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PERLA: A DECLARATIVE LANGUAGE AND MIDDLEWARE FOR PERVASIVE SYSTEMS

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PERLA: A DECLARATIVE LANGUAGE AND MIDDLEWARE FOR PERVASIVE SYSTEMS*

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Abstract. The system aims at managing, with a unique language, data sampled from different nodes of a pervasive system, providing them to the final user. It is composed of three elements: the **nodes** are heterogeneous devices equipped with sensors, which collect data and send them through the network managed by the middleware; **PERLA (PERvasive LAnguage)** is the SQL like language used to query logical objects, that are abstractions of the nodes; the **middleware** is a stack of software layers providing an implementation of the logical object abstraction. Answers to the queries take into account the context the system operates within, in order to provide the user with data appropriate to different environmental conditions.

1 The Language

PERLA is a language which allows the user to interact with logical objects by wrapping physical devices [1]. It is worth to notice that a logical object can abstract both a single sensor node and a set of devices (e.g. a whole *WSN*). The language currently supports three kinds of queries.

Low Level Queries are executed on a single logical object and define how and when the sampling should be performed, how sampled data should be locally processed, and which results have to be produced. A clause is provided by the syntax of these queries to specify the conditions defining the set of logical objects the query will be instantiated and executed on. A clause has been introduced to support a special operation that allows dynamic changes in the set of logical objects executing a specific query, based on the results produced by another running query. We call this operation *PILOT JOIN*, due to the conceptual similarity with standard *SQL* join operation. In fact, it forces each involved logical object to start (or stop) the query execution if the joined stream contains (or not) a record that matches the current value of logical object attributes, as specified in the condition part of the *PILOT JOIN* clause. This operation is the key feature enabling the execution of context dependent queries [2]: the content of the joined stream is a description of the current environmental situation, while the join condition defines the context-aware data tailoring the user is interested in. Moreover, the values of the current matching record can be used

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in other clauses to adapt the query behavior to the current context. **High Level Queries** are very similar to the normal streaming databases ones and they allow to manage different streams produced by low level queries. Finally, **Actuation Queries** are not intended to collect data from a logical object, but rather to send commands to the logical object they are executed on.

2 The Middleware

The goal of the middleware is to provide an abstraction for each device in terms of logical objects and to support the execution of PERLA queries. During the design of the middleware, we strove to make the definition and the addition of new devices easy. We also tried to minimize the amount of low level code the user has to write to make the new device recognizable by the middleware. When a query is submitted to the system, the **language parser** transforms it in a suitable format for distribution and execution. High level queries are executed by the **high level query executor** which is a streaming database engine. The process is more complex for low level queries: firstly the **logical objects registry** is used to find the set of devices that will be involved in the query execution. Then, each involved **low level query executor** starts sampling its device (through the abstraction provided by the logical object) and managing sampled data as required by the query. We decided to implement the whole software, from the logical objects layer up, using *JAVA* technology. We also assumed that each logical object (that we can now consider as a *JAVA* remote object) is reachable via *TCP/IP*. If the physical device is connected to a different network (e.g. a *CAN-BUS* channel), the correspondent logical object will be instantiated on the nearest device equipped with both a *JAVA Virtual Machine* and a *TCP/IP* connection. The communication protocol between the logical object and the physical device is managed by a specific software layer provided with the middleware. Another important component is a **C library** that has been developed to minimize the low level programming effort by the user to integrate a new technology in the middleware. To reach this goal we defined the structure of a *XML file*, containing a full description of a device in terms of available sensors, measures that can be sampled and packets format. The effort required to the user to integrate a new technology is limited to the creation of the *XML* descriptor and the extension of the *C library* with the definition of device specific sampling routines. The logical object wrapping the device is then automatically and dynamically generated by the middleware.

References

1. Schreiber, F.A., Camplani, R., Fortunato, M., Marelli, M., Pacifici, F.: Perla: A data language for pervasive systems. In: PerCom, IEEE Computer Society (2008) 282–287
2. Bolchini, C., Curino, C.A., Orsi, G., Quintarelli, E., Rossato, R., Schreiber, F.A., Tanca, L.: And what can context do for data? In: Communications of ACM, to appear

PerLa
PERvasive LAnguage

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FULL DECLARATIVE SQL-LIKE HIGH LEVEL LANGUAGE

to query

PERVASIVE SYSTEMS

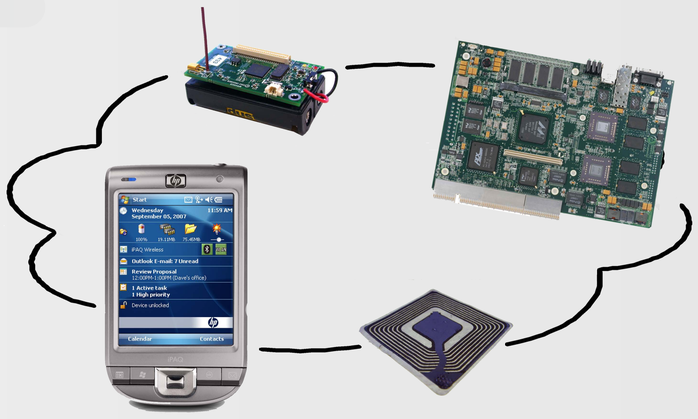
hiding the complexity of handling

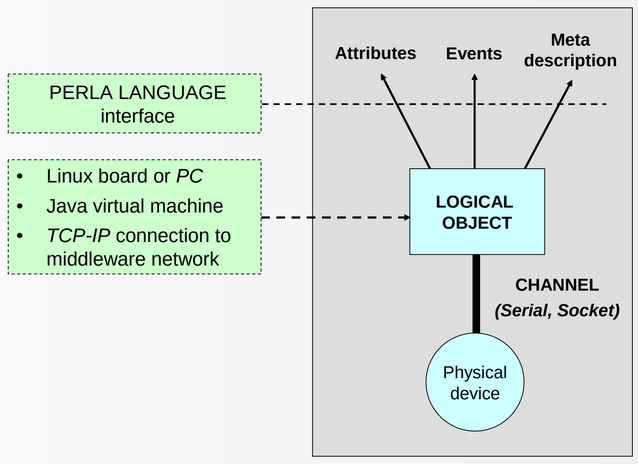
DIFFERENT TECHNOLOGIES

TARGETS

- RUN-TIME SUPPORT OF **HETEROGENEITY**:
  - *WSN nodes*
  - *RFID tags*
  - *PDAs*
  - *AD HOC boards*
  - *…*

  } can be queried simultaneously, with the same language
- SUPPORT OF **NON INTELLIGENT DEVICES** (*RFID TAGs* can be queried exactly as *WSN nodes*)



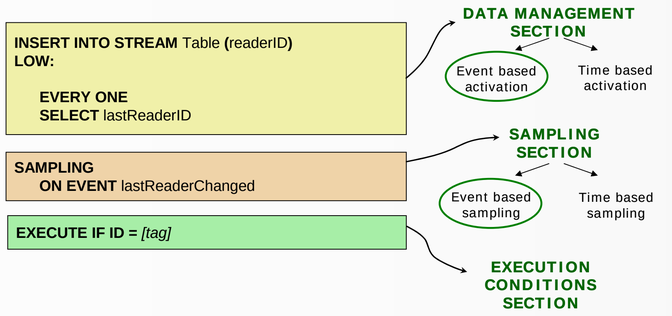


LOGICAL OBJECTS

- THE **LANGUAGE SEMANTICS** IS DEFINED ON THE CONCEPT OF **LOGICAL OBJECT**
- EACH DEVICE IS ABSTRACTED AS A LOGICAL OBJECT:
  - **ATTRIBUTES** (*id, temperature, pressure, power level, last sensed RFID reader, …*)
  - **EVENTS** (*last sensed RFID reader changed, …*)
  - **META-DESCRIPTION** (*name, data type, … for each attribute*)

QUERIES

Produce e record whenever the tag with ID [tag] is sensed by a reader in the system



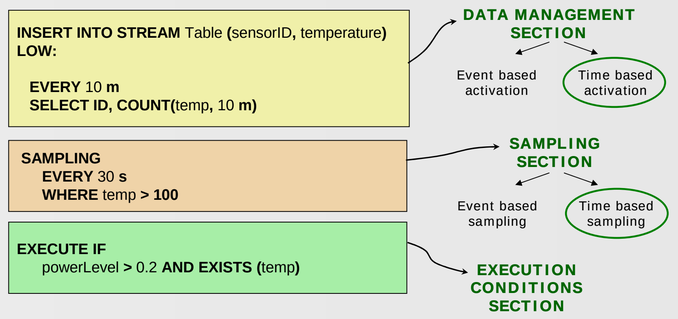
- **LOW LEVEL QUERIES**

  DEFINE THE BEHAVIOR OF A SINGLE OR OF A GROUP OF DEVICES ABSTRACTED BY A SINGLE LOGICAL OBJECT
- **HIGH LEVEL QUERIES**

  DEFINE DATA MANIPULATION OVER THE STREAMS COMING FROM LOW LEVEL QUERIES (~ STREAMING DATABASE)
- **ACTUATION QUERIES**

  SET THE VALUES OF SOME LOGICAL OBJECT ATTRIBUTES

Sample the temperature every 30 seconds and, every 10 minutes, report the number of samples that exceeded a given threshold

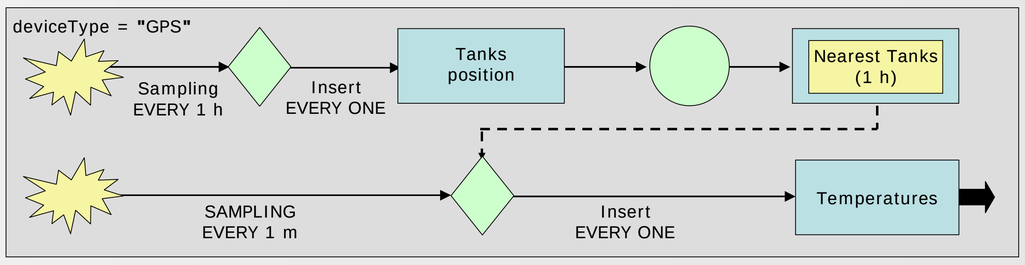


A COMPLETE QUERY EXAMPLE

There is a set of tanks, containing some temperature sensors. A GPS and a base station are mounted on each tank.

The temperature sensors contained in the tank nearest to a given point P must be sampled every minute.

The distances of the tanks from the point P must be revaluated every hour.



WSN node
Logical object wrapping a single WSN node equipped with a temperature sensor

Field Name	Data Type	Description
ID	ID	Logical object identifier
baseStationID	ID	ID of the base station the WSN node is currently connected to
temp	FLOAT	Sampled temperature

GPS
Logical object wrapping a GPS device

Field Name	Data Type	Description
ID	ID	Logical object identifier
linkedBaseStationID	ID	ID of the base station mounted over the same tank
locationX	FLOAT	Sensor location – X coordinate
locationY	FLOAT	Sensor location – Y coordinate
deviceType	STRING	Type of device

The PILOT JOIN operation

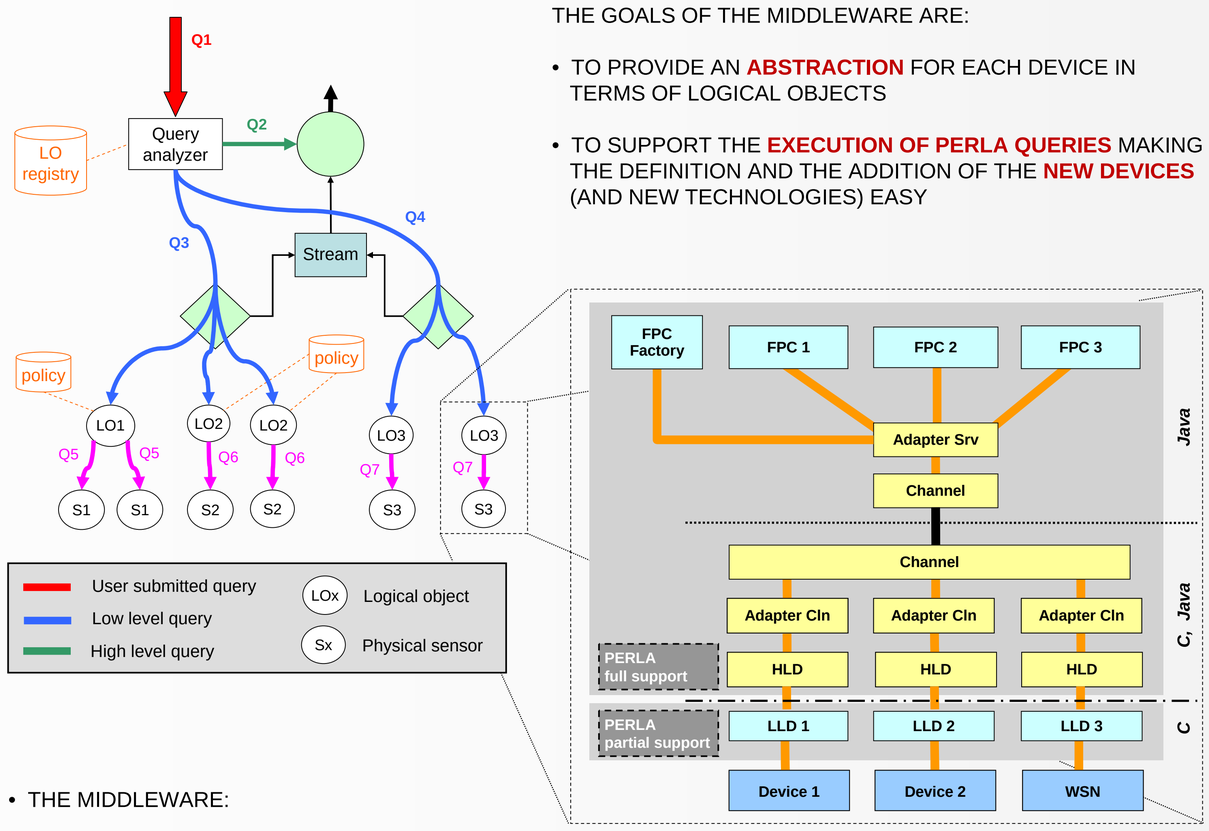
- **PILOT JOIN** is a special operation that allows **dynamic changes** in the set of **logical objects** executing a specific low level query, based on the results produced by another running query.
- It forces each involved logical object to start (or stop) the query execution if the **joined stream** contains (or not) a record that matches the current value of logical object attributes, as specified in the condition part of the PILOT JOIN clause.
- The PILOT JOIN operation is the key feature enabling the execution of **CONTEXT DEPENDENT QUERIES**:
  - the content of the joined stream is a description of the current **ENVIRONMENTAL SITUATION**,
  - the join condition defines the **CONTEXT-AWARE DATA TAILORING** the user is interested in.

```
CREATE STREAM TanksPositions (gpsID ID, linkedBaseStationID ID, distanceFromP FLOAT) AS
LOW:
  EVERY ONE
  SELECT ID, linkedBaseStationID, dist_from_P(locationX, locationY)
  SAMPLING EVERY 1 h
  EXECUTE IF deviceType = "GPS"                                   CONTEXT DEFINITION

CREATE SNAPSHOT NearestTank (gpsID ID, linkedBaseStationID ID)
WITH DURATION 1 h AS
HIGH:
  SELECT TanksPositions.gpsID, TanksPositions.linkedBaseStationID
  FROM TanksPositions (1 h)
  WHERE TanksPositions.distanceFromP = MIN(TanksPositions.distanceFromP)   CONTEXT-AWARE DATA TAILORING

CREATE OUTPUT STREAM Temperatures (sensorID ID, temp FLOAT) AS
LOW:
  EVERY ONE
  SELECT ID, temp
  SAMPLING EVERY 1 m
  PILOT JOIN NearestTank ON NearestTank.linkedBaseStationID = baseStationID
```

PERLA MIDDLEWARE



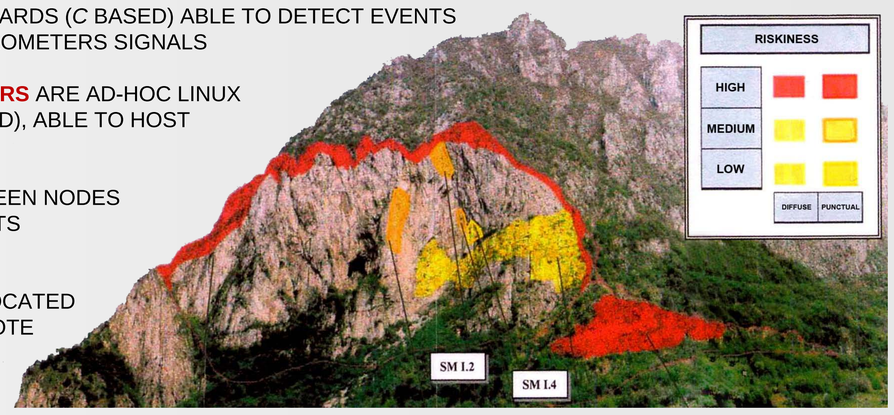
THE GOALS OF THE MIDDLEWARE ARE:

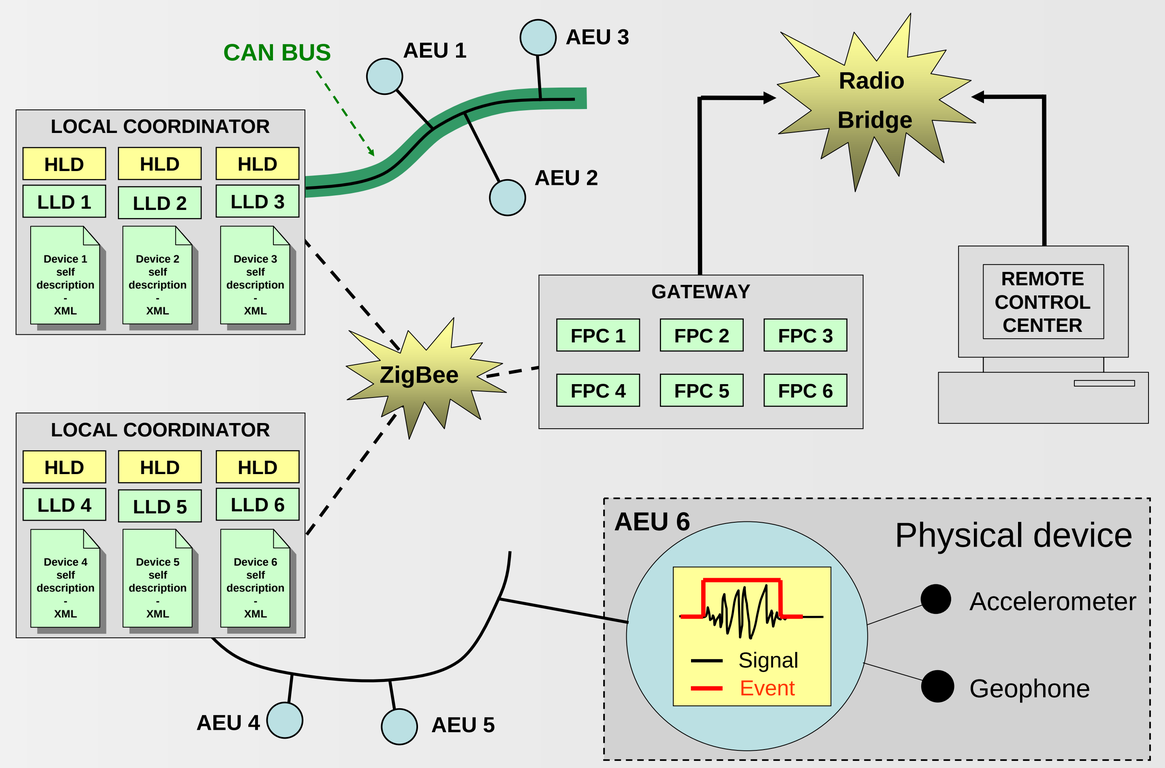
- TO PROVIDE AN **ABSTRACTION** FOR EACH DEVICE IN TERMS OF LOGICAL OBJECTS
- TO SUPPORT THE **EXECUTION OF PERLA QUERIES** MAKING THE DEFINITION AND THE ADDITION OF THE **NEW DEVICES** (AND NEW TECHNOLOGIES) EASY

- THE MIDDLEWARE:
  - **PARSES** AND **VERIFIES** PERLA QUERIES
  - **DYNAMICALLY GENERATES** LOGICAL OBJECTS CORRESPONDENT TO PHYSICAL DEVICES
  - MANAGES THE **COMMUNICATION PROTOCOL** BETWEEN PHYSICAL DEVICES AND LOGICAL OBJECTS
  - SENDS HIGH LEVEL QUERIES TO THE HIGH LEVEL EXECUTOR AND LOW LEVEL QUERIES TO LOGICAL OBJECTS
- THE EFFORT REQUIRED TO THE USER TO INTEGRATE A NEW TECHNOLOGY IS LIMITED TO:
  - THE CREATION OF AN **XML DESCRIPTOR**
  - THE DEFINITION OF **DEVICE SPECIFIC SAMPLING ROUTINES**

FIRST PERLA DEPLOYMENT: ROCKFALL MONITORING on San Martino face (Lecco, Italy)

- **ACCELEROMETERS** AND **GEOPHONES** ARE USED TO MONITOR **INCLINATION** AND **VIBRATIONS**
- **NODES** ARE *DsPic* BOARDS (*C* BASED) ABLE TO DETECT EVENTS ANALYZING ACCELEROMETERS SIGNALS
- **LOCAL COORDINATORS** ARE AD-HOC LINUX BOARDS (JAVA BASED), ABLE TO HOST LOGICAL OBJECTS
- THE CHANNEL BETWEEN NODES AND LOGICAL OBJECTS IS A **CAN-BUS**
- **PERLA PARSER** IS LOCATED ON A PC IN THE REMOTE CONTROL CENTER





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