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EXCELENCIA SEVERO OCHOA

Enabling distributed, compute-intensive FaaS on the edge with COMPSs

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Outline

- Motivation
- Programming Model: COMPSs
- Decentralizing the COMPSs runtime
- Use Case: Cagliari Airport
- Conclusion

Motivation

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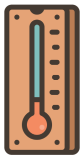
IoT/Edge Platforms

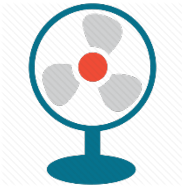
3 types of elements composing the system:

Events/Data Generators (sensors)

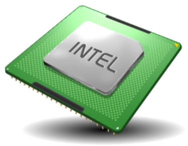
elements monitorizing certain condition and informing about it

- Continuosly generating information → Streams of data
- Eventually notifying a change → Events




Event-reactors/ Data Consumers (displays)

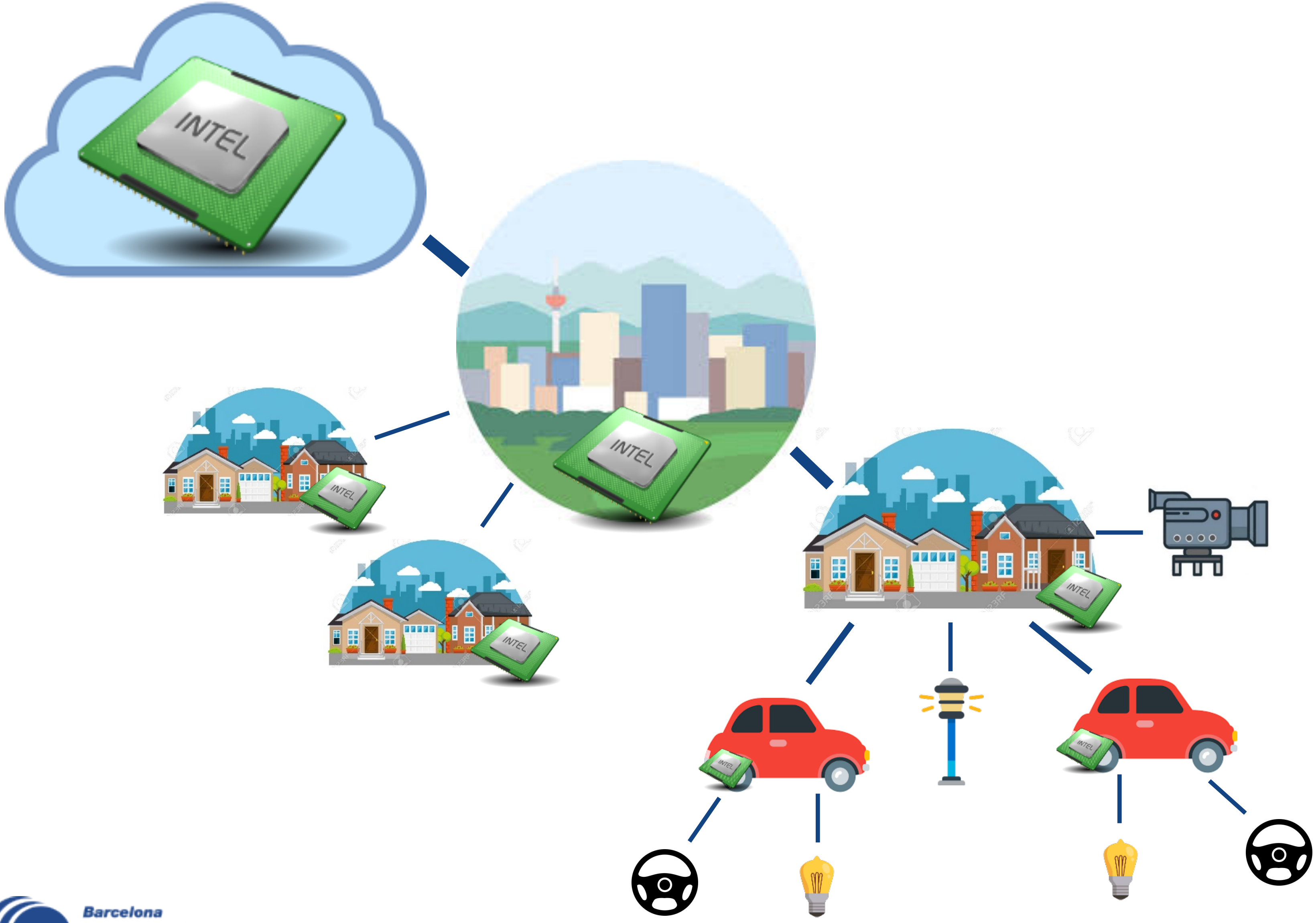
elements on which the platform realizes actions (changing its state)



Computing elements

elements within the infrastructure with ability to process and transform information

Cloud-Edge Continuum



Computation on IoT/Edge platforms

3 purposes for computation:

- Sense-process-actuate:

  A sensor detects something and triggers a computation to give a proper response to such event.

- Stream processing:

  A sensor continuously provides data that needs to be processed.

- Batch Jobs:

  Analyse big amounts of data collected by the sensors

Programming Model:
COMPSs

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BSC vision on programming models

Simple Parallel Programming Model

- What do I need to compute?
- What data do I need to use?
- Provide Hints

Let the difficult parts to the runtime

Act on behalf of the user

Enable Monitoring and Analysis

Generate data to evaluate how application performs

Applications

Programming Model:
High-level, clean, abstract

Power to the runtime

Middleware API

Program logic independent of computing platform

General purpose
Task based
Single address space

Intelligent runtime, parallelization, distribution, interoperability

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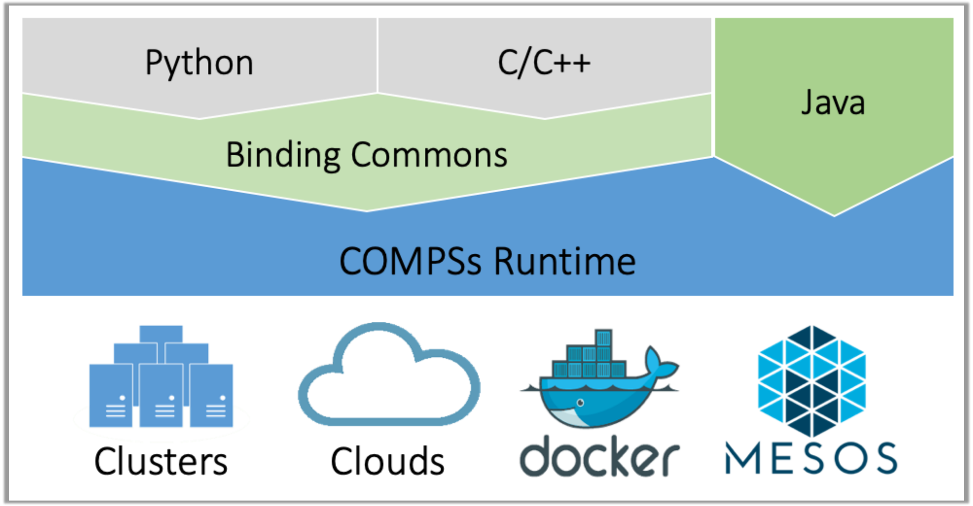
COMP Superscalar (COMPSs)

- General purpose programming language + annotations/hints
- Sequential programming with no API calls
- Agnostic of the computing infrastructure
- Task-based: task is the unit of work

- Builds a task graph at runtime that express potential concurrency
  - Implicit workflow
- Exploitation of parallelism
  - … and of distant parallelism



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COMPSs Example - Java

Matmul.java

```java
public class Matmul {
    public static void main (String[] args) {
        int[][] A;
        int[][] B;
        ...
        int[][] C = multiply(A, B);
        ...
    }
}
```

Simple.java

```java
public class Simple {
    public static int[][] multiply (
        int[][] A, int[][] B) {
        // Matrix multiplication code
        // C = AB
        ...
        return C;
    }
}
```

CEI.java

```java
public interface CEI {
    @Method(declaringClass = "Simple")
    public int[][] multiply (
        @Parameter(direction = IN) int[][] A,
        @Parameter(direction = IN) int[][] B
    );
}
```

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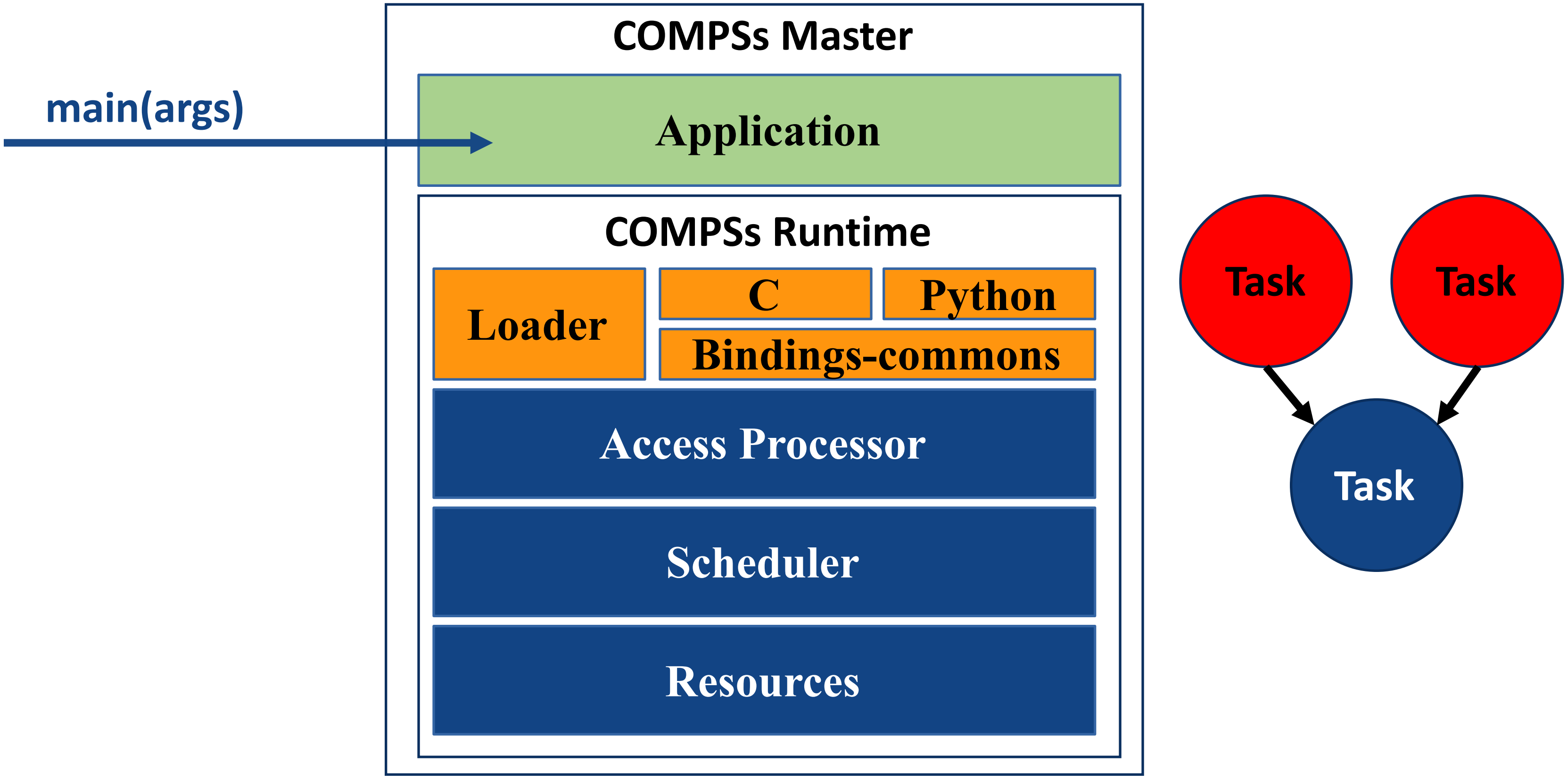
COMPSs runtime



Decentralizing the COMPSs runtime

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Environment differences

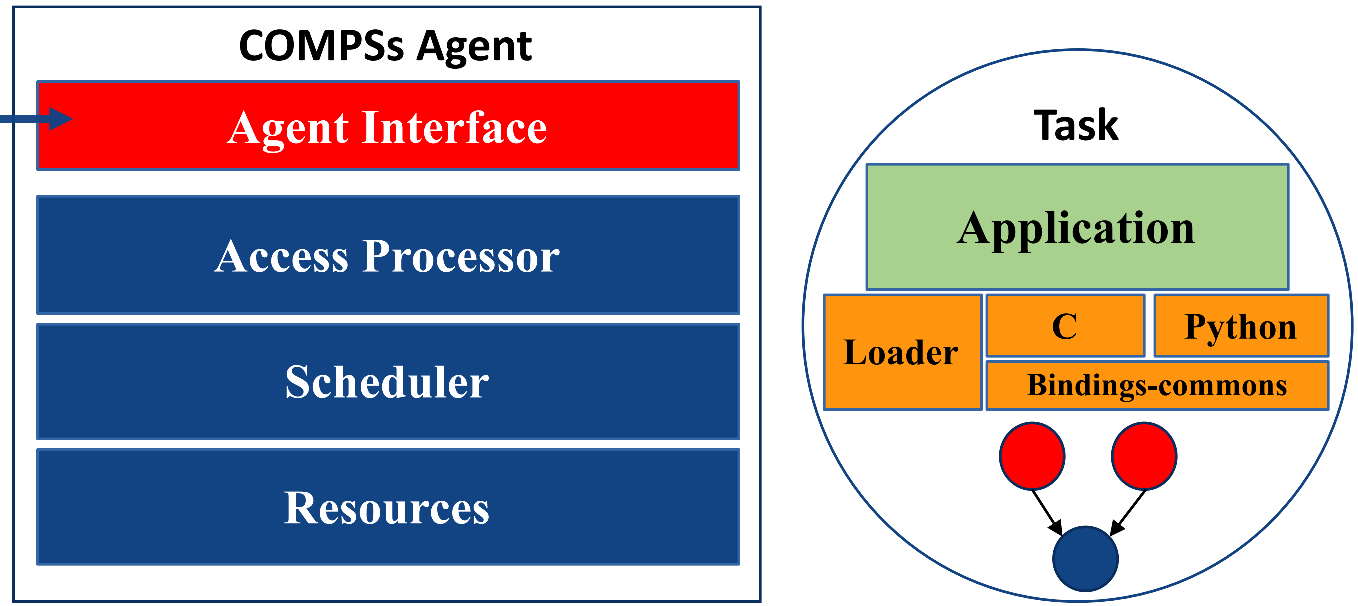
COMPSs' usual flow:

- 1 application
- Infrastructure is stable
- 1 node (MASTER):
  - Spawns tasks
  - Orchestrates the execution over the available resources (WORKERs)

COMPSs for Edge Computing

- N applications at the same time
- Infrastructure is dynamic
- Any agent may generate new tasks
- Execution orchestration is a shared responsibility

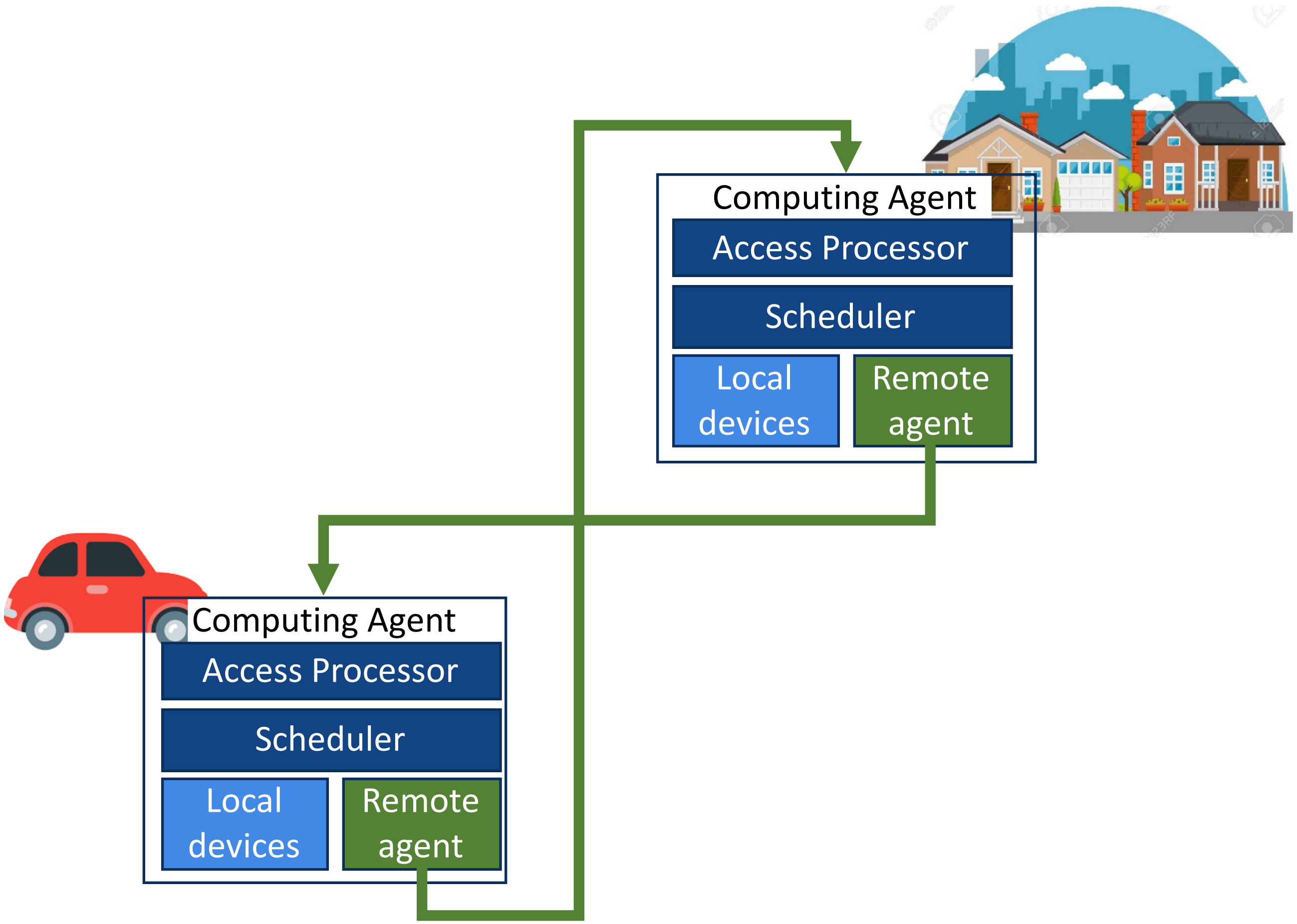
COMPSs agent



Start App Request

- Class
- Method
- Params
- CEI

Agents interaction



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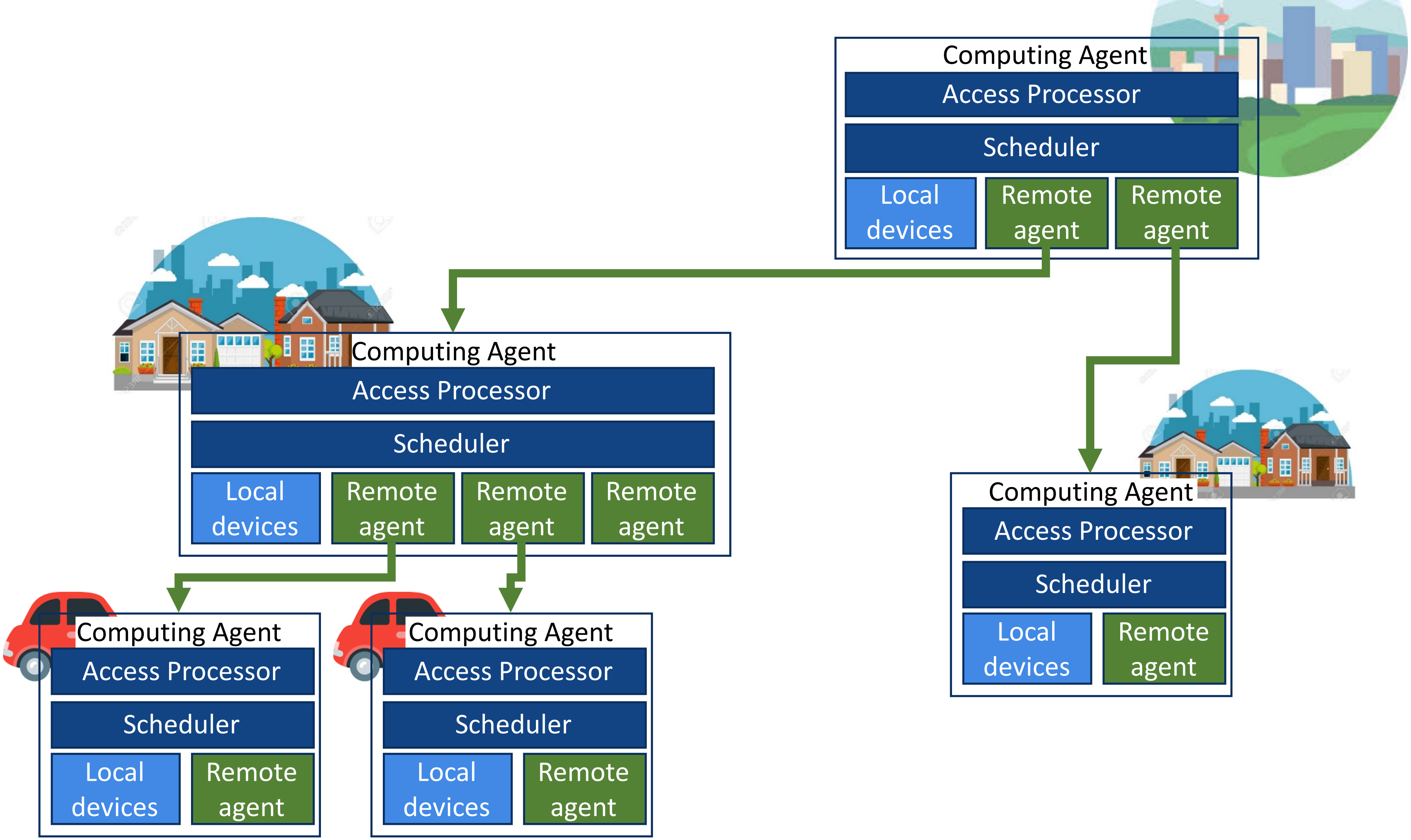
Computing agents hierarchy



Use Case:
Cagliari (IT) airport

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Smart Fog-Hub Service

In 2017 more than 4 billion passengers concentrated in airports

- Features
  - track the presence of people and objects in the field
  - proximity marketing services
  - suggestions on best use of airport services
  - Recommender system based on consumers' behavior

- Objectives
  - Reduce latency and response times
  - Capability to distribute computing in case of overloading
  - Pleasant experience for travelers while in the airport field

Customer Experience

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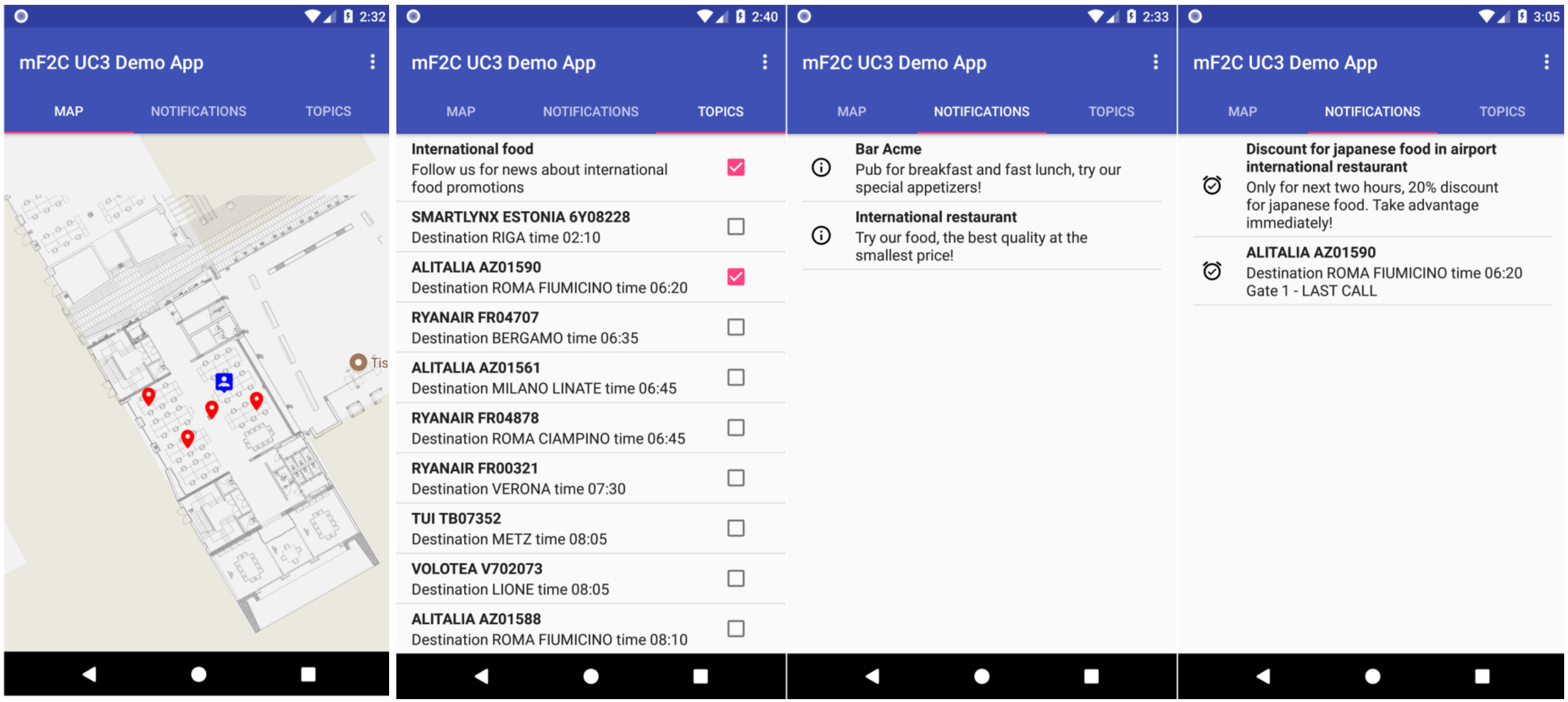
Android App



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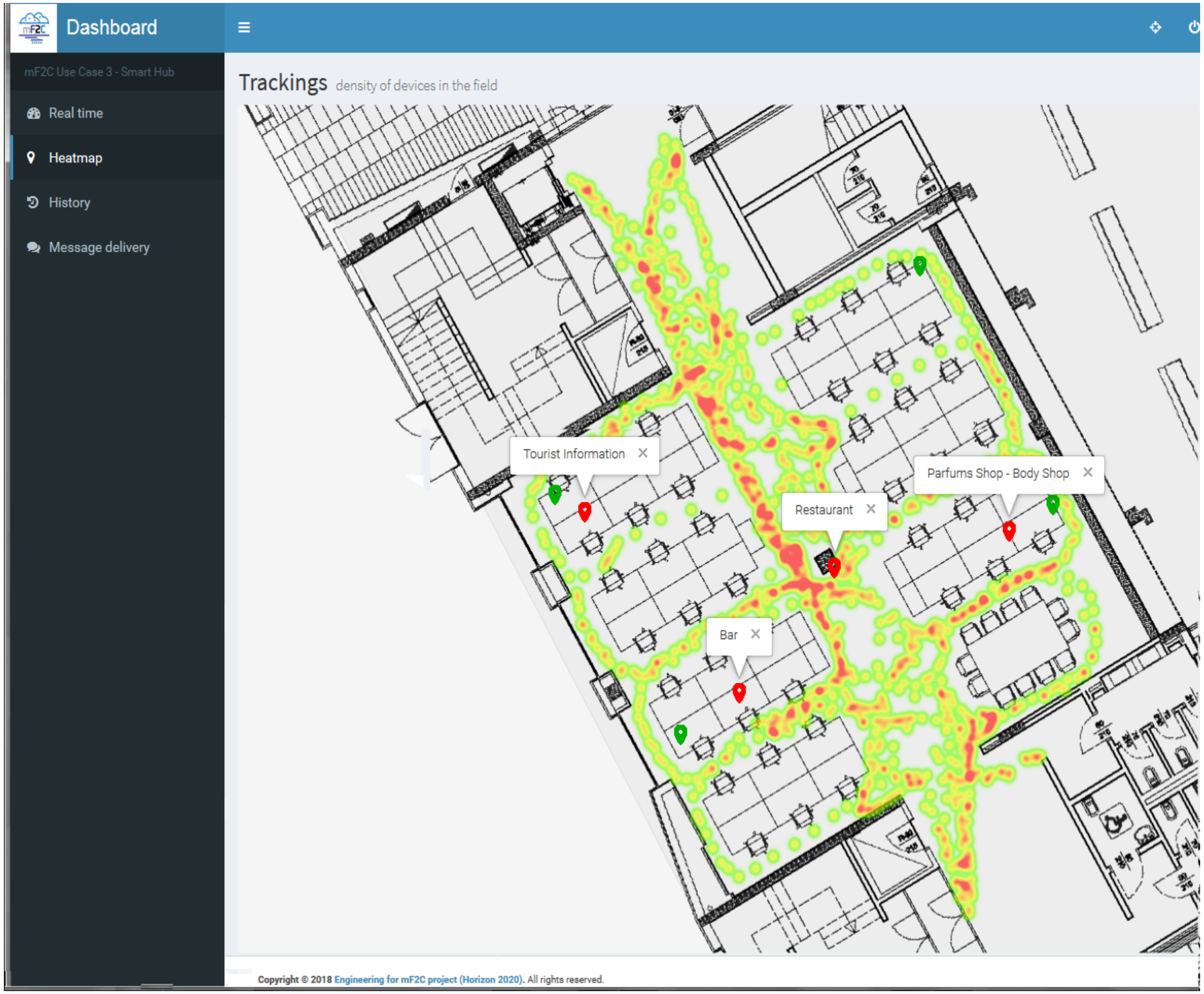
Dashboard



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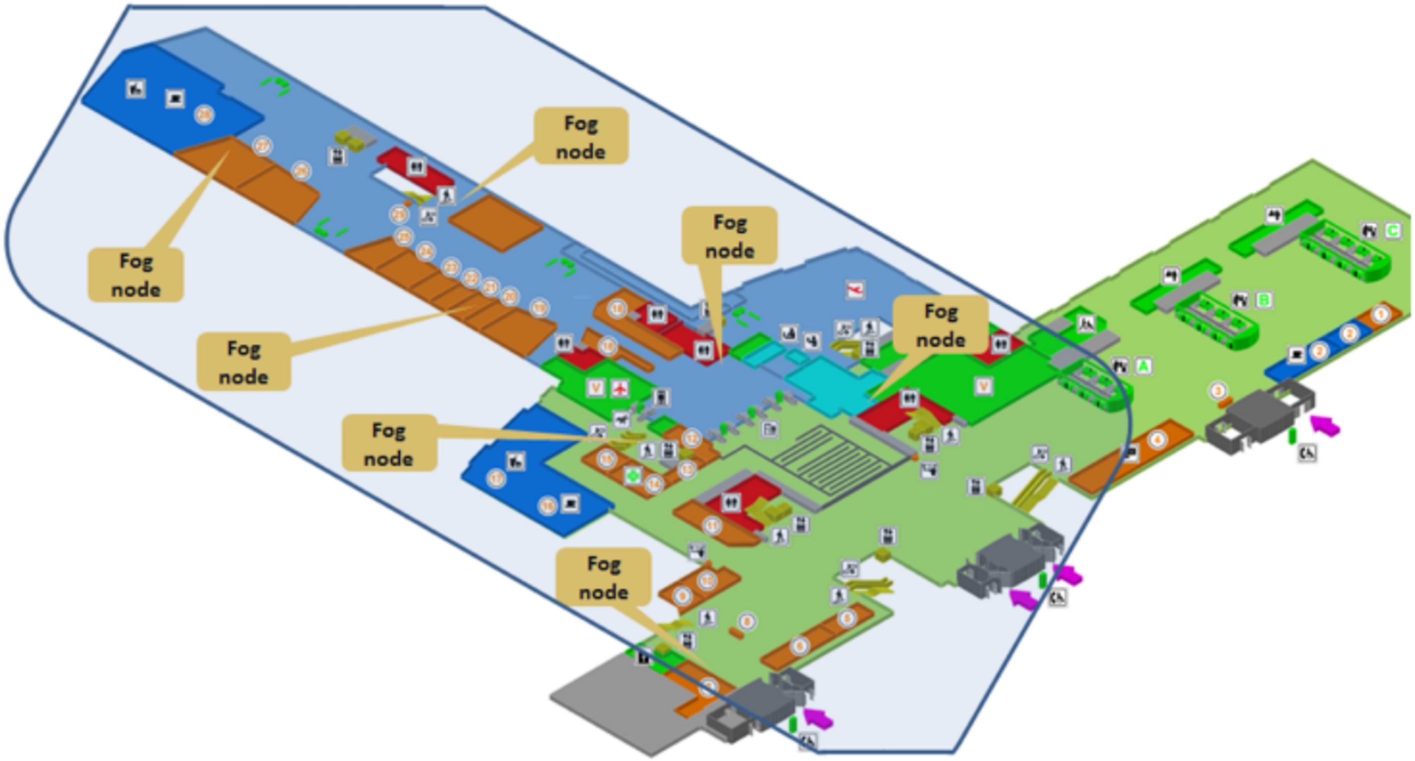
Use Case deployment



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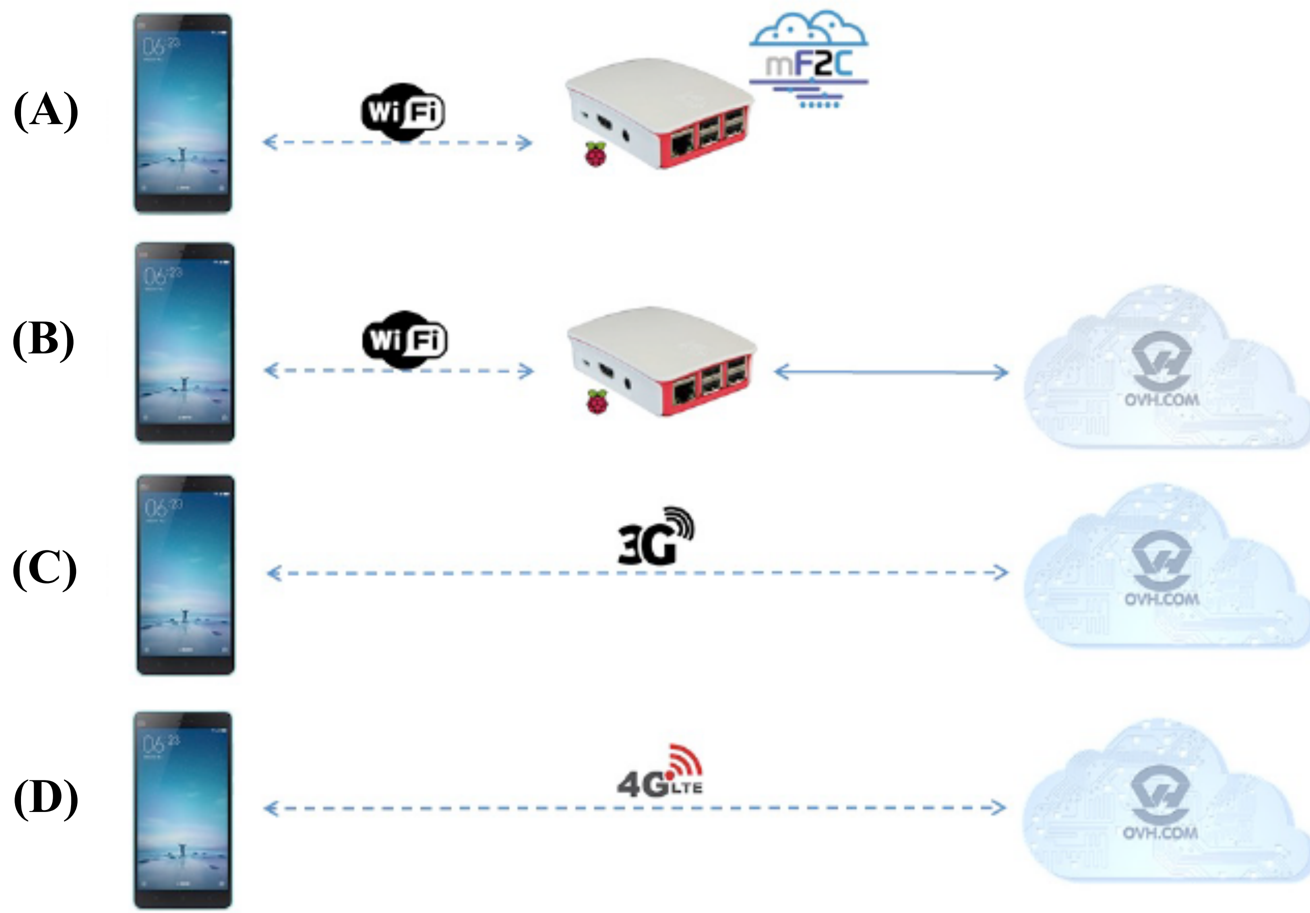
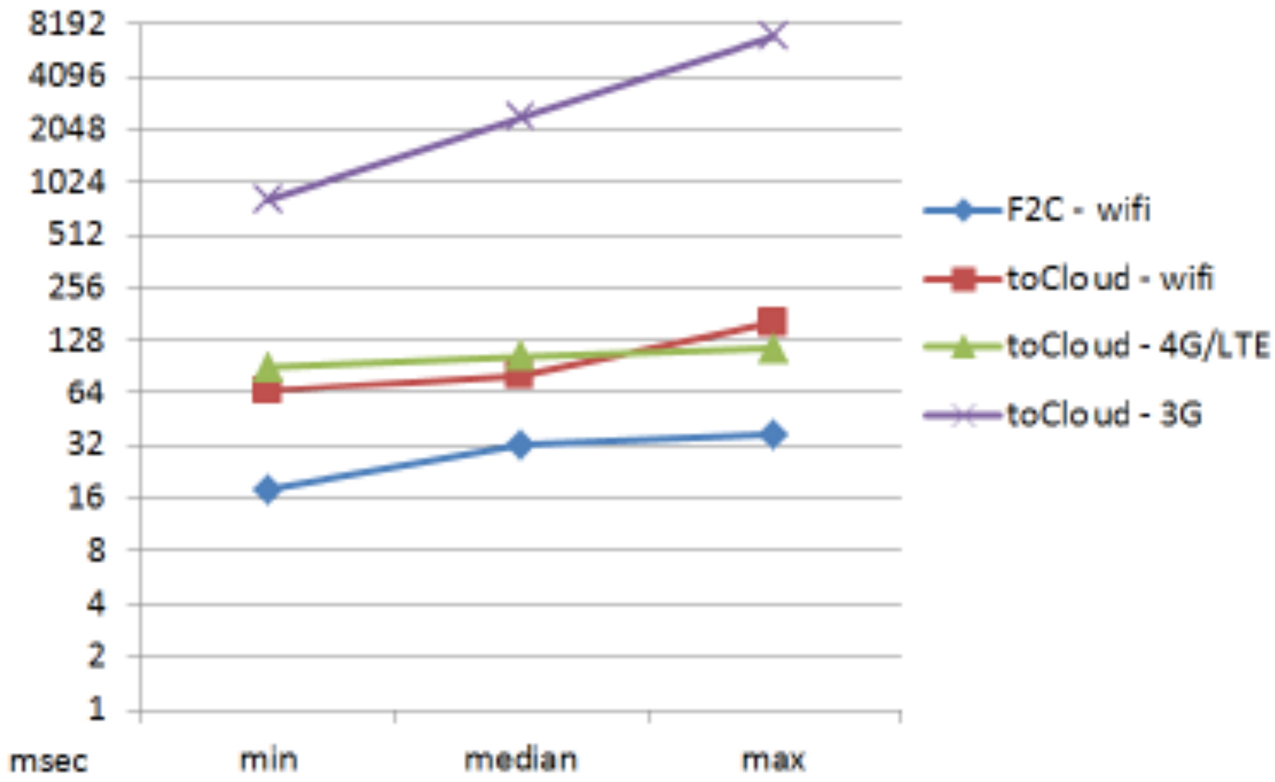
Benchmarking scenarios



Test Results



Conclusions

Summary

- IoT/Edge infrastructures are composed of **autonomous** nodes with network and computing capabilities

- COMPSs
  - Developers code being unaware of the parallelism and infrastructure-related concerns
  - Detects tasks and the parallelism inherent in the application
  - Orchestrates the execution of these tasks on the available infrastructure
  - Supports computation on the three scenarios (batch, stream and sense-process-actuate)

- COMPSs agents
  - Allows devices to remain autonomous and compute in an isolated manner
  - By interacting with other agents, and agent has access to the available computing power

- The airport use case shows the viability and the benefits of the presented solution

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THANK YOU!

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COMPSs

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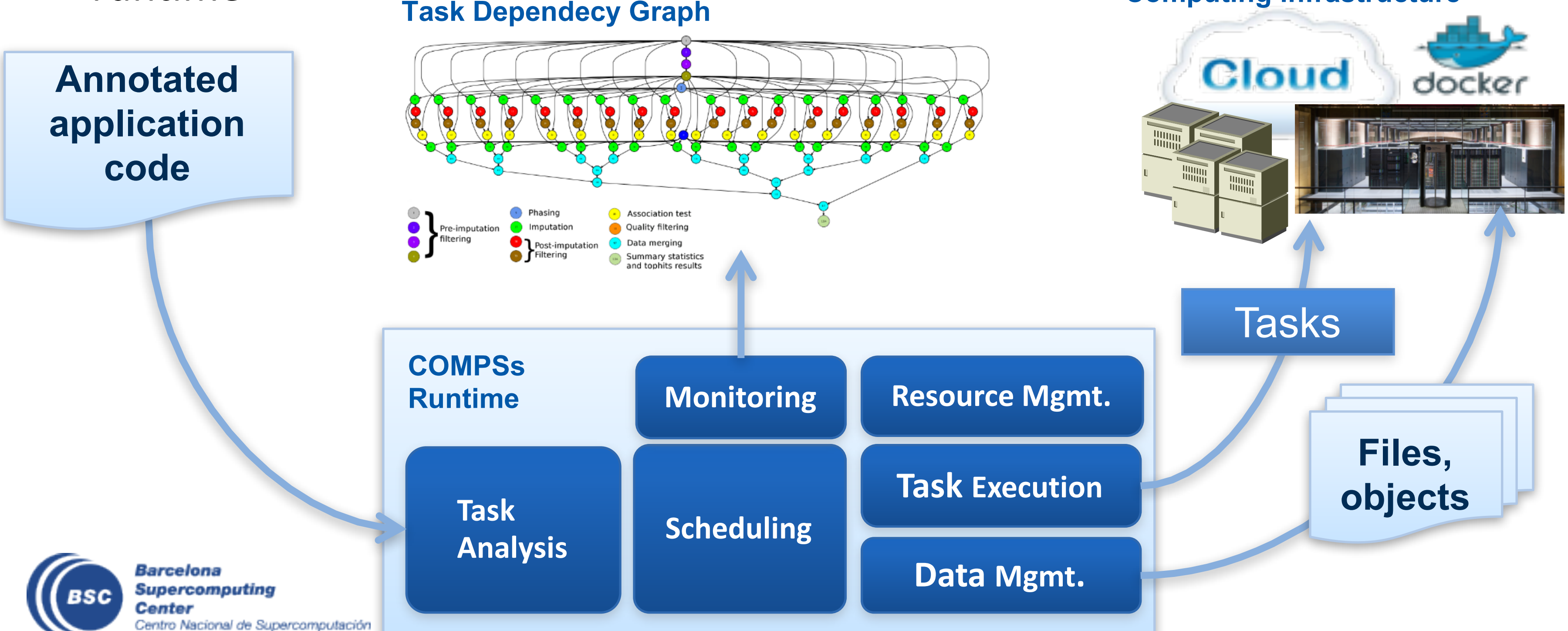
COMPSs Runtime

- COMPSs applications executed in distributed mode following the master-worker paradigm
- Sequential execution starts in master node
- Tasks are offloaded to worker nodes
- All data scheduling decisions and data transfers are performed by the runtime



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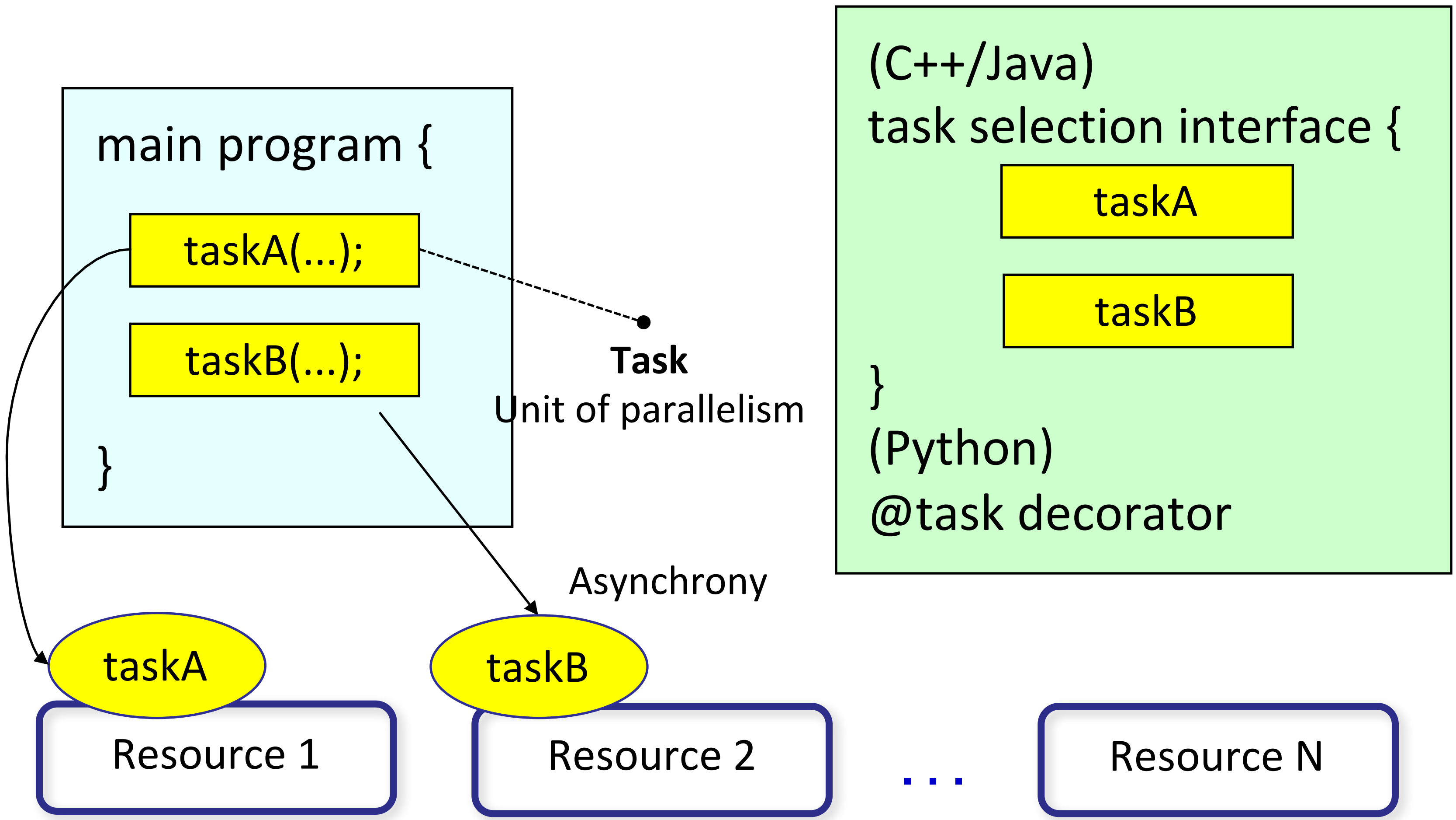
Programming Steps

1. Identify tasks

2. Select tasks



Programming Model Example

```
for (i = 0; i < 3; i++) {
        increment(counter1);
        increment(counter2);
        increment(counter3);
}
printCounters(counter1, counter2, counter3);
```

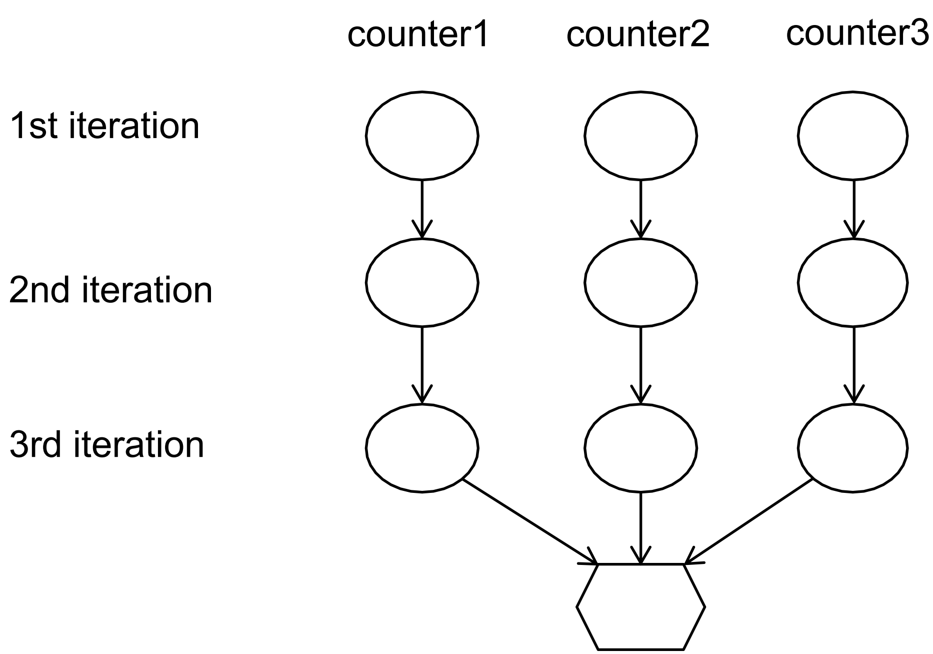
```
public interface SimpleItf {

    @Method(declaringClass = “SimpleImpl")
    void increment(
         @Parameter(type = FILE, direction = INOUT)
         String counterFile
    );

}
```

Implementation

Parameter metadata



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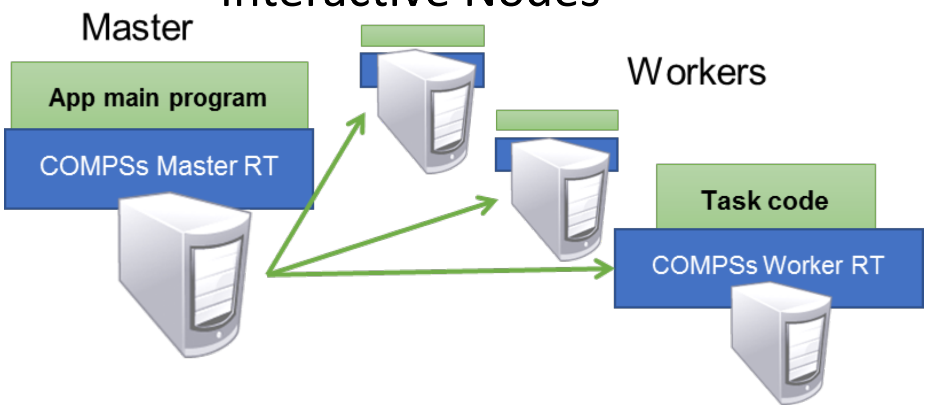
Advanced Features

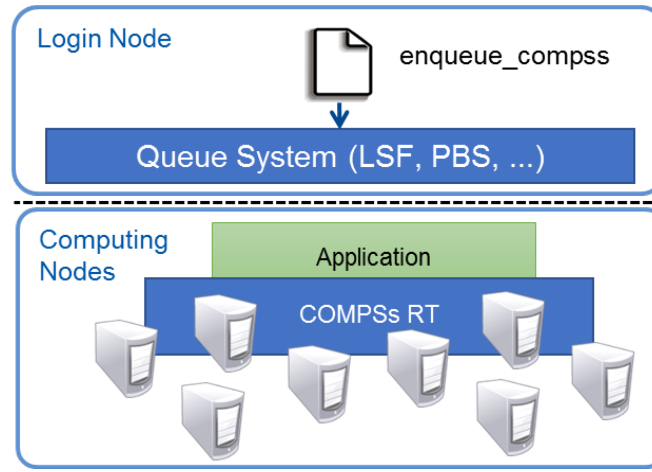
- Constraints to support heterogeneous tasks
  - @Constraints(…)
- Versioning
  - @Implements(…)
- Combination of binary execution
  - @Binary(…)
- Integration with Programming Models
  - @MPI(..) @Decaf(…)
  - COMPSs + OmpSs
- Nested
  - @COMPSs(…)

Execution Environments

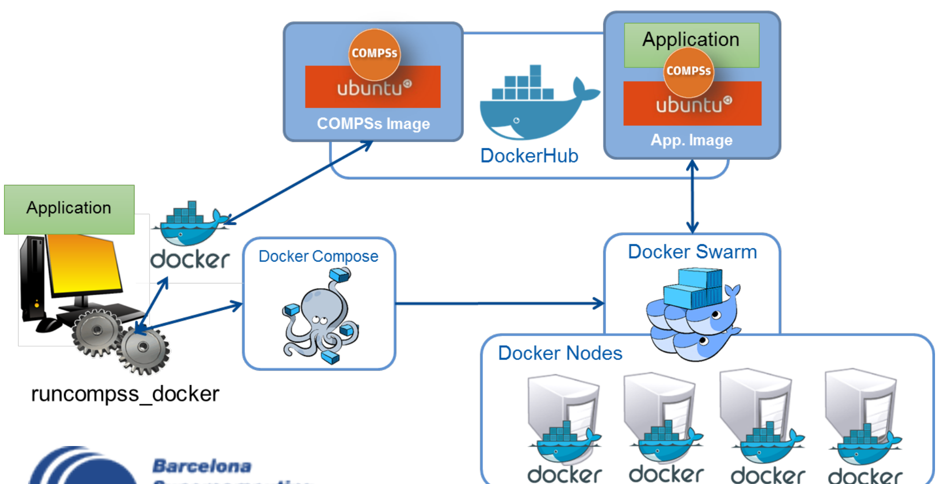
- Interactive Nodes



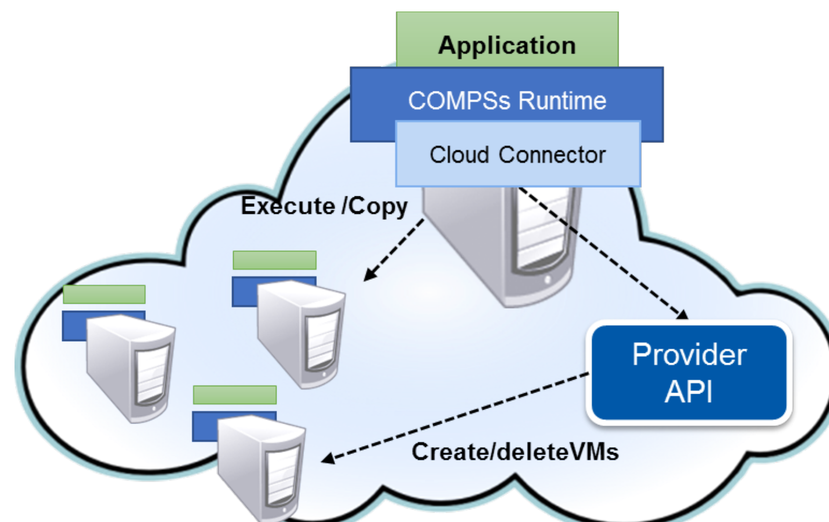
- Clusters



- Containers



- Clouds



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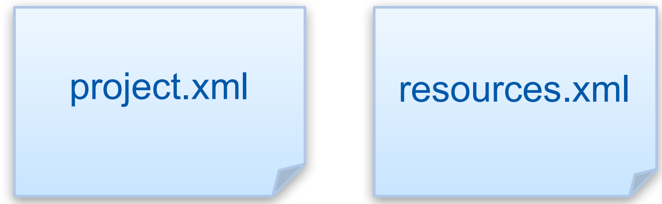
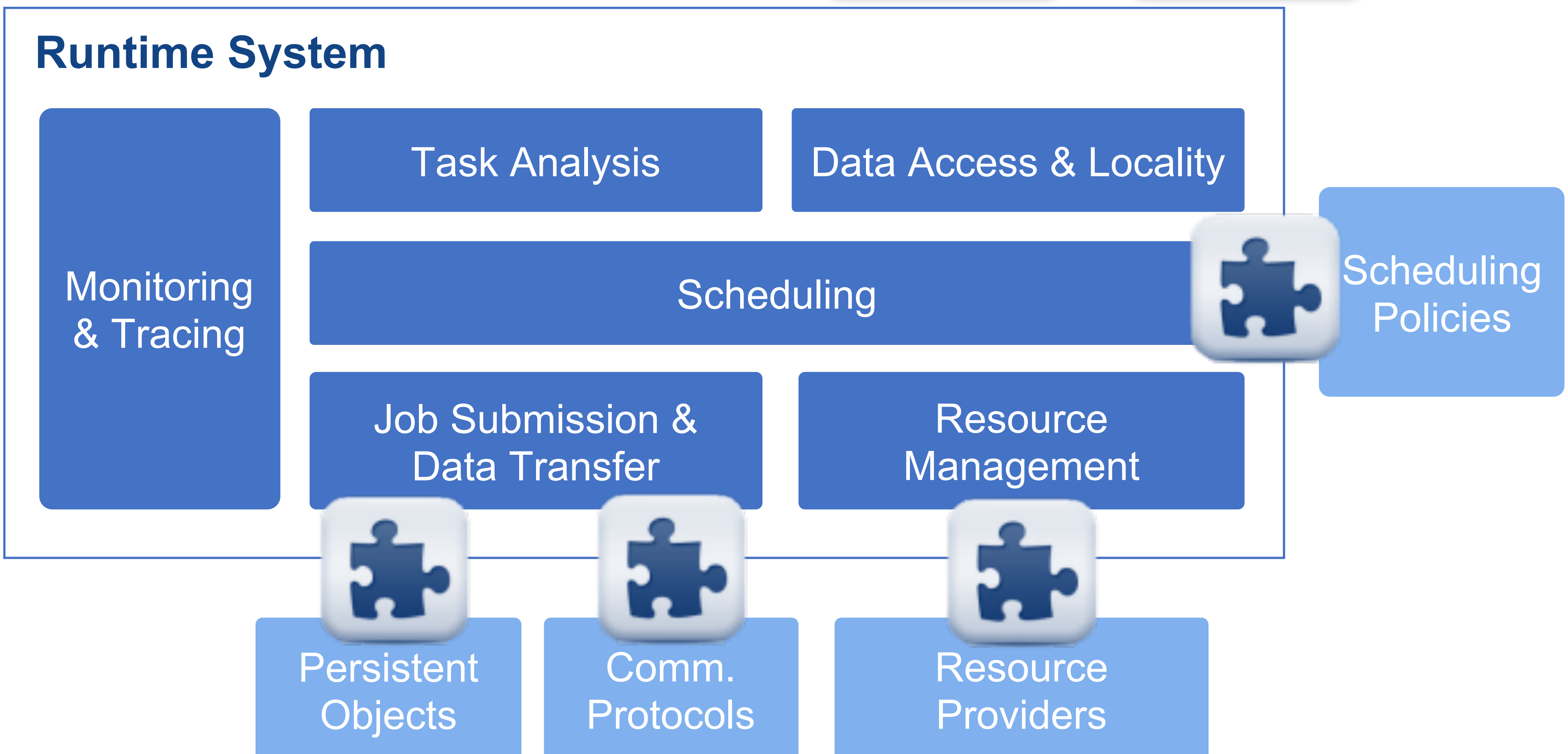
Runtime Extensions

Execution commands:

- runcompss (interactive & cloud)
- enqueue_compss (clusters)
- Runcompss_docker (socker clusters)





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mF2C

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Background – Open Fog

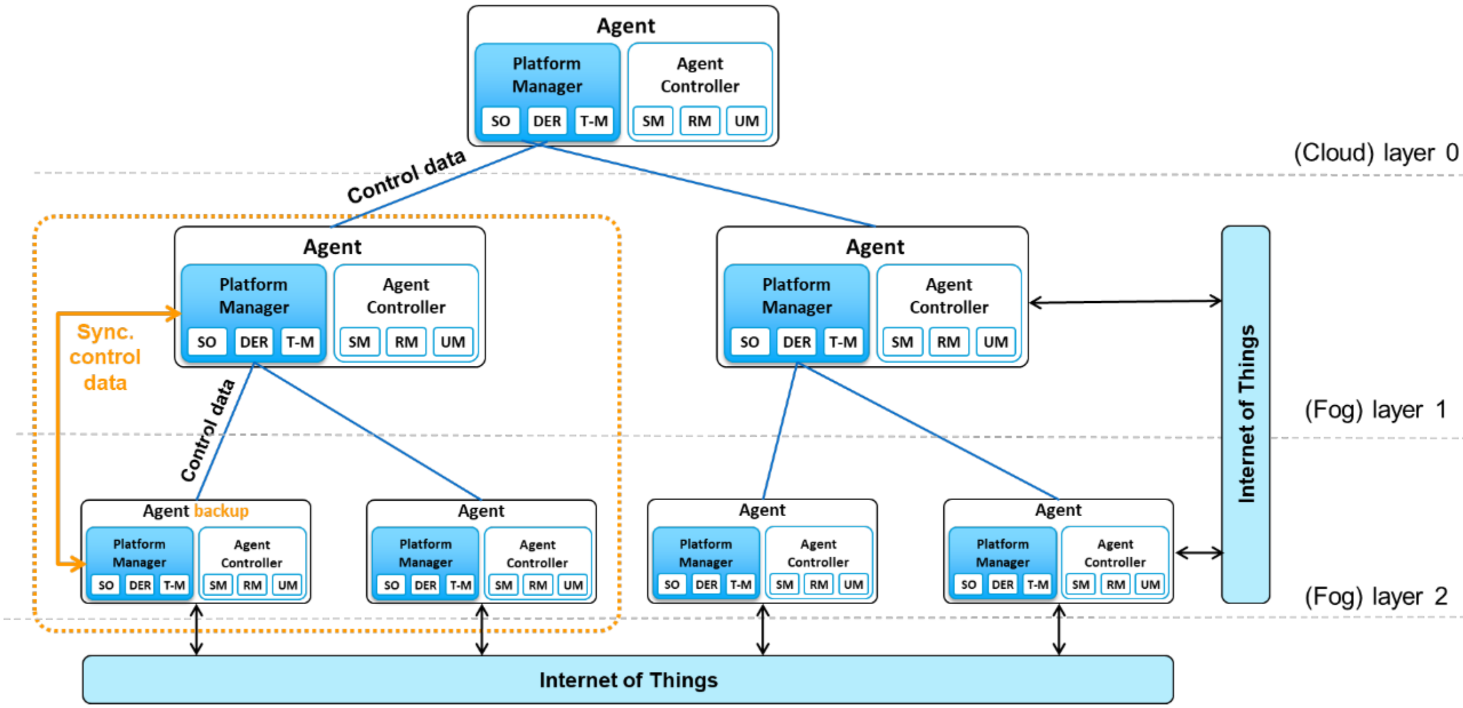
The architecture is an extension of the traditional cloud computing model

- Processes are moved from the cloud to the edge of the network, in Fog nodes
- Deployments can reside on multiple layers of a network topology,
- Deployments retain all the benefits of cloud computing, such as containerization, virtualization, orchestration, resource-efficient management

Fog Nodes peculiarities

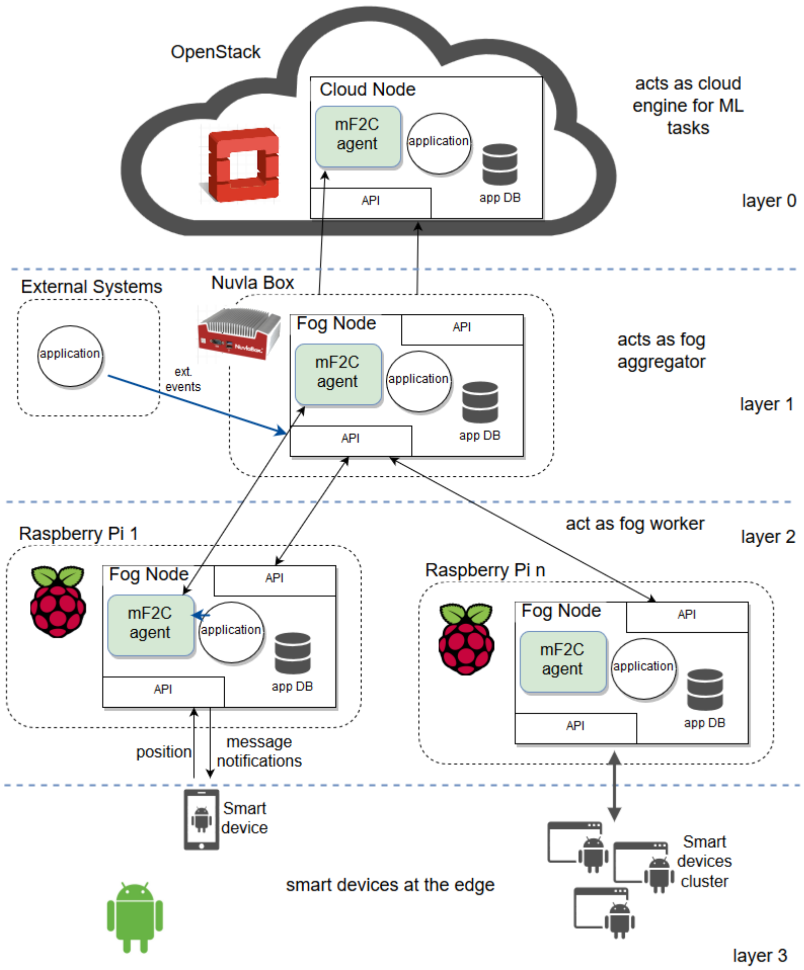
- Autonomous processing
- Local storage and IP communications
- Hosted in open (even hostile) fields
- Capable of acting in mobility

mF2C architecture



Use case architecture

- **Cloud** – based on a OpenStack instance, wired connected with the fog layers, providing scalable computing power for Machine Learning algorithms
- **Edge Fog** – with a fog aggregator based on Nuvlabox with 8GB, providing real-time computing and storage resources and 6 rPI with 1GB hub providing session management and fast response to the edge devices
- **Edge IoT** – Android smartphones connected to the edge nodes through wifi, and using an Android app to interact with the system



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Testbed

- Proximity processing
  - Client – call a request for a list of nearby POIs using geographic position
  - Server – calculates the POIs in proximity and returns a JSON array

- Client

  Smartphone XIAOMI with Android 5.0.2, running app calling a Rest HTTP API

- Server
  - A VM runs a dockerized image with proximity calculation

  1. rPI3 with 1GB RAM
  2. VM running on a public cloud (4-core processor and 4GB RAM)

Interaction with IoT devices

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Interaction with sensors

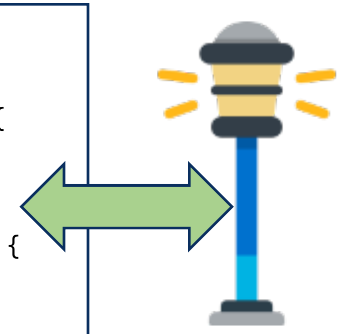
- Every sensor is attached to one device with computing capabilities
  - Events:
    the device trigger a function execution on any COMPSs agent
  - Streams:
    the device publishes the stream of data directly

Interaction with displays/devices

- Through a Controller class
  - Handles all the communication with the device
  - Offers a simple API to interact with the device
- Each instance of this controller class interacts with one device
- Device can be controlled by any agent if the object is transferred

```
public void task(Streetlamp sl) {

   …
   sl.on();
   …

}
```

```
class Streetlamp {

   public void on() {
      …
   }

   public void off() {
      …
   }
}
```



Interaction with displays/devices

- Using the storage framework
  - Controller class is a Persistent Object
  - One Controller instance is made persistent for each device using a universal ID
  - Any agent able can interact with any registered resource by using an ID

Device Manager

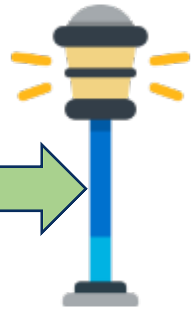
```
Streetlamp sl = new Streetlamp();
sl.makePersistent("light21758");
```

COMPSs task

```
public void task() {

   …
   Streetlamp sl;
   sl = Storage.getByAlias("light21758");
   sl.on();
   …

}
```

Storage Framework

```
class Streetlamp
  extends StorageObject {

   public void on() {
     …
   }

   public void off() {
     …
   }
}
```



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