SHORT INTRODUCTION TO PerLa MIDDLEWARE

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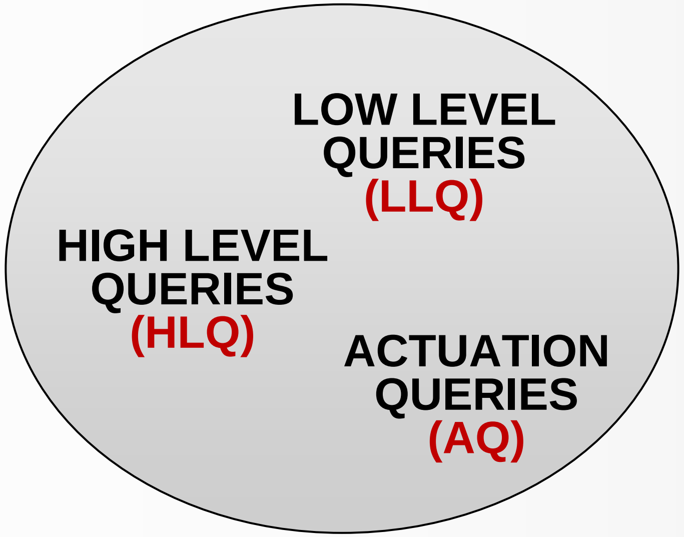


HIGH LEVEL QUERIES (HLQ)

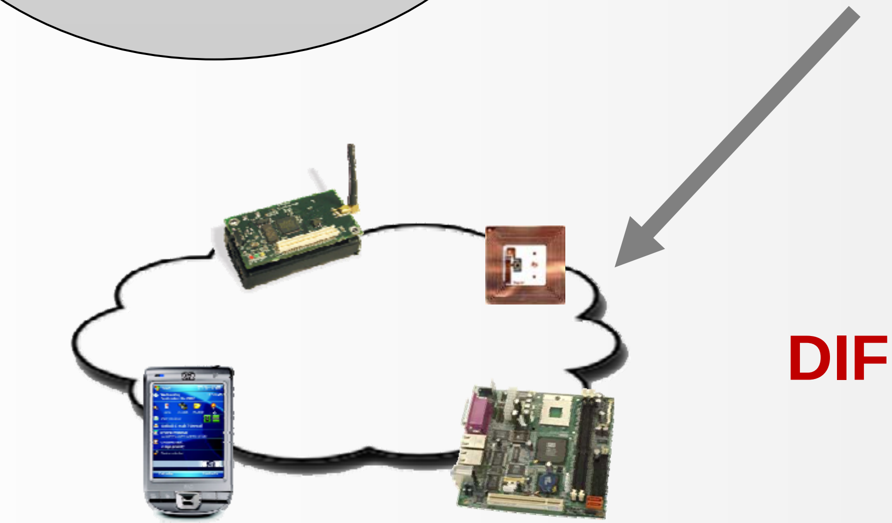
LOW LEVEL QUERIES (LLQ)

ACTUATION QUERIES (AQ)

FULLY DECLARATIVE SQL-LIKE HIGH LEVEL LANGUAGE

to query

PERVASIVE SYSTEMS



hiding the complexity of handling

DIFFERENT TECHNOLOGIES

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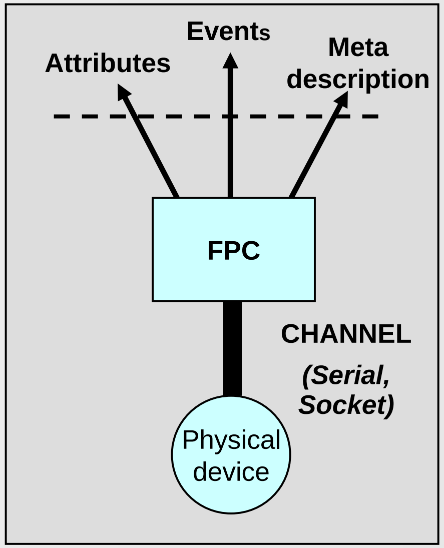
FPC ABSTRACTION

- The **LANGUAGE SEMANTICS** is defined on the concept of **Functionality Proxy Component (FPC)**
- Each device is abstracted as an FPC:
  - **ATTRIBUTES** (*id, temperature, pressure, power level, last sensed RFID reader, …*)
  - **EVENTS** (*last sensed RFID reader changed, …*)
  - **META-DESCRIPTION** (*name, data type, … for each attribute*)



THE LANGUGE: OVERVIEW

- LANGUAGE FEATURES
  - Data representation (FPC abstraction)
  - Physical device management
  - **FUNCTIONAL** characteristics
    - Raw data manipulation
    - Provide query results
    - Set sampling parameters
  - **NON-FUNCTIONAL** characteristics
    - Constraints on the functionality
    - QOS (mainly power management)
    - Determine the participation of a node to a query

LOW LEVEL QUERIES

- Define the behaviour of a single or of a group of devices abstracted by an FPC
  - Precise definition of **SAMPLING** operations
    - read attributes from a device
    - insert values into a temporary buffer (local buffer)
  - Perform simple **SQL OPERATIONS** (filtering, grouping, …)
    - on data in the local buffer
  - Insert records in the final data structure

QUERY EXAMPLE (1)

```
CREATE SNAPSHOT TrucksPositions (linkedBaseStationID ID) WITH
DURATION 1 h AS LOW:
    SELECT linkedBaseStationID
    SAMPLING
        EVERY 1 h
        WHERE is_in_CriticalZone(locationX, locationY)
     EXECUTE IF deviceType = "GPS"
```

```
CREATE OUTPUT STREAM OutOfTemperatureRangePallets (palletID ID) AS
LOW:
    EVERY 10 m
    SELECT ID
    SAMPLING
        EVERY 10 m
        WHERE temp > [threshold]
    PILOT JOIN TrucksPositions
        ON baseStationID = TrucksPositions.linkedBaseStationID
```

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HIGH LEVEL QUERIES

- Perform complex SQL queries on data windows extracted from one or more input streams
  - **TIME DRIVEN**
  - **EVENT DRIVEN**
- Every record is time-stamped
- Similar to queries used in streaming DataBases

QUERY EXAMPLE (2)

```
CREATE OUTPUT STREAM LowPoweredDevices (sensorID ID) AS LOW:
    EVERY ONE
    SELECT ID
    SAMPLING EVERY 24 h
        WHERE powerLevel < 0.15
    EXECUTE IF deviceType = "WirelessNode"
```

```
CREATE OUTPUT STREAM NumberOfLowPoweredDevices (counter INTEGER) AS
HIGH:
    EVERY 24 h
    SELECT COUNT(*)
    FROM LowPoweredDevices(24 h)
```

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PerLa MIDDLEWARE OVERVIEW

PerLa MIDDLEWARE GOALS (1)

- The main goals of the middleware:

  1. provide an **ABSTRACTION** for all the devices connected to the system

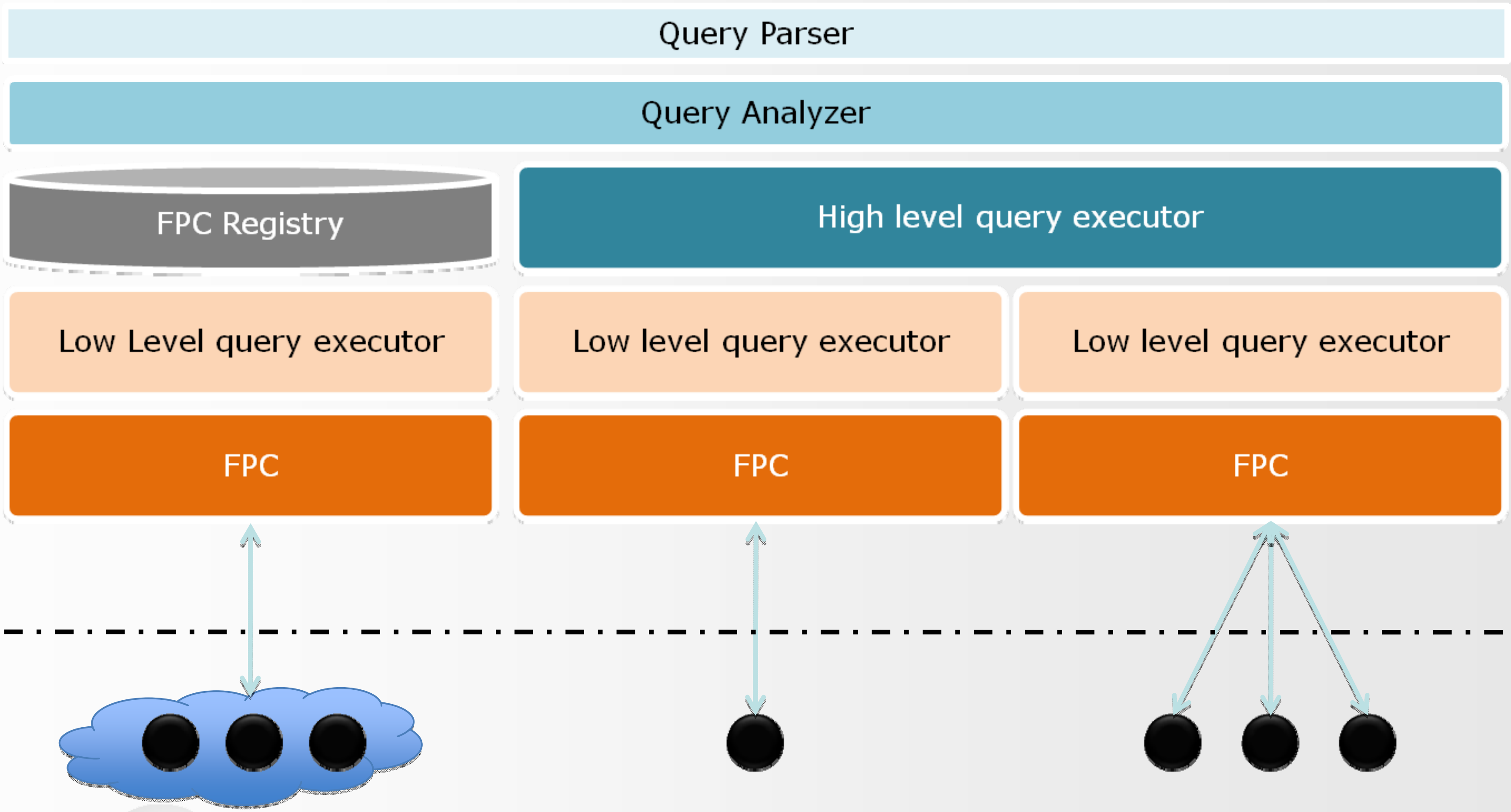
  2. support the **EXECUTION OF PERLA QUERIES**

  3. allow devices to automatically start query execution immediately after power-on (**PLUG & PLAY**)

  4. ease the **DEFINITION** and the **ADDITION** of new devices and technologies – **CODE-FREE** device introduction

PerLa MIDDLEWARE GOALS (2)

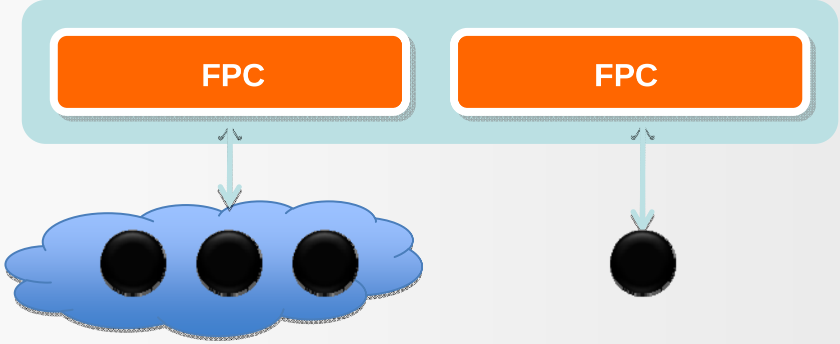
- Comprises all the software components needed to achieve the aforementioned goals



PerLa MIDDLEWARE GOALS (3)

1. provide an **ABSTRACTION** for all the devices connected to the system

- The **Functionality Proxy Component (FPC)** is used to provide this abstraction
- A single FPC works as a proxy for **ONE OR MORE** physical devices

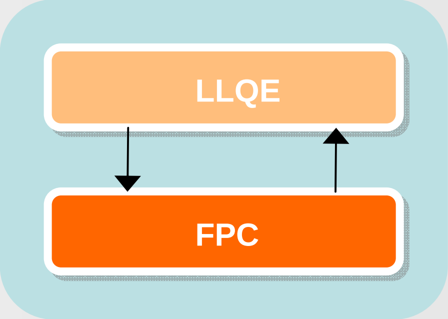


- By means of the FPC, **MANY HETEROGENEOUS DEVICES** can be accessed through the **SAME INTERFACE**

MIDDLEWARE GOALS (4)

2. support the **EXECUTION OF PERLA QUERIES**

- The **LLQE (Low Level Queries Executor)** is a Java component placed on top of the *FPC*.
- Retrieves data from the an *FPC* and to computes **QUERY RESULTS**.

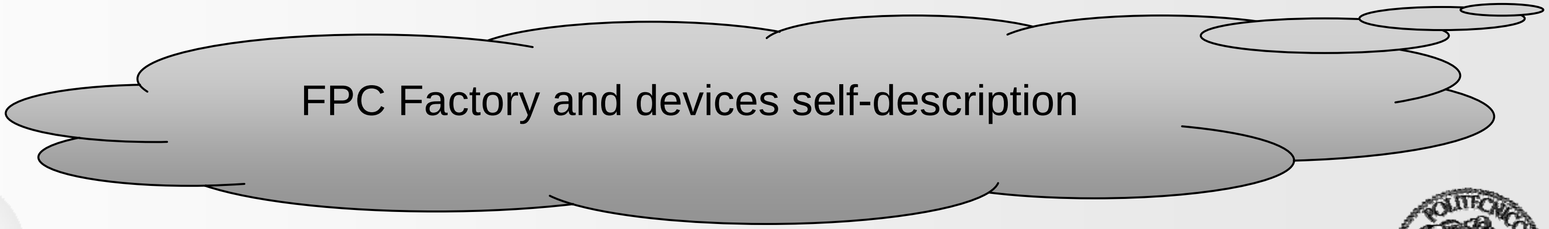


D. Viganò – Low Level Query Executor

MIDDLEWARE GOALS (5)

3. allow devices to automatically start query execution immediately after power-on (**PLUG & PLAY**)

- A **PLUG & PLAY** behavior at device start-up requires that:
  - The device **ESTABLISHES A CONNECTION** with the PerLa middleware
  - An *FPC* object, tailored to specifically work with the device, is **DYNAMICALLY GENERATED** and instantiated
  - The generated *FPC* is **REGISTERED** in the *FPC* Registry, enabling the device to be used at query-time


FPC Factory and devices self-description

MIDDLEWARE GOALS (6)

4. ease the **DEFINITION** and the **ADDITION** of new devices and technologies – **CODE-FREE** device introduction

- A device **SELF-DESCRIPTION** file is introduced to allow a complete automatic generation of the Java *FPC*

- A low level **C LIBRARY** is provided in order to reduce the amount of *C* code needed to manage a node based on a new technology
  - **HLD**: middleware-provided C code (FPC-device communication, timer multiplexing, sampling scheduling, …)
  - **LLD**: user-written *C* code (low level sampling routines, communication channel initialization, …)

FPC Factory and devices self-description

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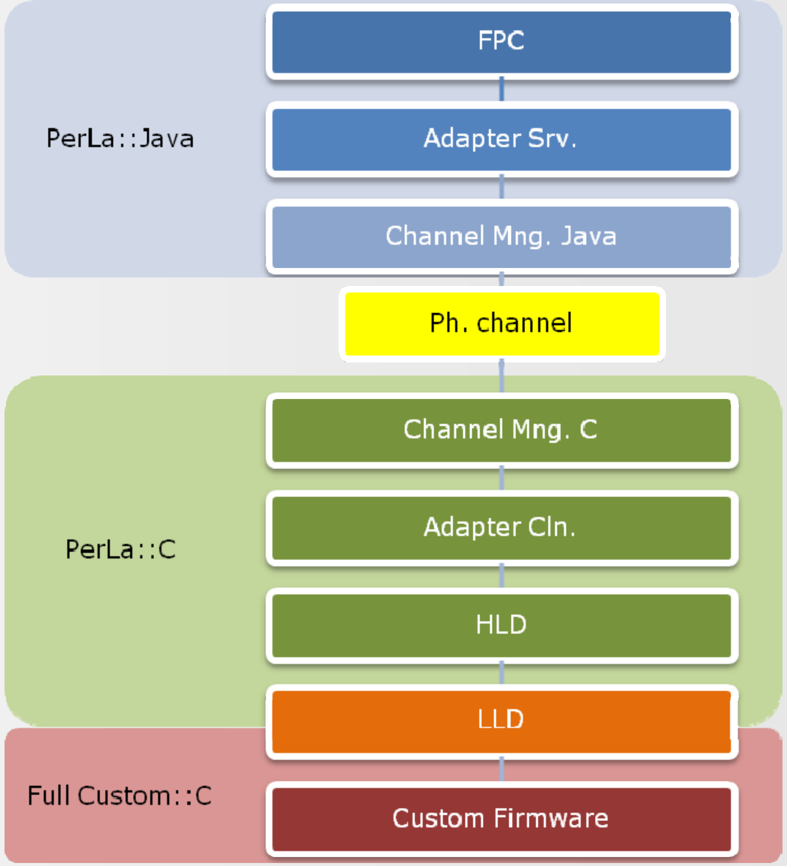
The FPC and the Device

FPC Features (1)

- The **FPC** is a **HIGH-LEVEL ABSTRACTION** of the physical devices which provides:
  - Methods to enumerate the attributes and events of a node
  - An interface to set or retrieve attributes on the device
  - Notifications to the system in response to events sensed by the devices

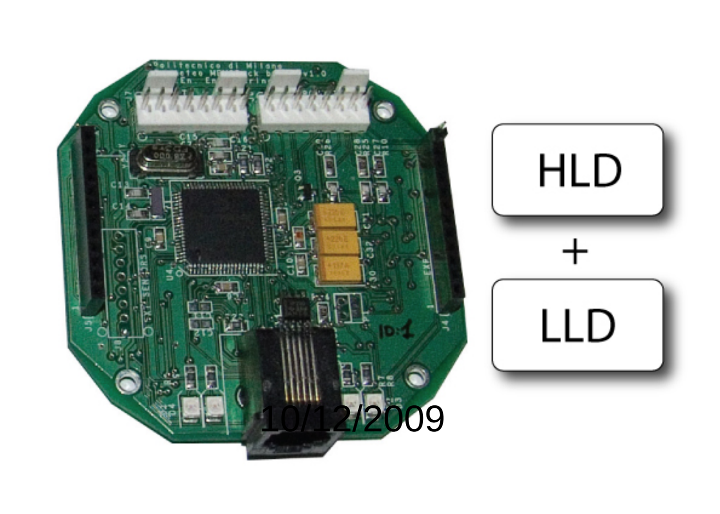
FPC Features (2)

- The **FPC** is a **JAVA OBJECT** that acts as a proxy between the physical device and the rest of the middleware
  - The communication between the Low Level Query Executor and the hardware devices are mediated by the *FPC*
  - Every *FPC* is tailored to fit a single sensor (or a group of them)
  - The system is provided with a *FPC* Factory, which automatically assembles *FPCs* on behalf of the user



BOUNDARIES OF THE MIDDLEWARE: HLD and LLD

- PerLa Middleware **C PORTABLE LIBRARY** (HLD, High Level Driver)
  - Communications with other PerLa Middleware components
  - General device management components (Timers, signal handling, Input/Output management…)
- The user is just required to write the missing software needed to access his device’s hardware (LLD, Low Level Driver)
  - Standard library of device drivers (CAN bus, Digital-IO, …)



DEVICE DESCRIPTOR (1)

- The device descriptor is an XML file that describes **CAPABILITIES** and **FEATURES** of a device
- Main sections of the descriptor:
  - Attributes and events of the device
  - Device features (available memory, uptime, available commands)
  - Network features (contact method, uptime, address format)
  - Message format expected by the *LLD*
- Most of the boilerplate code needed to handle a device is generated at run-time using the information contained in the Device Descriptor

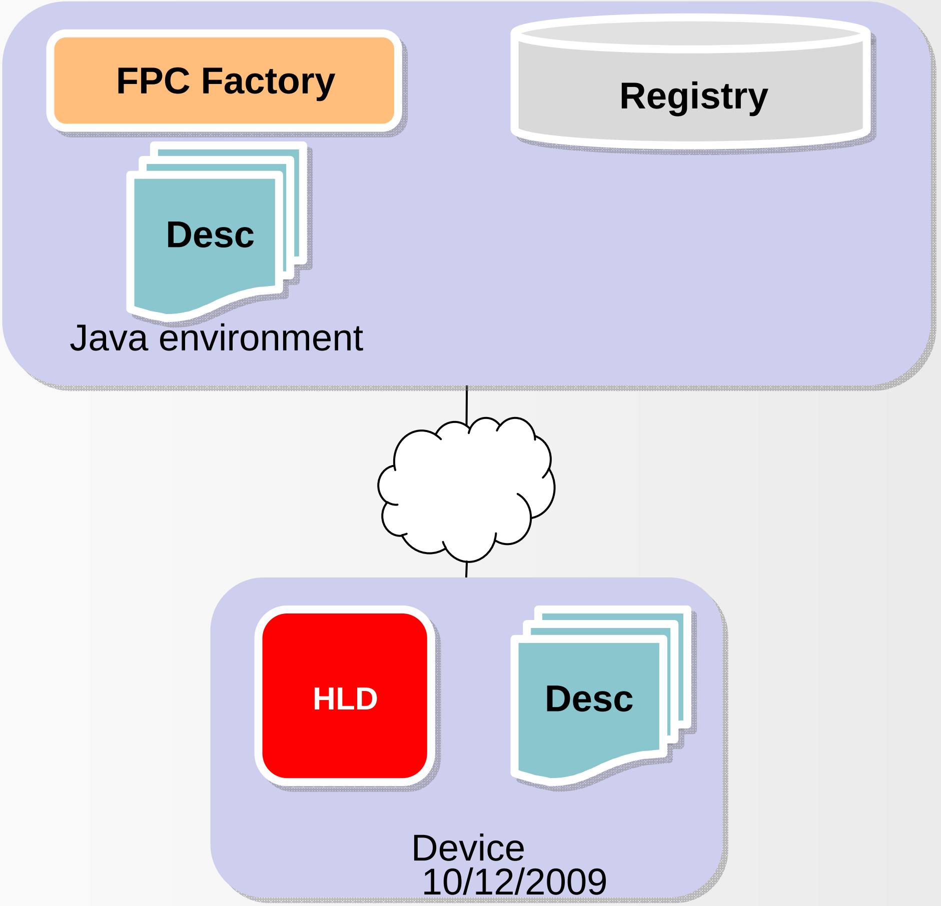
DEVICE DESCRIPTOR (2)

- A (very) simple Device Descriptor

```
<?xml version="1.0" encoding="UTF-8"?>
<perlaDeviceElement xmlns=http://www.example.org/SimpleDevice
   xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xsi:schemaLocation=http://www.example.org/SimpleDevice SimpleDevice.xsd
   name="testDeviceSingolaStruttura">
                <perlaSingleDevice>
                                <parameterStructure name="t">
                                <parameterElement name="p">
                                                <length>2</length>
                                                                <type nameType="int">
                                                                                <sign>signed</sign>
                                                                </type>
                                                                <attributeType>nonProbing</attributeType>
                                                                <permission>r</permission>
                                                                <continuousValue />
                                                                <conversionFunction>
                                                                                <builtInFunction></builtInFunction>
                                                                </conversionFunction>
                                                </parameterElement>
                                                <permission>r</permission>
                                                <type>Test</type>
                                                <size>10</size>
                                                <endianess>BigEndian</endianess>
                                </parameterStructure>
                </perlaSingleDevice>
</perlaDeviceElement>
```

FACTORY AND FPCs ASSEMBLING (1)

- Device Binding process: **PLUG & PLAY**
- Once started up the *HLD* sends the **DEVICE DESCRIPTOR** towards the nearest Java device suitable to host a *FPC*



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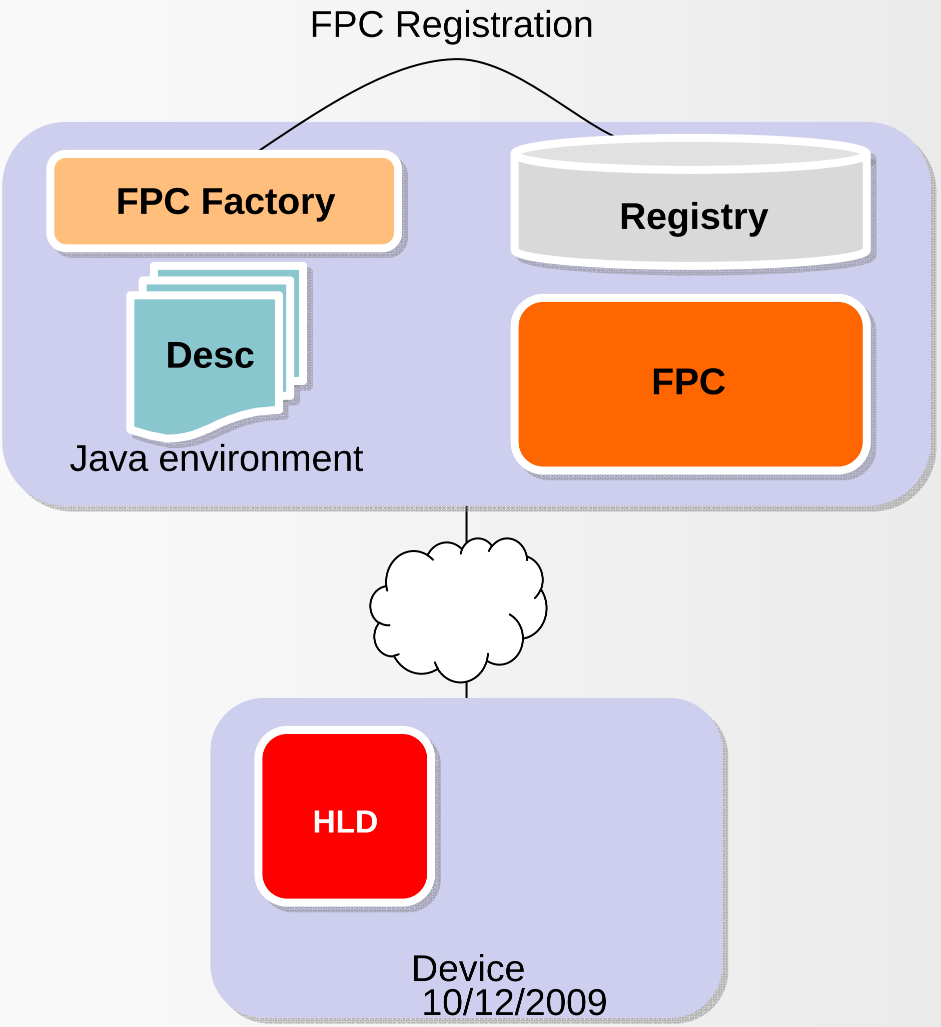
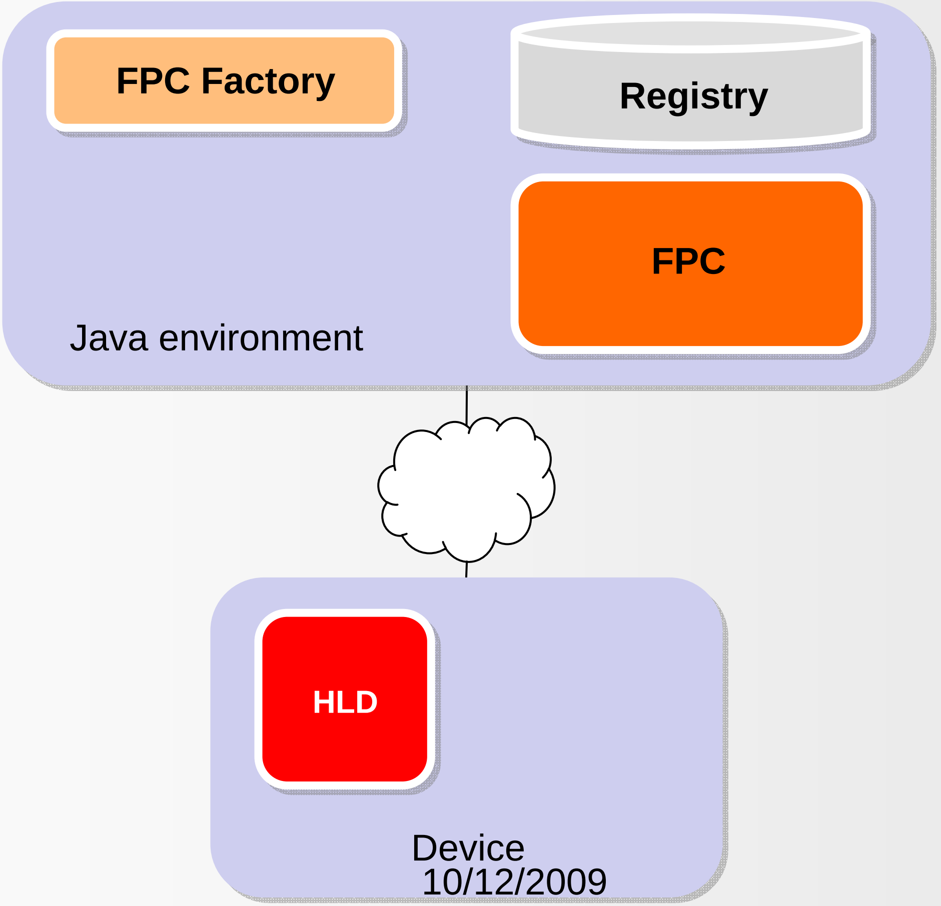
FACTORY AND FPCs ASSEMBLING (2)

- The FPC Factory assembles the *FPC* and registers it in the Registry



FACTORY AND FPCs ASSEMBLING (3)

- The newly created *FPC* acknowledges the device of its creation
- The device is ready to be used



FACTORY AND FPCs ASSEMBLING (4)

- The *FPC* is **CREATED AD-HOC** for every physical device
  - The Factory, after parsing the Descriptor, combines different modules and configures them
  - New modules can be added if not present in the default library
  - Data structures are dinamically created on the fly

- The nodes don’t have to comply with our rules, we comply with theirs!

OPEN POINTS

- There is currenlty an implementation of the FPC Factory, but needs to be expanded

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Low Level Query Executor

LOW LEVEL QUERY EXECUTION

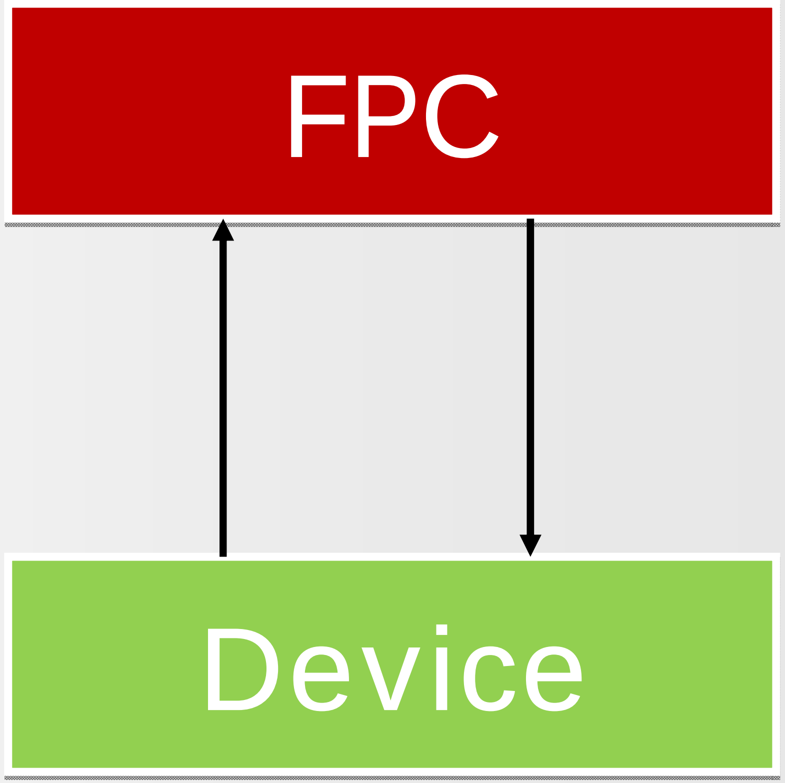
-summary-

- What and why
  - **GOALS, FUNCTIONALITIES, POSITION and STRUCTURE**
- How
  - **...THE WORK GETS DONE**
- Open points
  - **FUTURE DEVELOPMENTS**

WHAT: Goals and functionalities

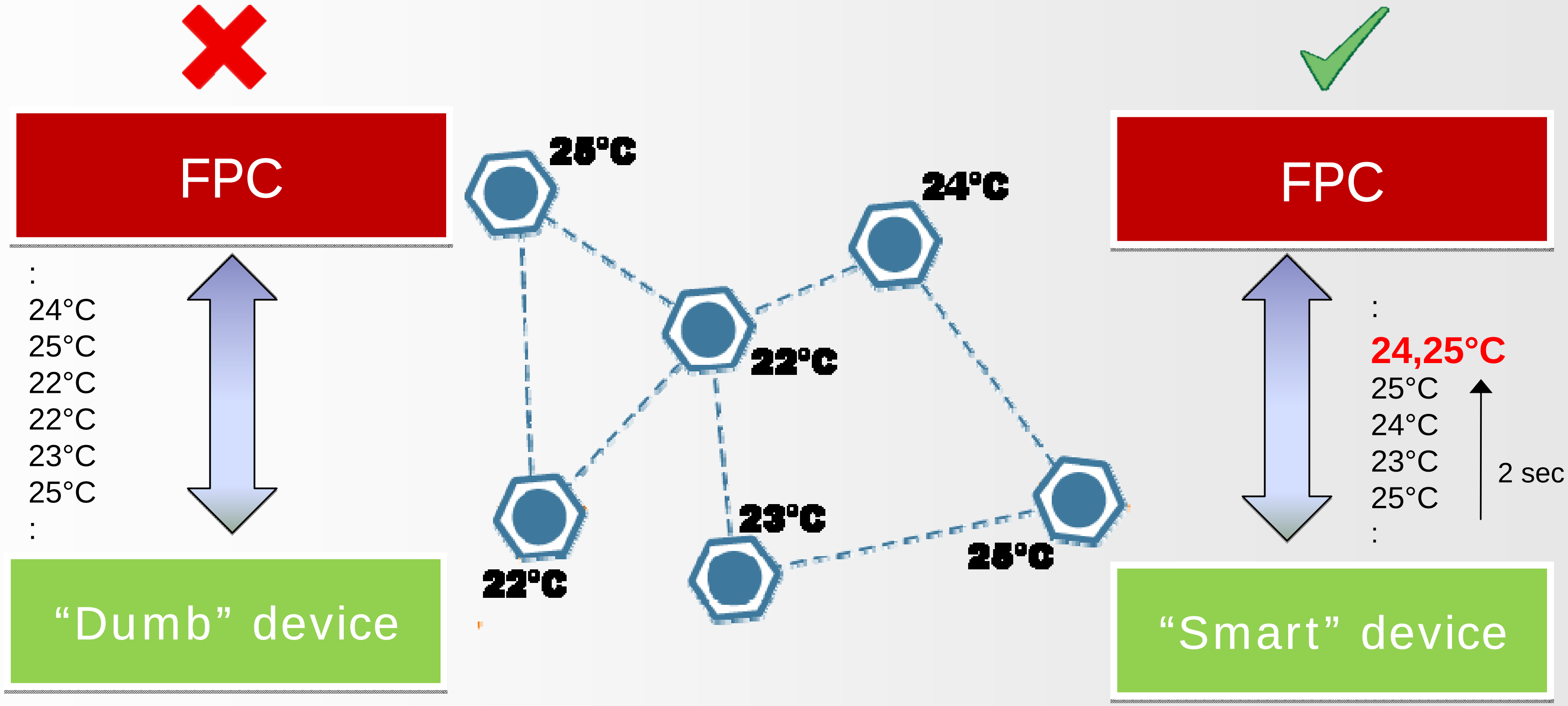
- **FPC** is the key component charged of dealing with the multitude of devices...

- ...but its tasks don't include data processing. Let's see it in an example!



WHAT: Goals and fucntionalities

```
SELECT  temp, AVG(temp,2s);
WHERE  temp > 22
```



✗

FPC

:
24°C
25°C
22°C
22°C
23°C
25°C
:

"Dumb" device

✓

FPC

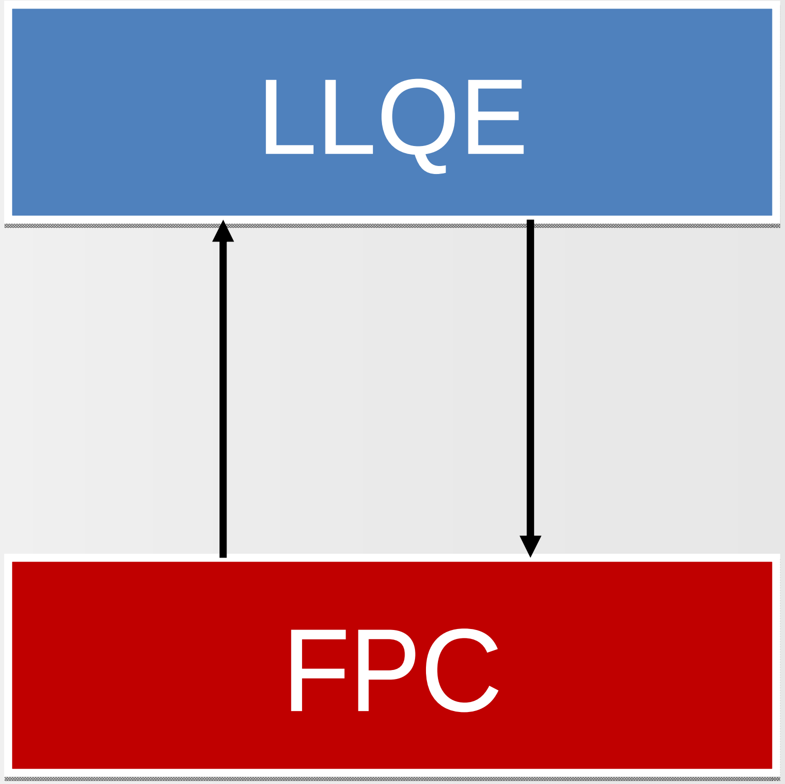
:
24,25°C
25°C
24°C
23°C
25°C
:

2 sec

"Smart" device

WHAT: Goals and functionalities

- A large number of nowadays sensors don’t have full computational power
- A **LOW LEVEL EXECUTOR** must be introduced to supply for the computability lacks of such devices
- Finds its location over the FPC, to which is strictly linked

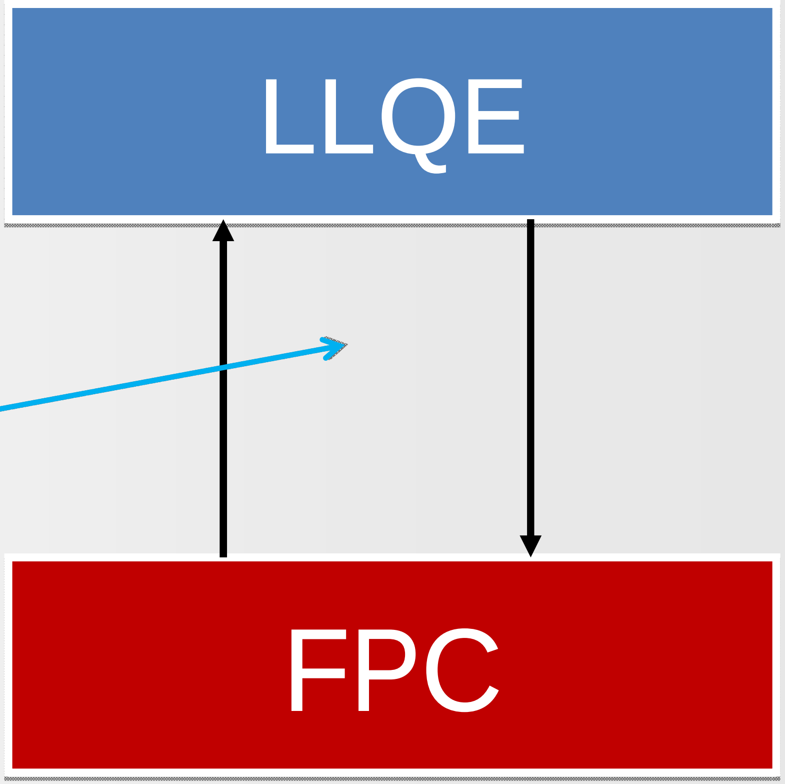


WHAT: Goals and functionalities

LOW LEVEL EXECUTOR tasks are wider than those suggested by its name:

1. **PHYSICALLY RETRIEVE** data from the network
2. **FILTER DATA** according a condition
3. **PROCESS DATA**

The internal structure reflects this order



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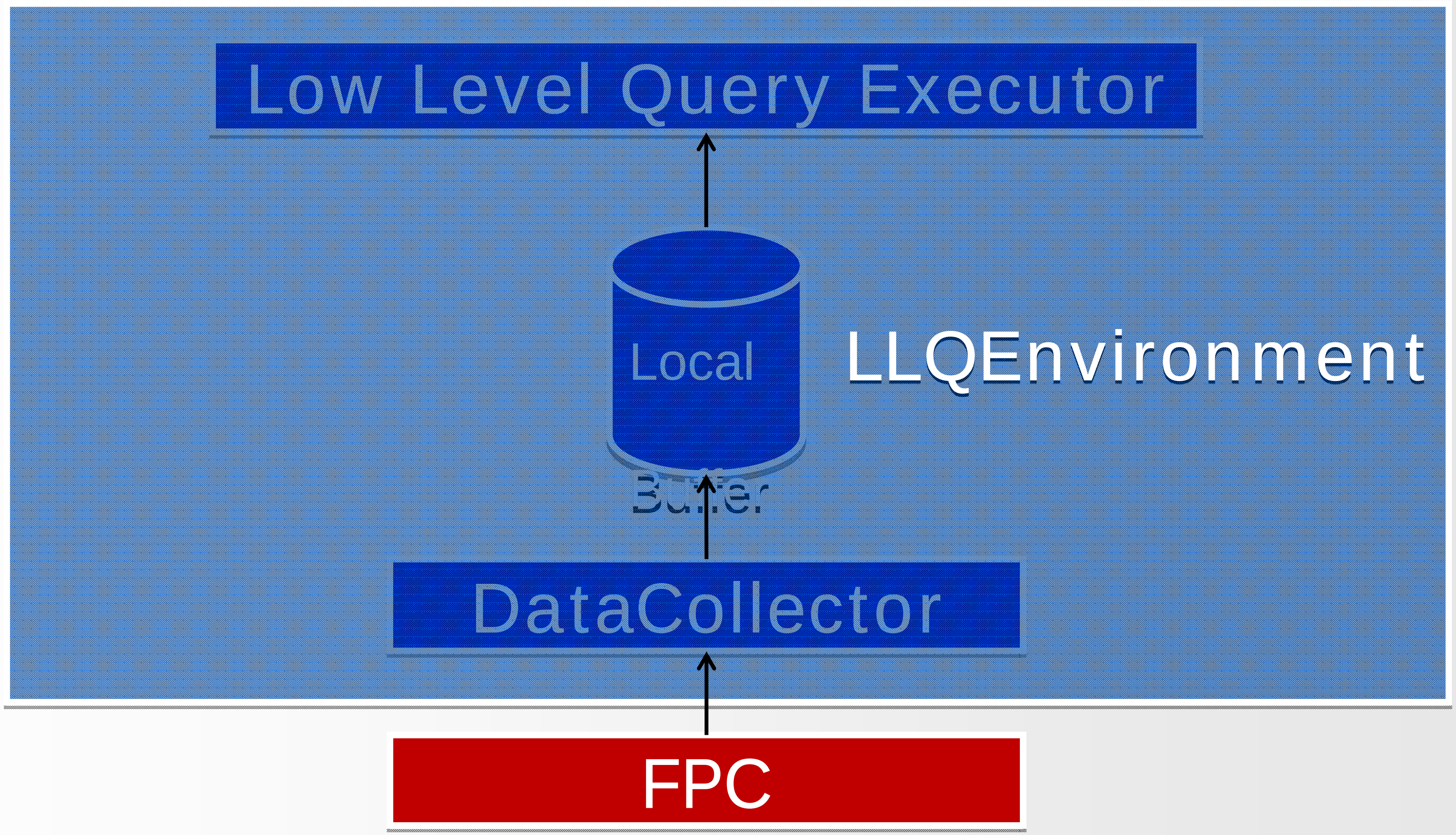
WHAT: LLQE Structure and position



Low Level Query Executor

Local Buffer

LLQEnvironment

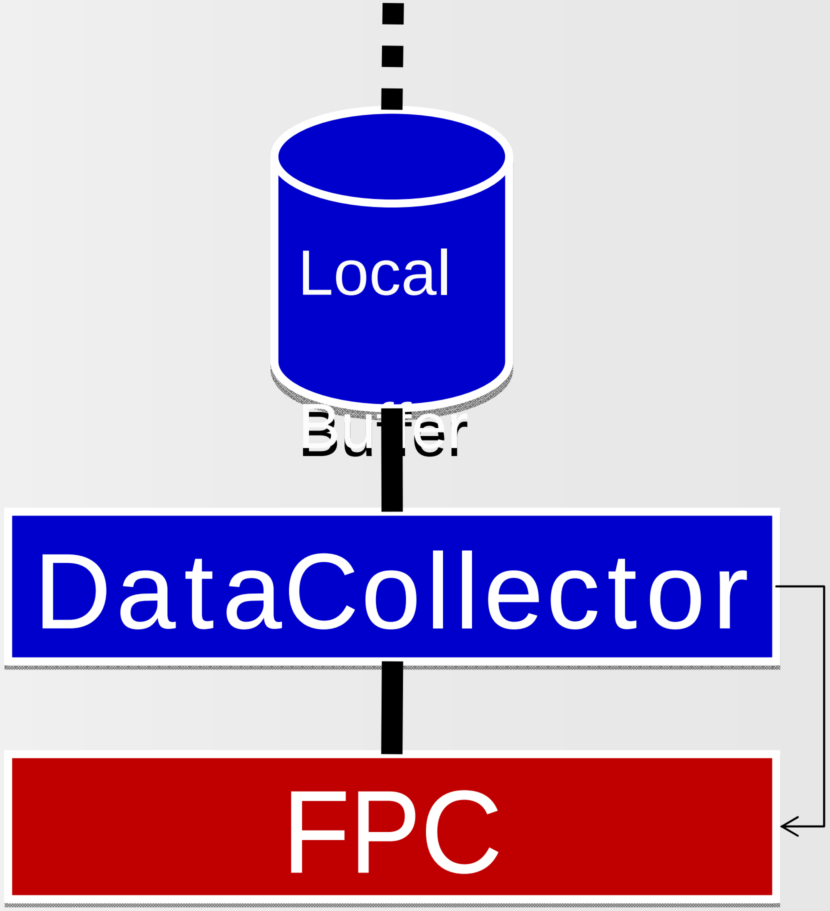
DataCollector

FPC

HOW: Pipes vs. method calls

- All the previous structures are created at runtime by the **QUERY ANALYZER** component

- DataCollector, FPC and Local Buffer are uncoupled thanks to **PIPES**



TESTBED QUERY: ArtDeco Demo

```
CREATE STREAM DataFromWineyard (SensorID ID, avgTemp FLOAT, avgHum
FLOAT, varTemp FLOAT, varHum FLOAT) AS
HIGH:
    EVERY 1 h
    SELECT AVG(temperature, 10 m), AVG(humidity, 10 m),
    VARIANCE(temperature, 10 m), VARIANCE(temperature, 10 m)
    FROM RawDataFromWineyard
    GROUP BY SensorID
```

```
CREATE STREAM RawDataFromWineyard (SensorID ID, temperature FLOAT,
humidity FLOAT) AS
LOW:
    EVERY 10 m
    SELECT humidity, temperature
    SAMPLING EVERY 60 s
```

Conclusion and open points

- The interface beetween FPC and DataCollector entity has been defined and consolidated
- LLQ Executor (data processing part) is currently under implementation: we're currently dealing with aggregates calculus.
- An interface towards the HLQs "world" must be designed and explored, as well as the HLQs "world" itself.
- A complete errors managing policy must be designed and implemented

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FUTURE WORKS

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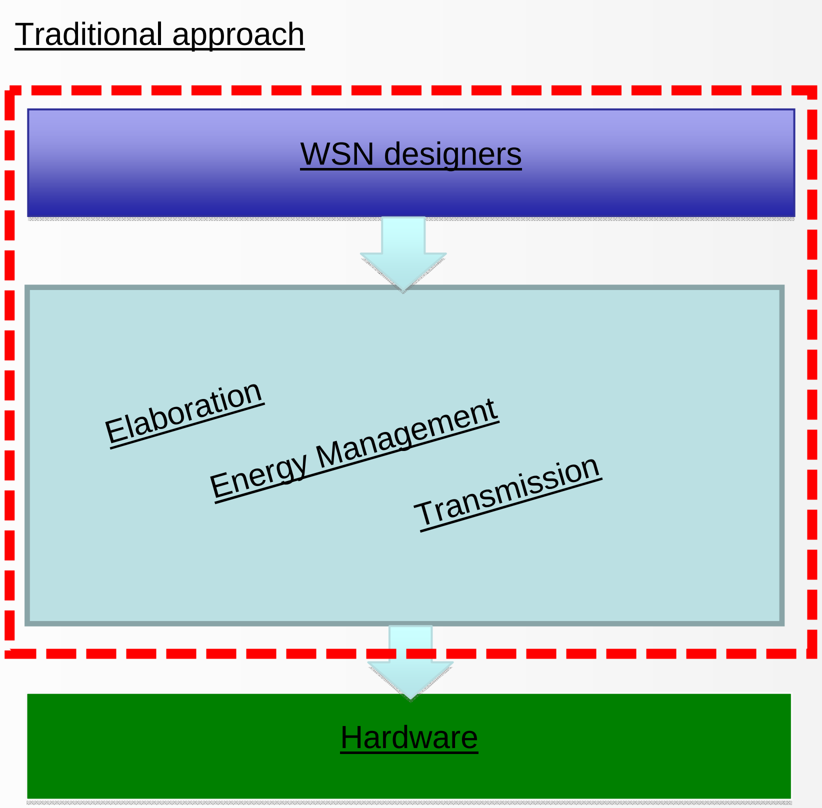
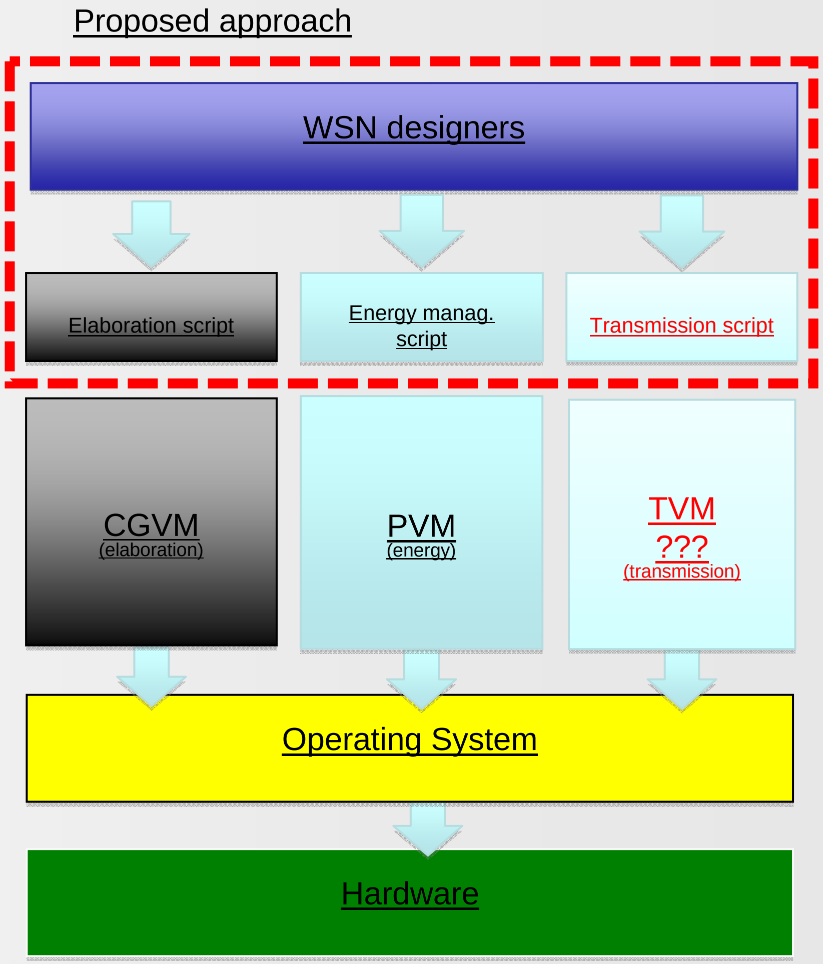
FUTURE WORKS

- Add support for Context Management
  - How would it be possible to extend the Pilot Join in PerLa to enhance context-awareness?
  - Some ideas:
    - Add data structures for explicit context (just like the **SNAPSHOT**)
    - Create a **Context Manager** which enables **active** management of contexts
    - Think about intelligent **Context Discovery** (for the future)
- Add support for context-based routing
  - Up to now, routing is used only as data transport
    - “net neutrality” vision
- Push the “intelligence” to the nodes
  - Node behavior determined at run-time
    - Data elaboration
    - Routing strategies
    - Power management

New: low level approach





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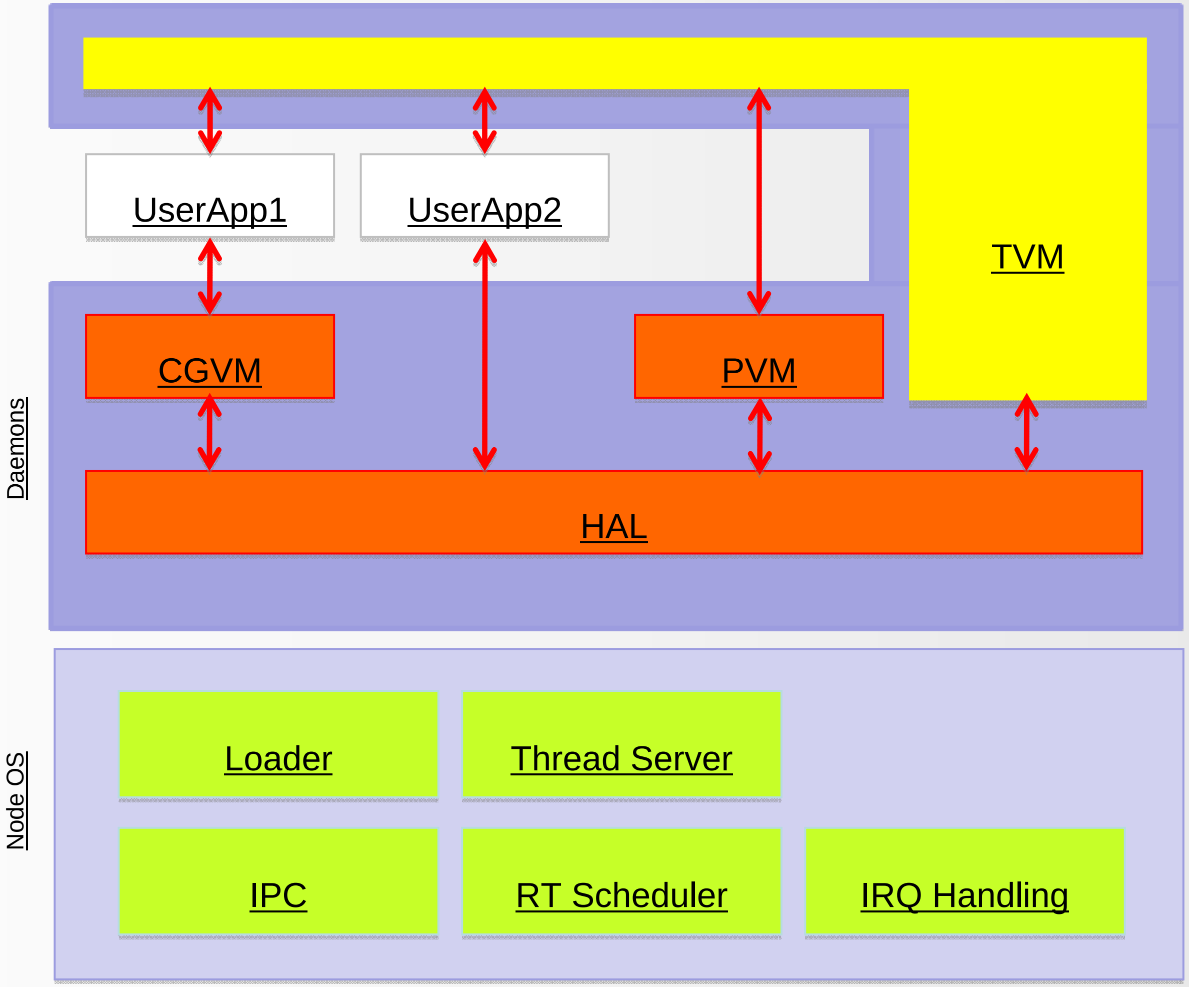
Node SW architecture



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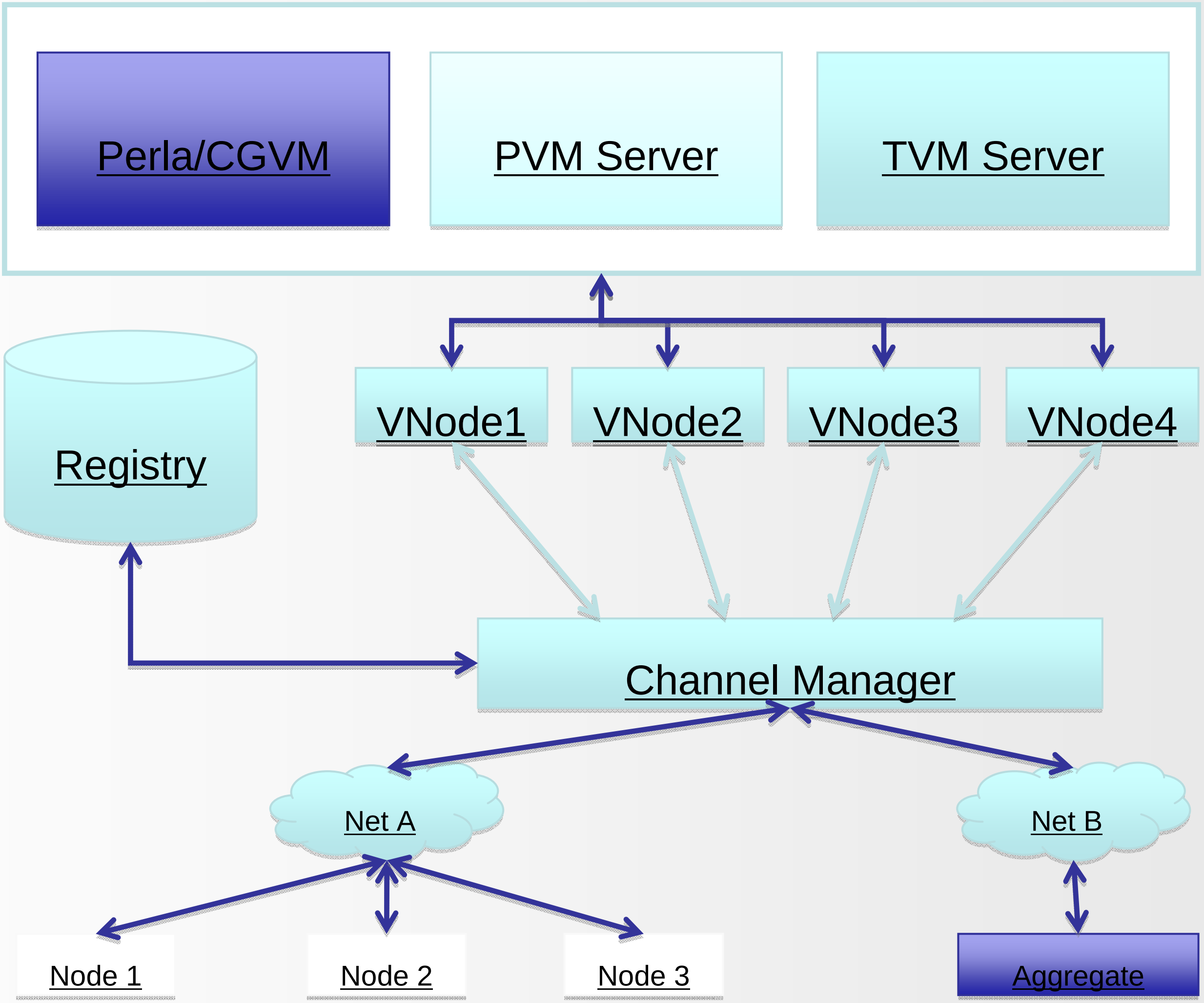
Middleware evolution



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