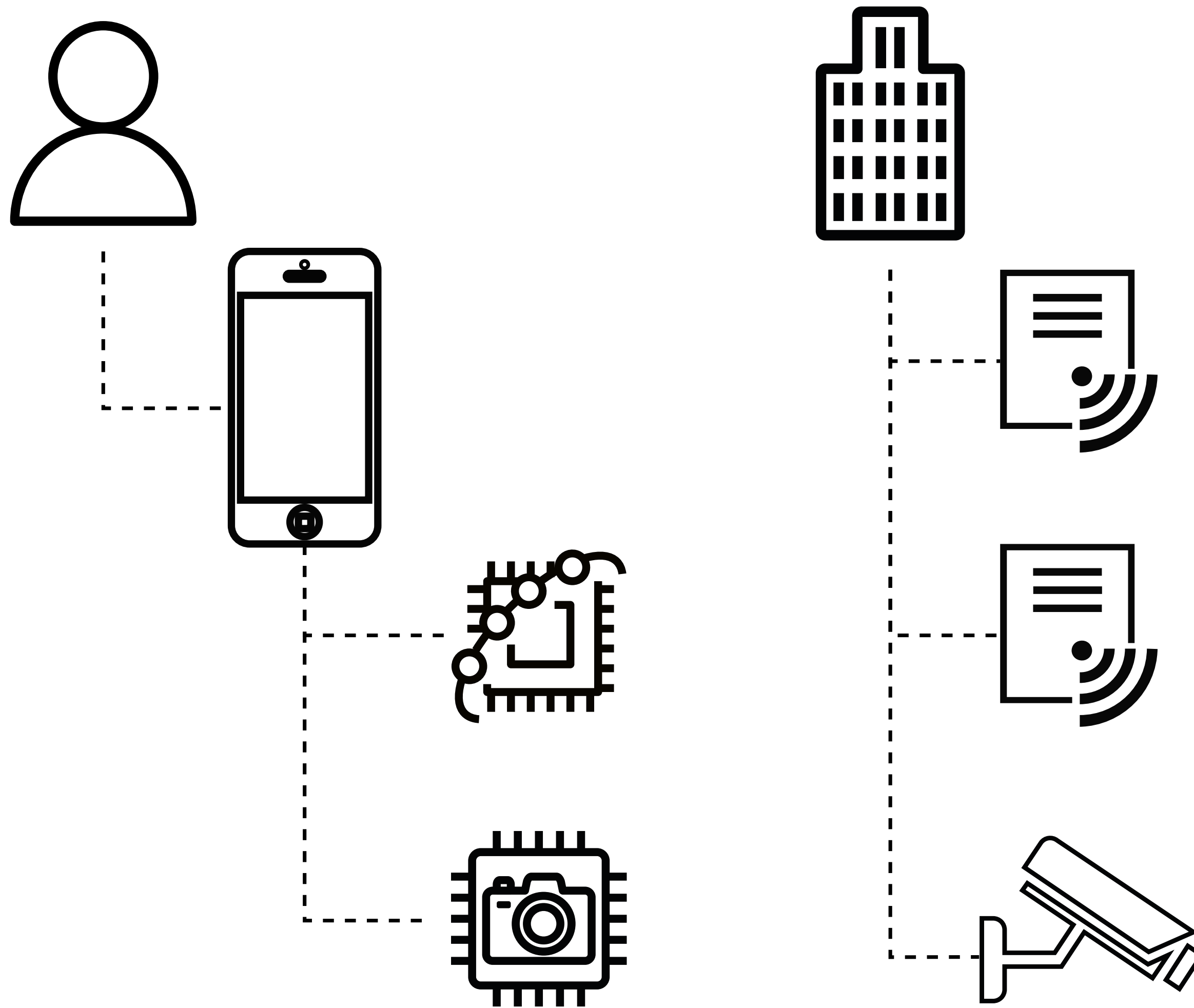


Raw Data



Processed Data

DataObject



Absolute and Relative Positions

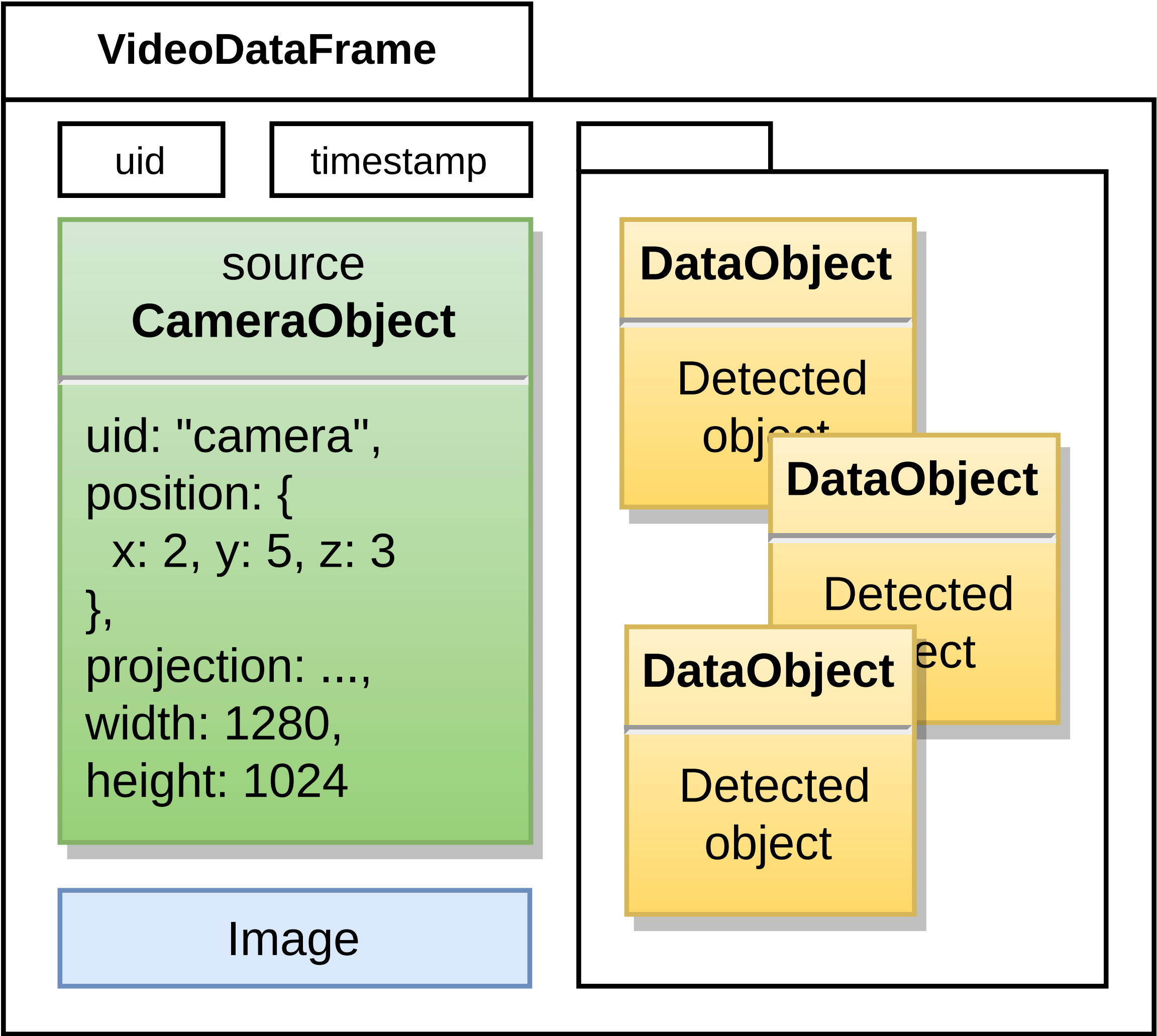
Absolute

- ▶ 2D, 3D, Geographical, ...

Relative

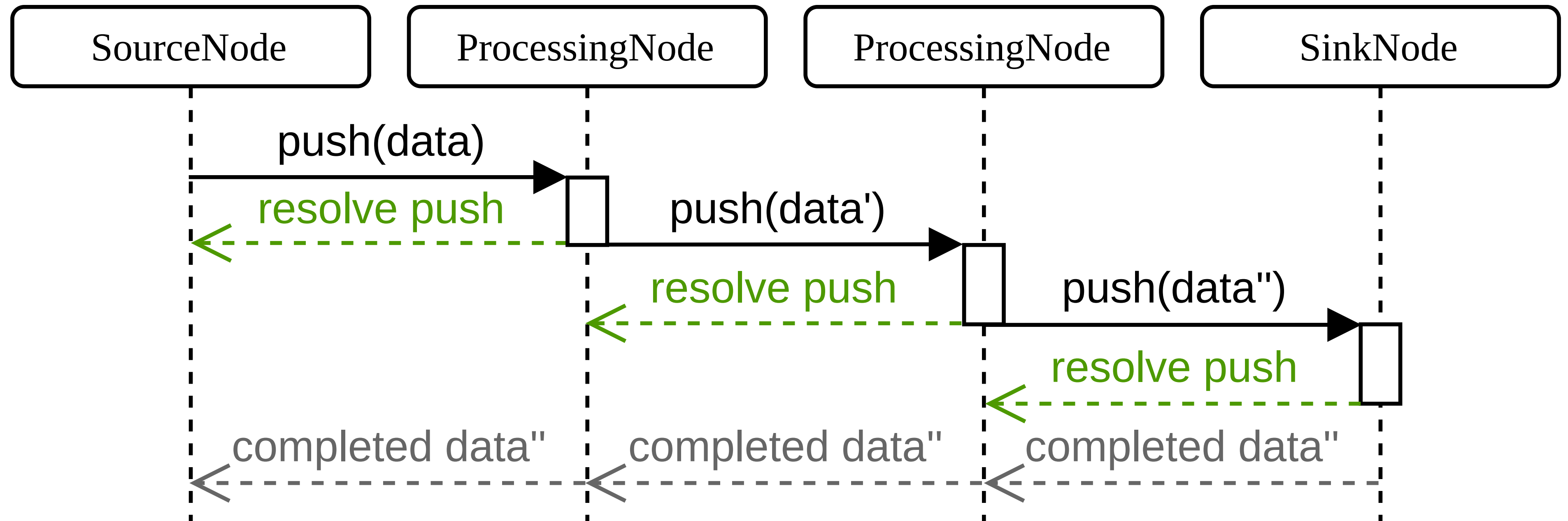
- ▶ Distance, angle, velocity, ...
- ▶ Relative to another *object*

DataFrame



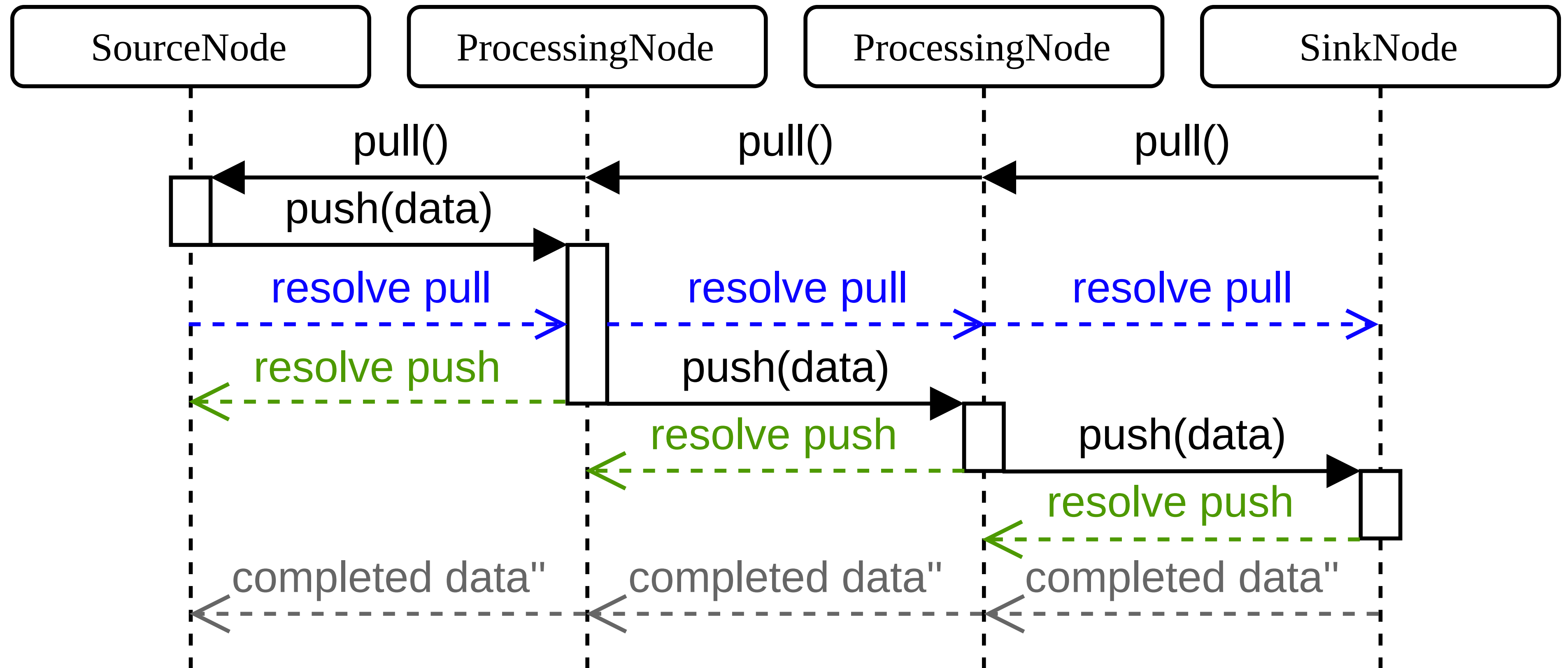
DataFrame ...

Pushing Data



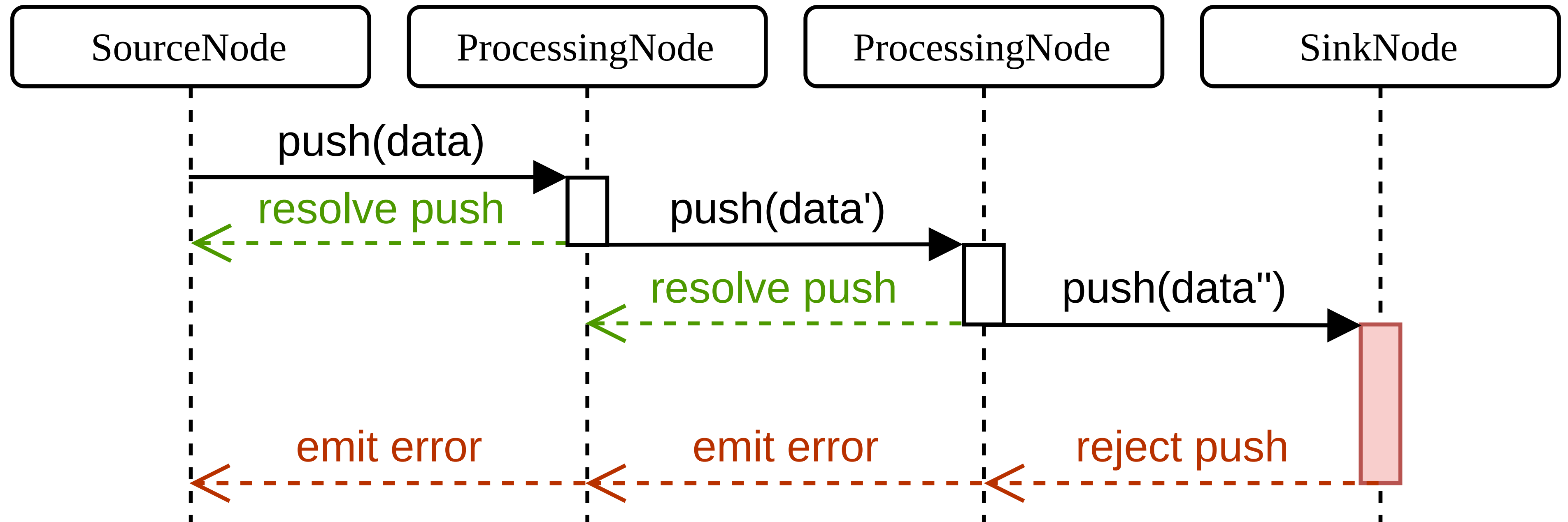
DataFrame ...

Pulling Data



DataFrame ...

Pushing Error



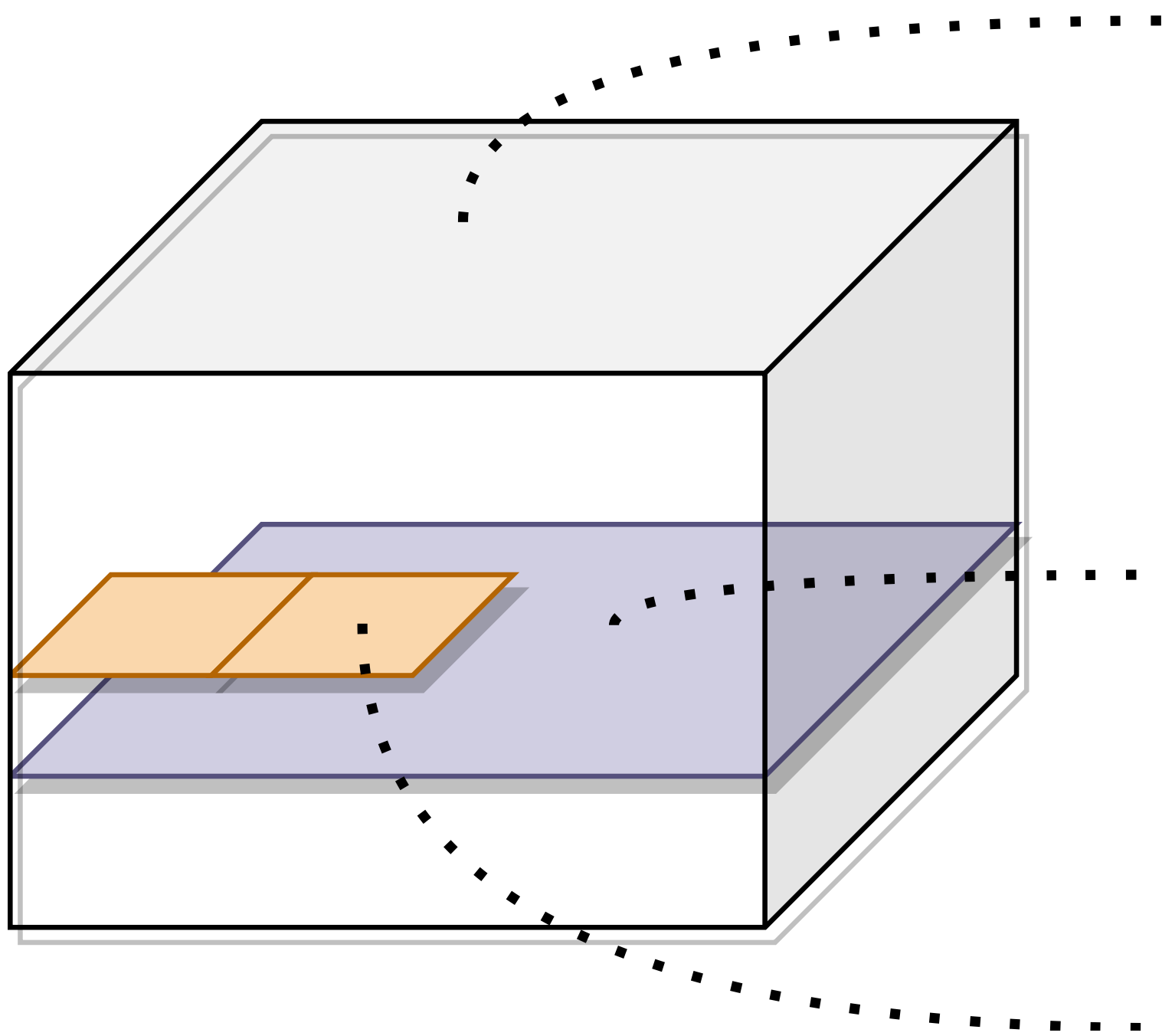
SymbolicSpace

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 ...



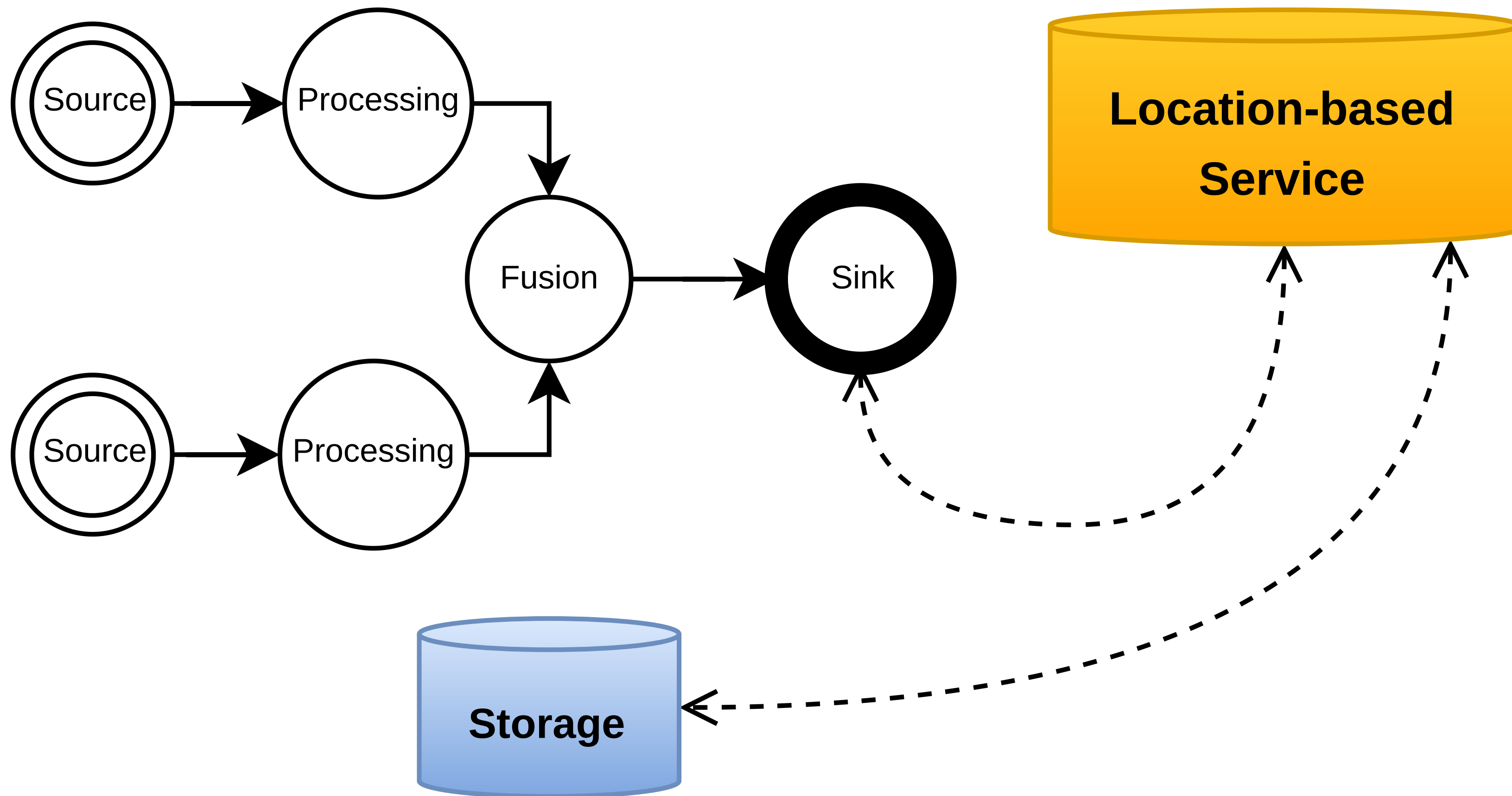
```
const building = new Building("PL9")
  .setBounds({
    topLeft: new GeographicalPosition(
      50.8203,
      4.3922),
    width: 46.275,
    height: 37.27,
    rotation: -34.04
  });

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),
  ]);
```

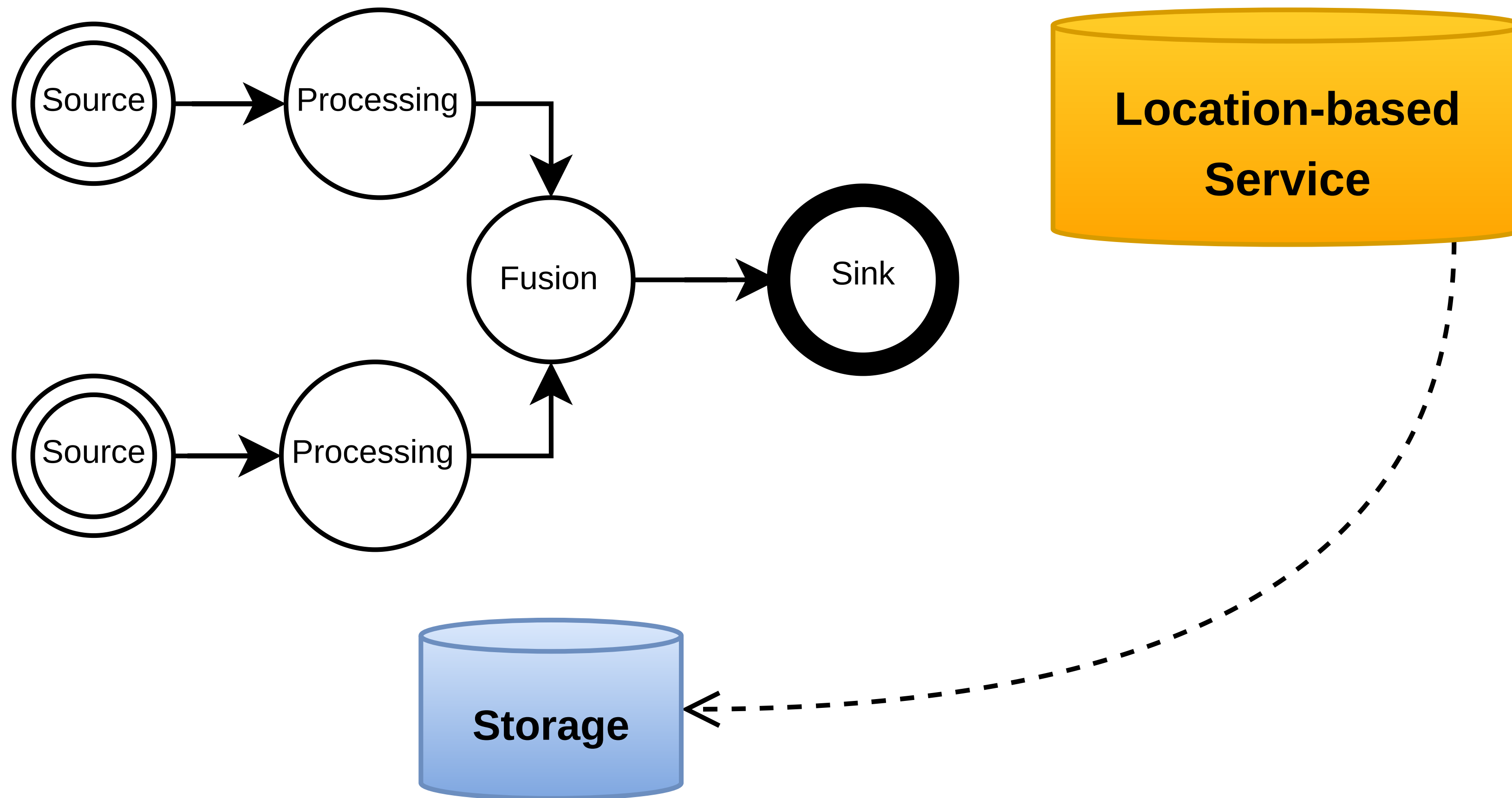
Location-based Service

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



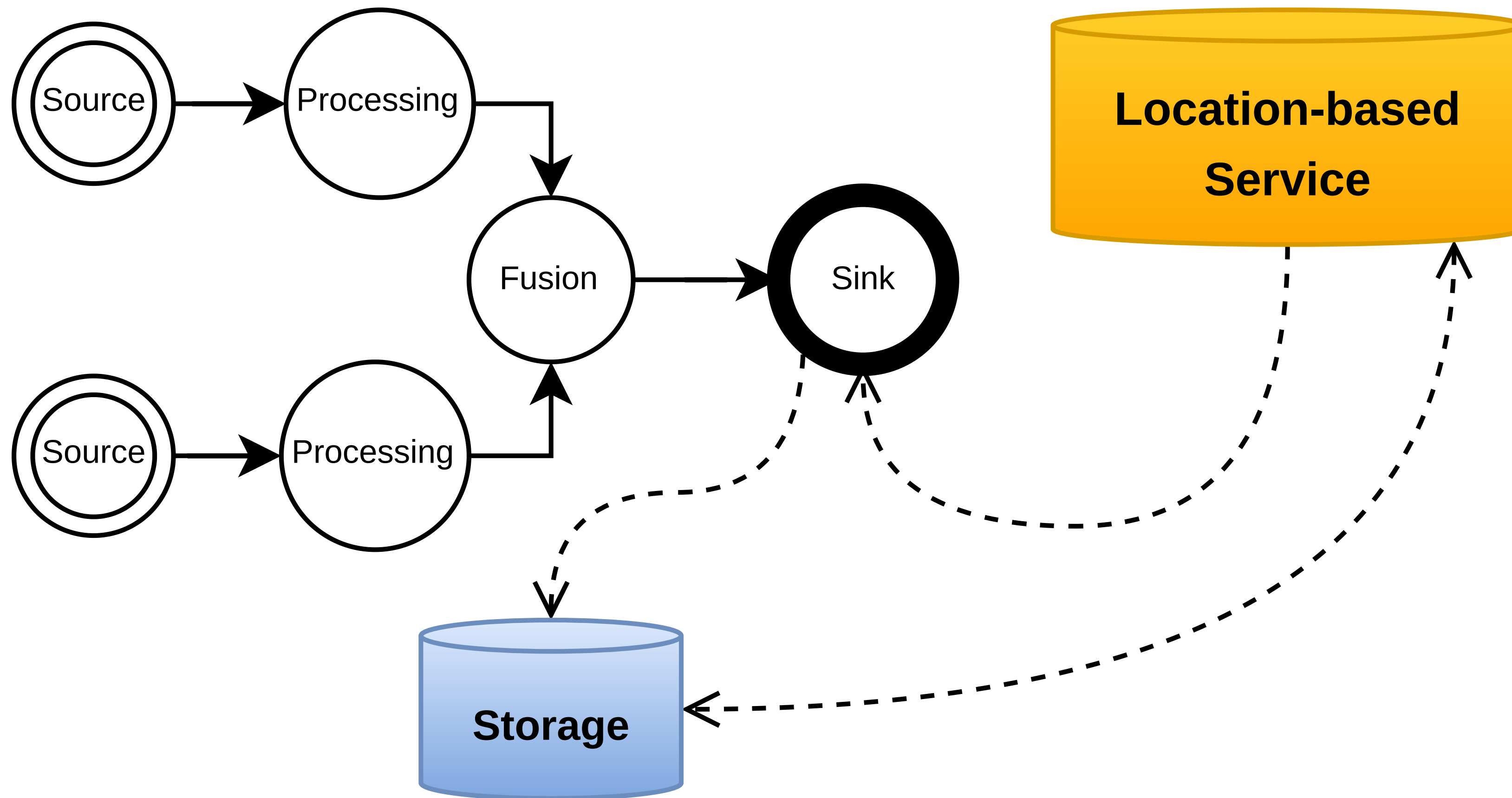
Location-based Service ...

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



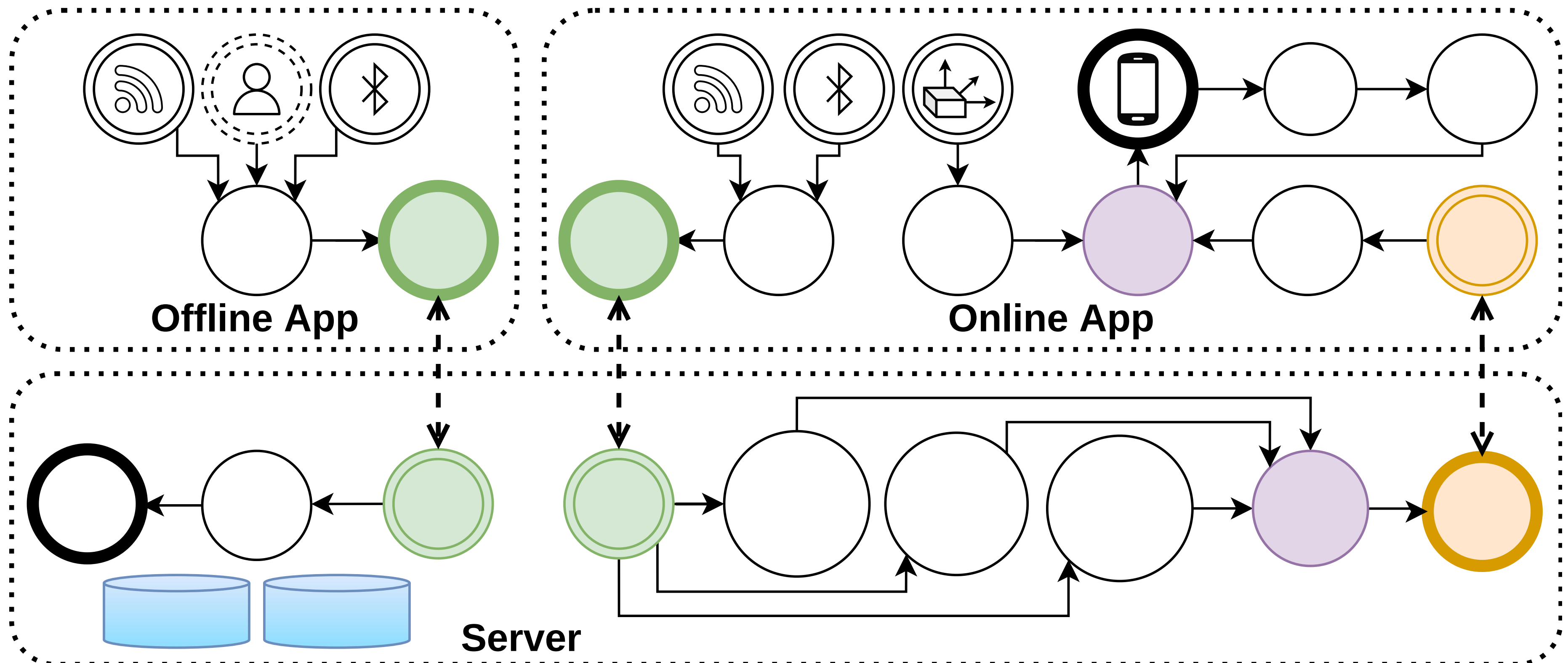
Location-based Service ...

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

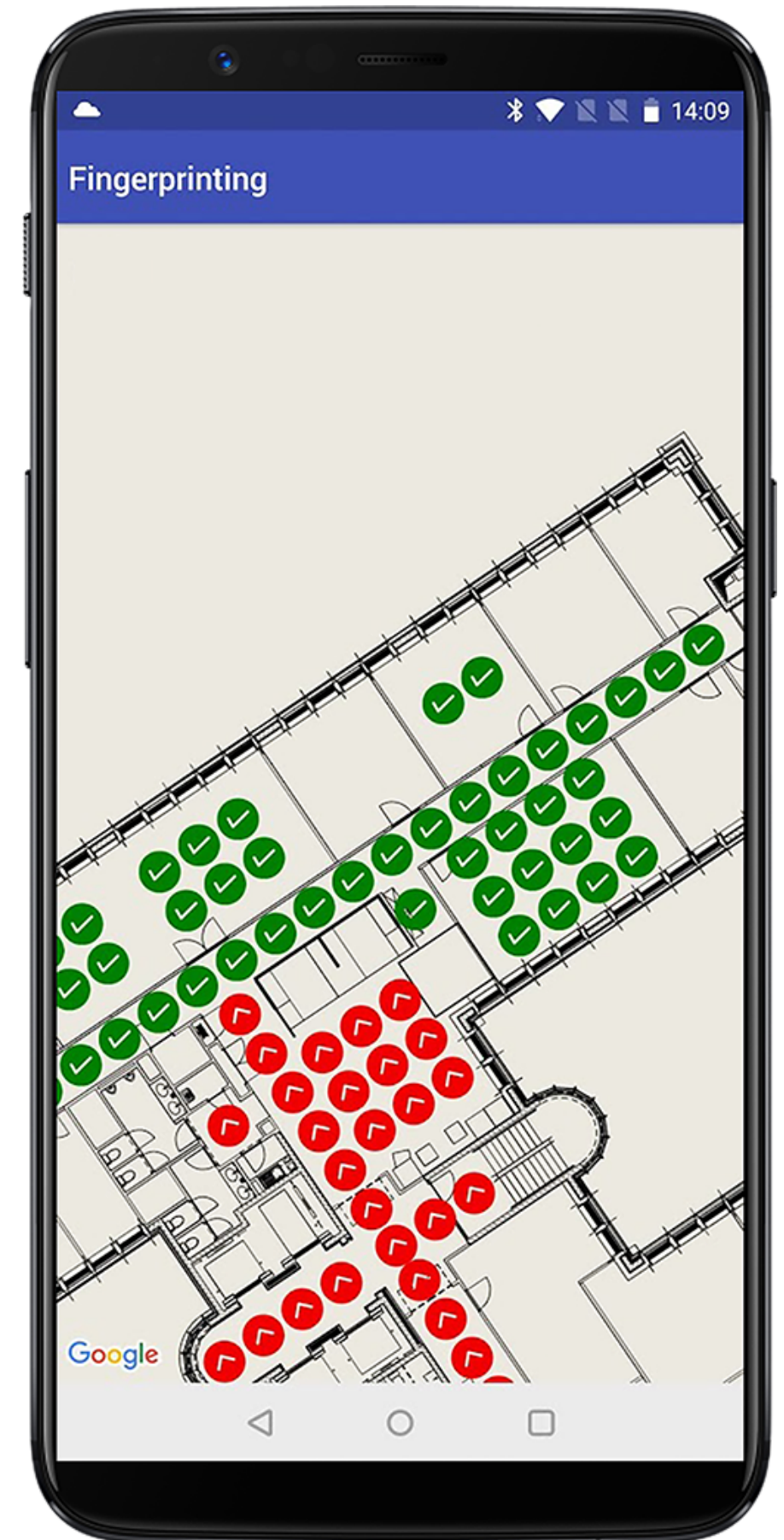
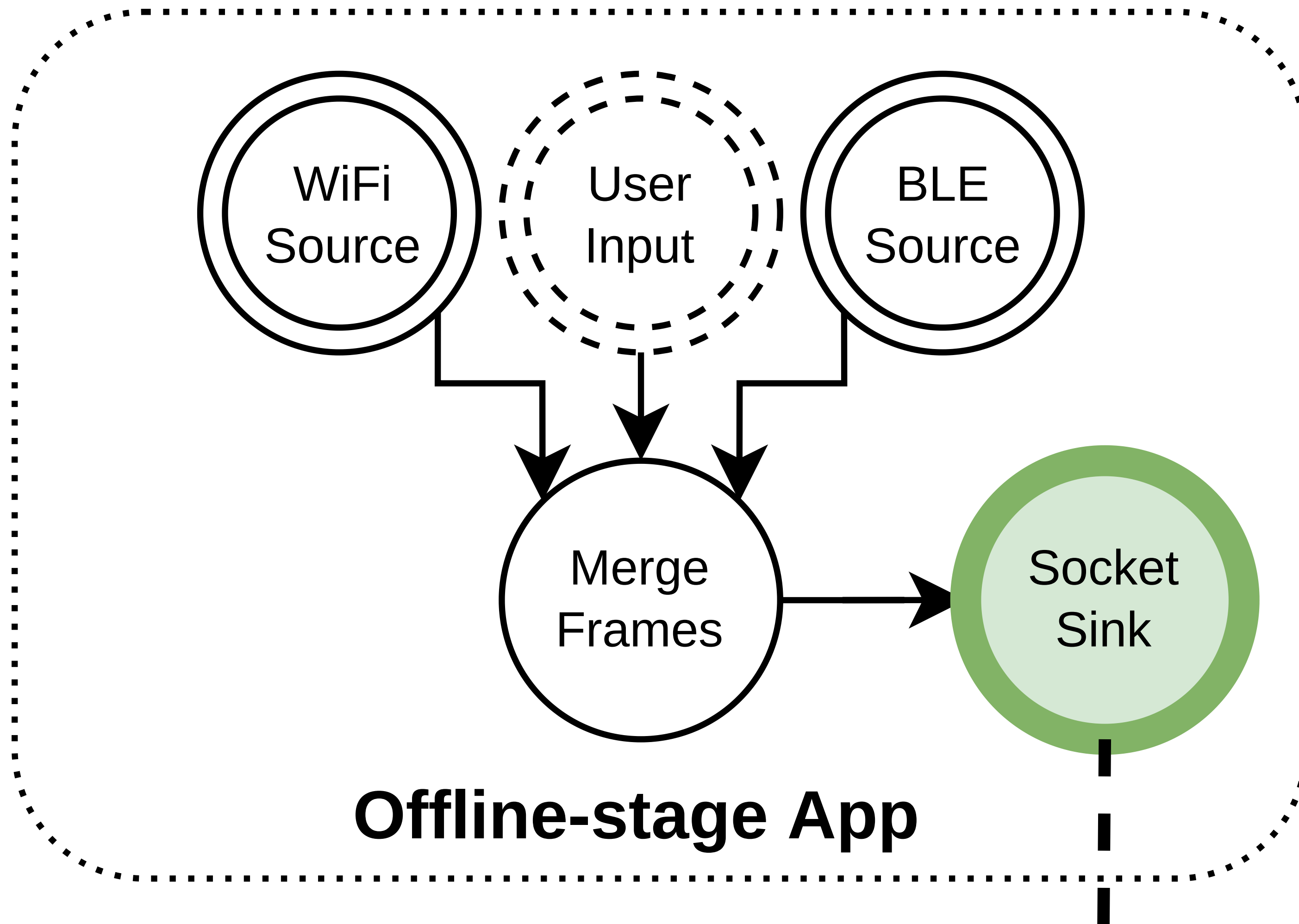


Demonstration

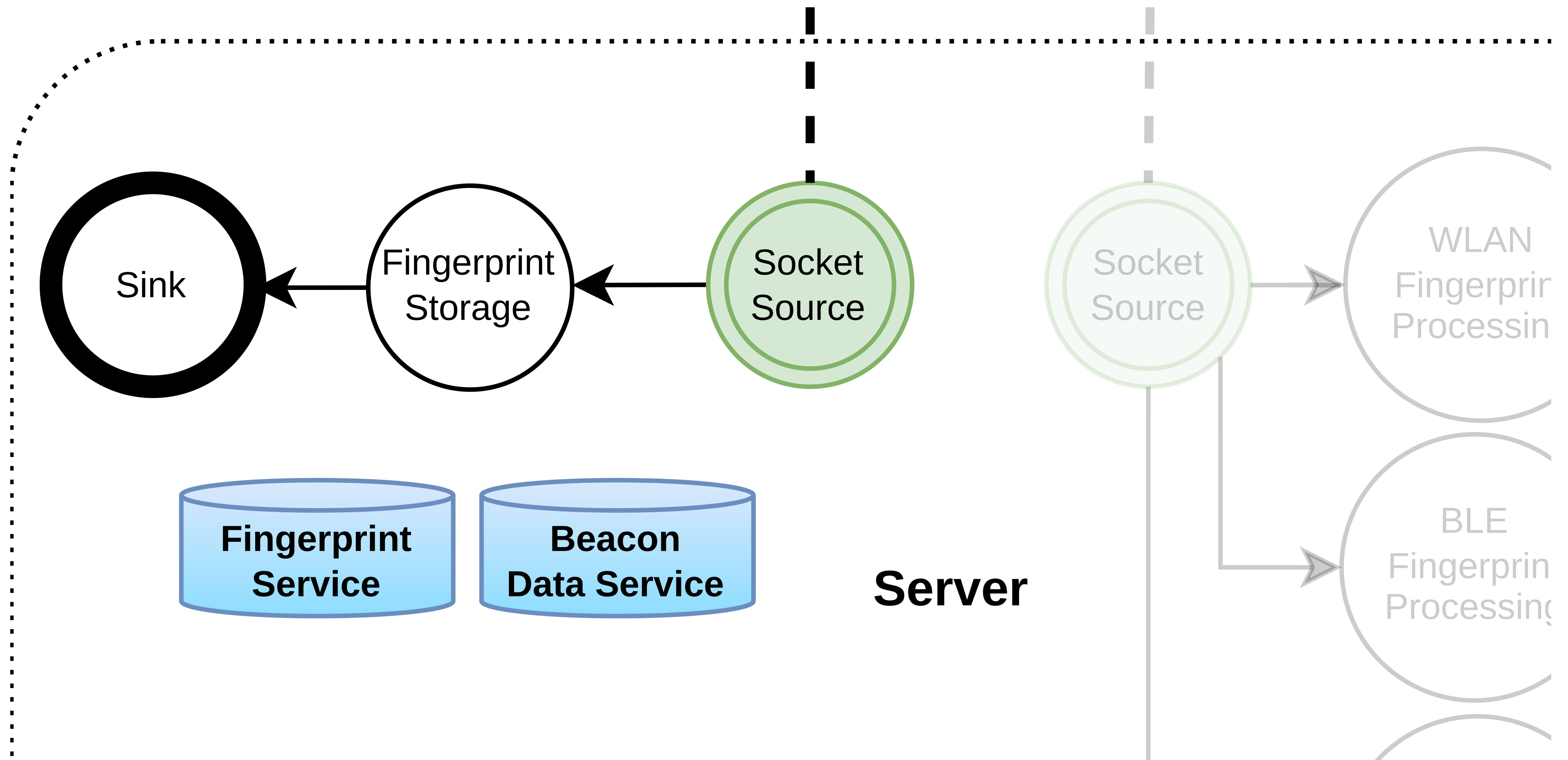
- ▶ Indoor positioning **use case**
- ▶ Use **existing techniques**
- ▶ Validation of **flexibility** and modularity



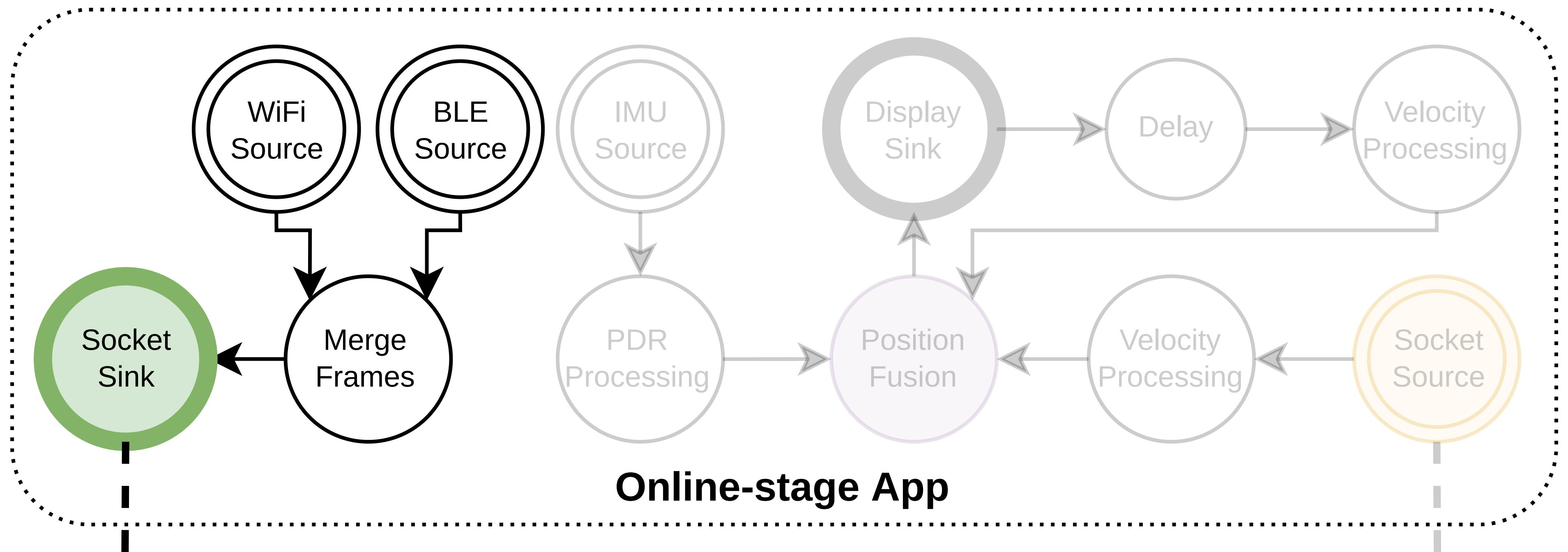
Positioning Model



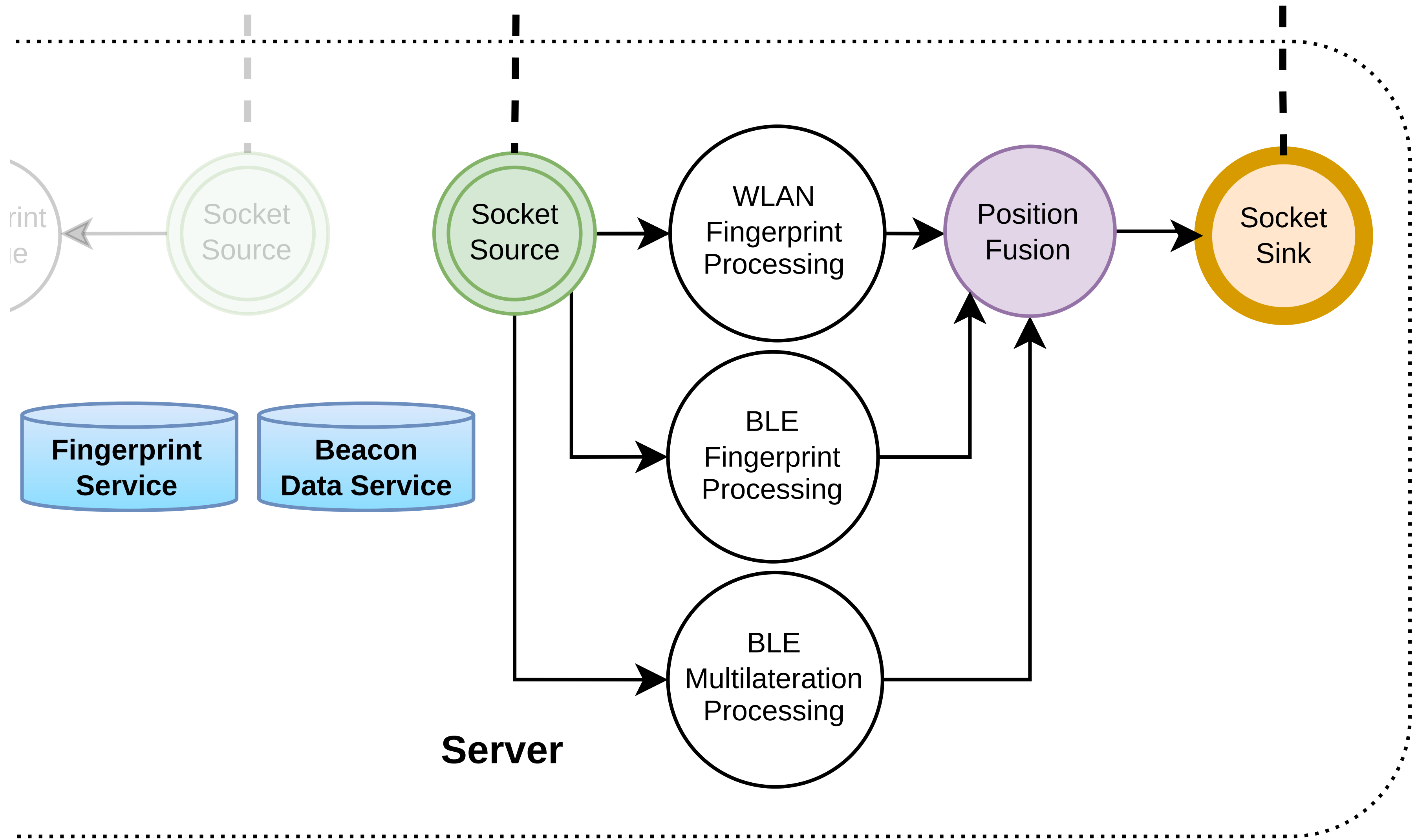
Positioning Model ...



Positioning Model ...

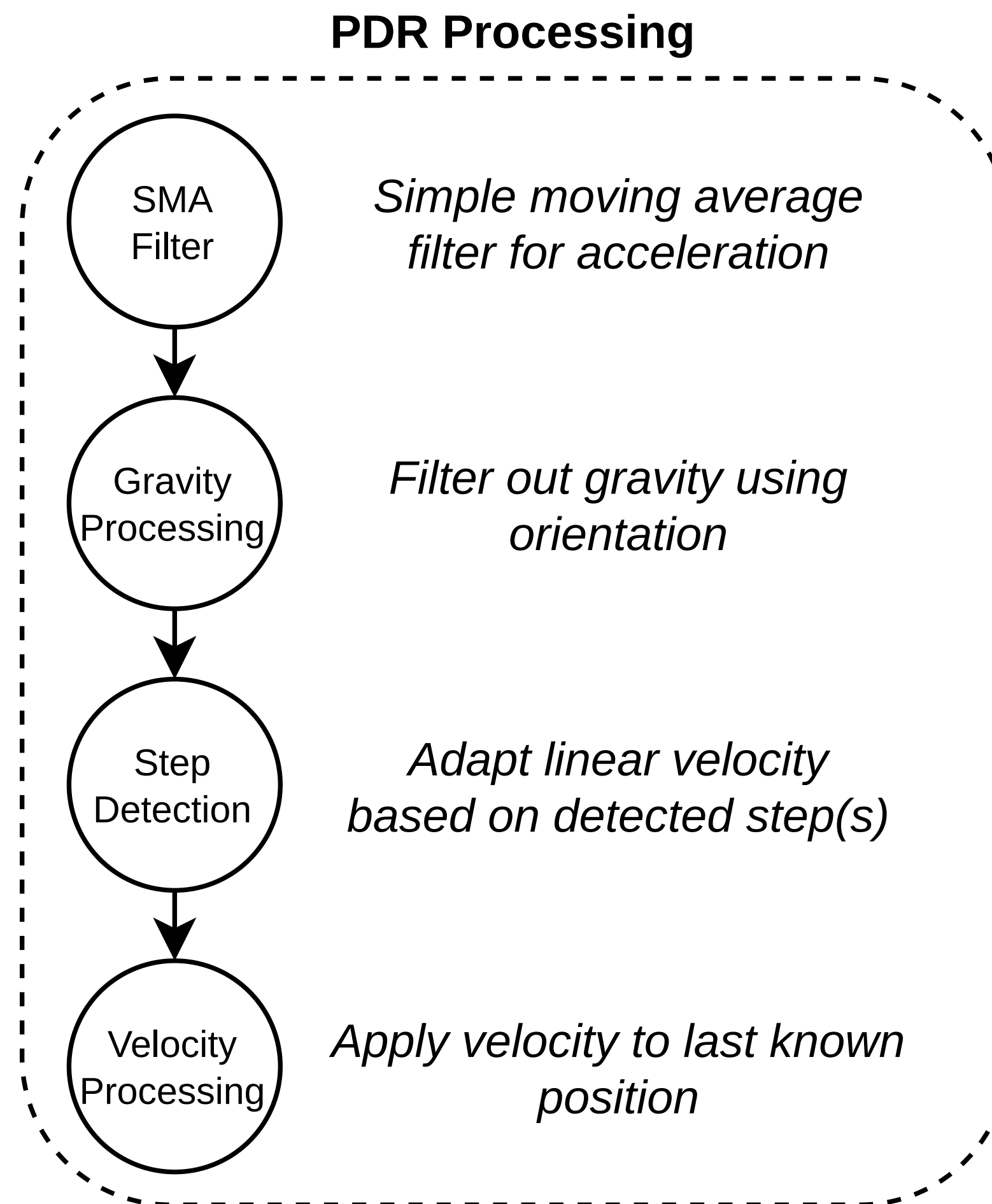


Positioning Model ...



Positioning Model

Online App

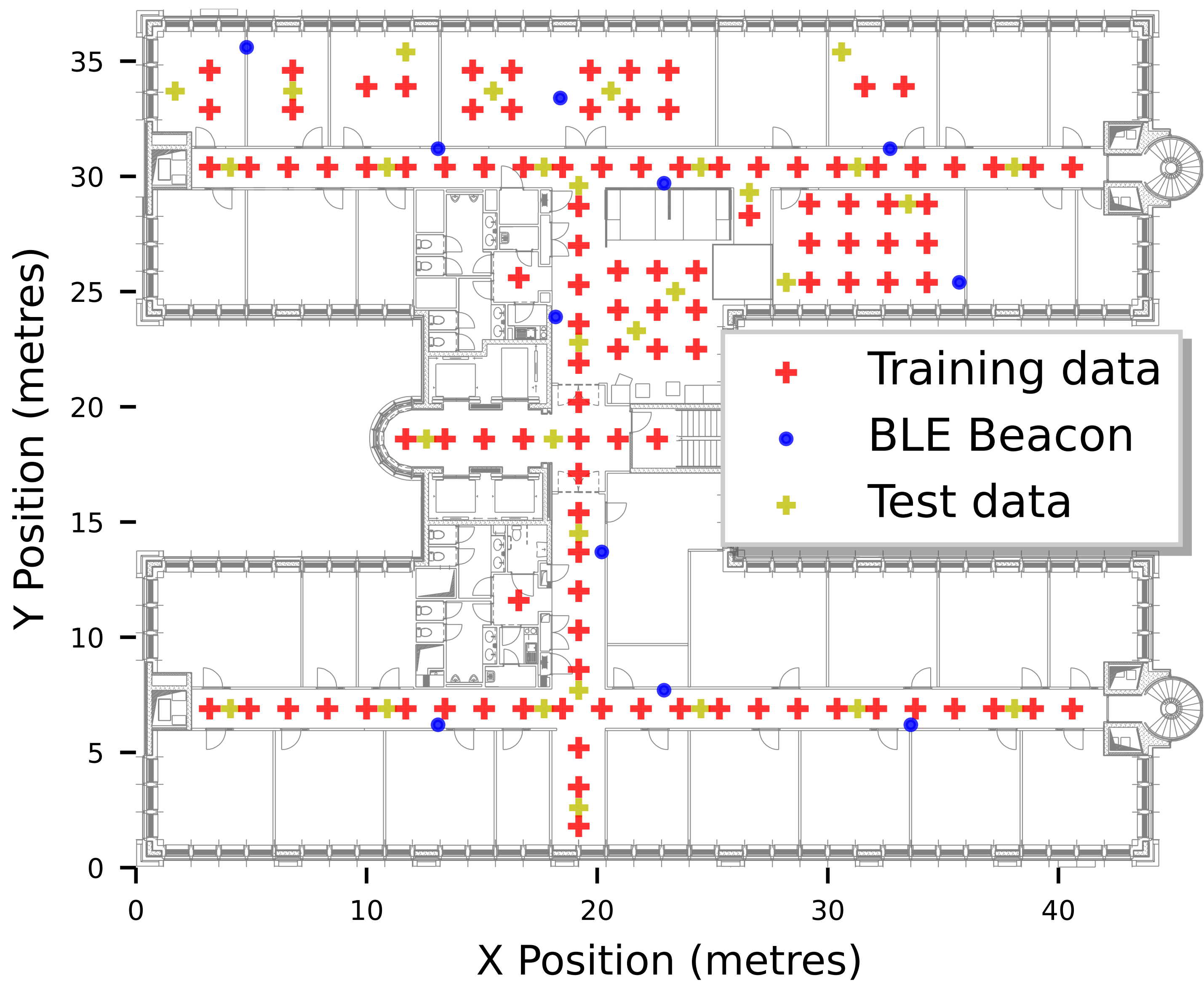


Positioning Model

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 |

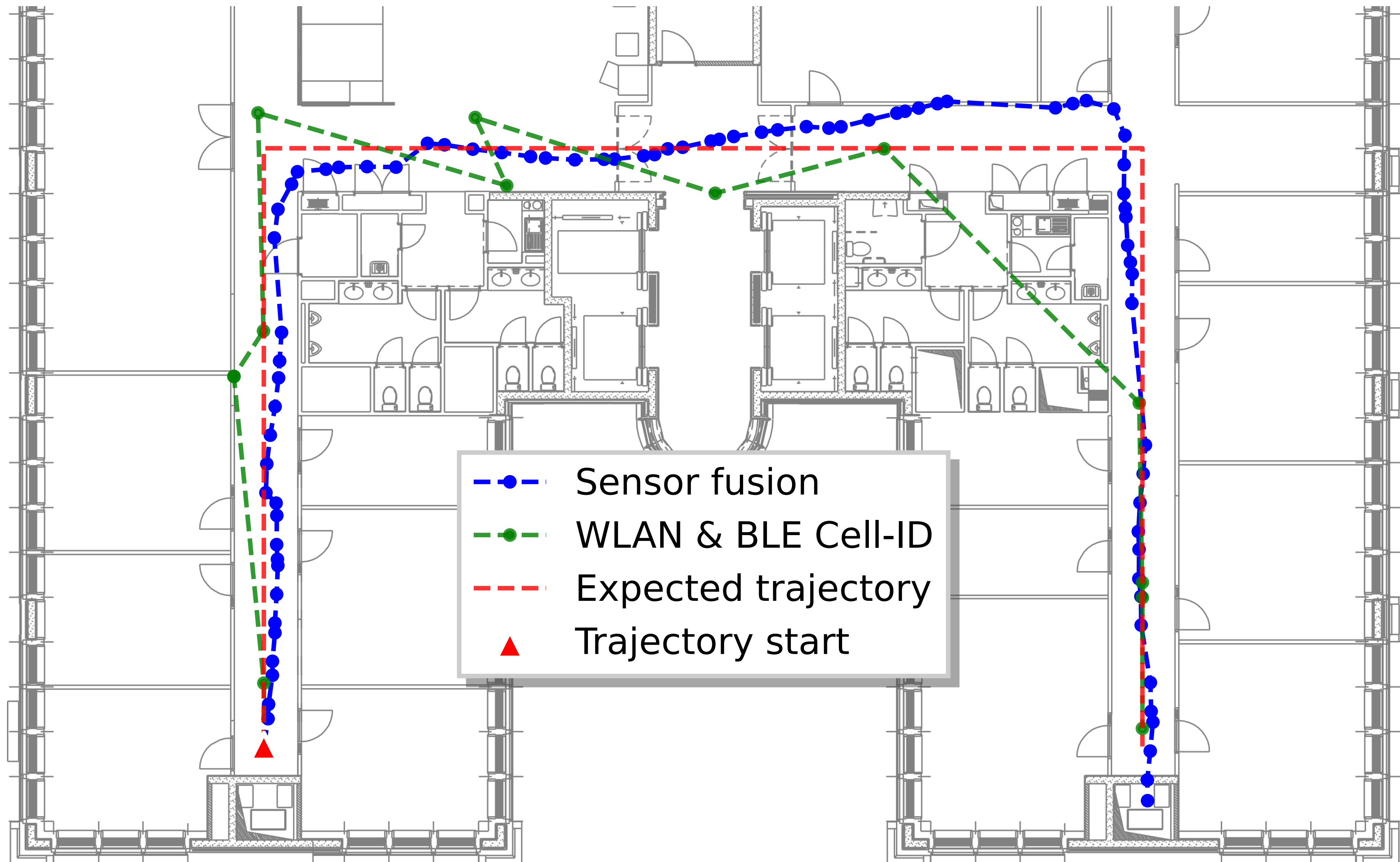
Validation Results

Static Positioning

| | WLAN fingerprinting | BLE fingerprinting | BLE multilateration | Fusion |
|----------------------|----------------------------|---------------------------|----------------------------|----------------|
| <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 % | 96.67 % |

Validation Results ...

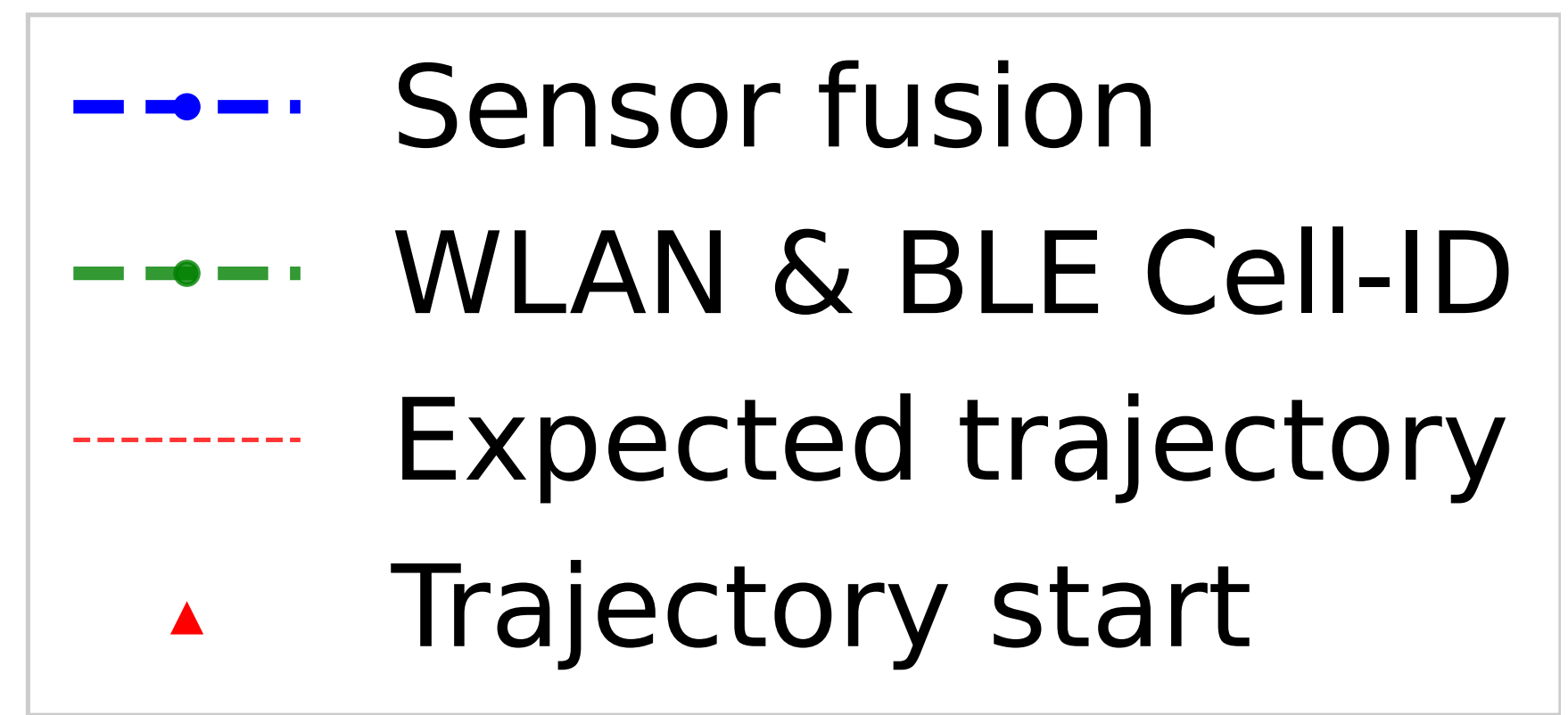
Trajectories



Validation Results ...

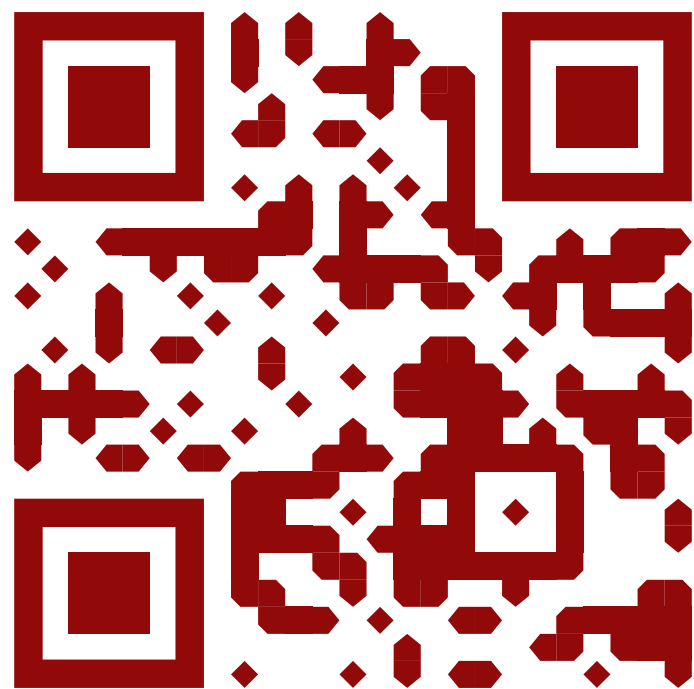
Trajectories

| | 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!