POLITECNICO DI TORINO
Dipartimento di Automatica e Informatica

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Infrastructures for Big Data analysis of Complex Systems

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1. Introduction

An ongoing **global urbanization** process is progressively reshaping the distribution of world energy consumption, while our cities remain unprepared on promoting sustainable energy behaviors.

Several efforts investigated energy consumption control at building level. Novel methodologies should tackle the problem **holistically** and devise a **district-wide** infrastructure, to be used by energy professionals and citizens.

The **simulation** of new energy distribution policies would greatly benefit on the one hand from a system in which building energy profiles, energy grid network information (i.e. topology and characteristics) and weather forecasts are automatically integrated and correlated.

On the other hand, such system should **validate** the simulation results, to assure **user comfort**.

2. Objective

This work proposes an **event-based IoT infrastructure for the modelling of a city district**, which provides a complete ecosystem for:

- The design or refurbishment of buildings;
- The monitoring of energy consumption and production;
- The simulation of control policies and energy flows;
- The increase of user awareness.

This work has been partially supported by EU, FP7 SMARTCITIES 2013 DIMMER project (District Information Modeling and Management for Energy Reduction).

3. Method

The DIMMER infrastructure (see Figure 1) consists of three independent layers: The *IoT Devices and Technologies Integration Layer*, for the integration of IoT devices and monitoring technologies; the *Services Layer*, composed by a set of Service interfaces to IoT devices and several data sources; and the *Applications Layer*, composed by the different applications which make use of the infrastructure.

The proposed infrastructure bets on several technological approaches to distributed information exchange:

- **Micro-Service Computing**;
- **Publish/Subscribe paradigm**.

Micro-Service Computing is a computing paradigm used to integrate heterogeneous data sources (i.e. routines or databases, IoT devices) behind "service" abstractions. This infrastructure exploits the RESTful Web Service style and the JSON data format for information exchange.

Publish/Subscribe is a software messaging pattern in which message producers and message consumers do not communicate directly and synchronously. Indeed, they exchange messages through an intermediate actor, the "broker". This approach produces several advantages: for instance, producers and consumers may be online in different times and still be able to communicate (but the broker should always be online).

By using these two design patterns, the infrastructure is able to:

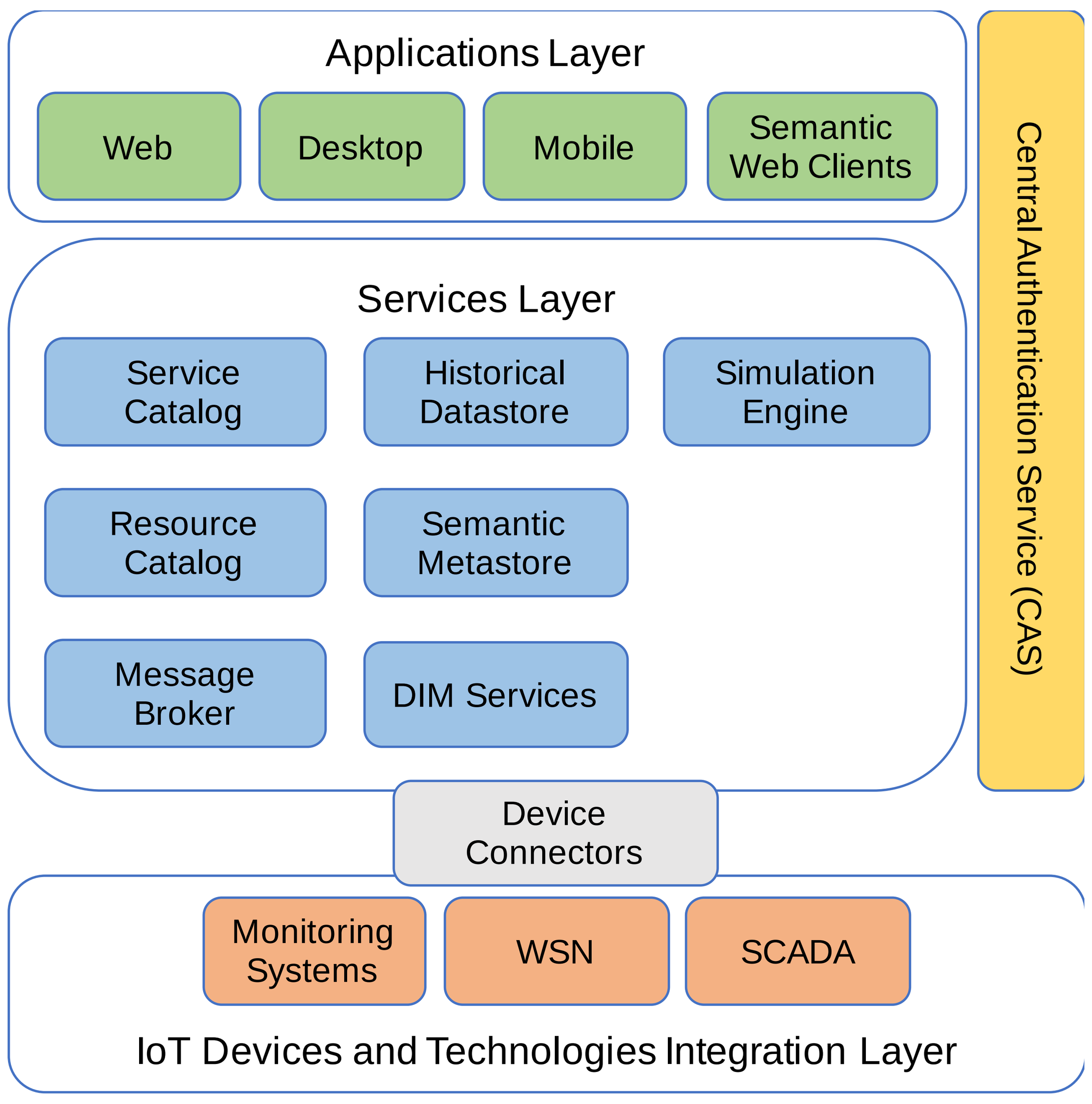

Figure 1: Architectural schema of DIMMER infrastructure

- **Integrate** heterogeneous **data sources** (e.g., Building Information Models [BIM], System Information Models [SIM] and Geographical Information Systems [GIS]) and **IoT devices**;
- **Simulate** new energy distribution policies for the energy distribution networks of the district, and **validate** them using data collected from **IoT devices**.

The integration of different data sources is achieved using the *DIM Services* component, through REST Web Services. Each data source, which consists of a relational database, is wrapped by a *Service Provider* – a middleware layer which provides a uniform **REST** interface to the underlying technology. In this way, the data source can be queried with standard HTTP actions, and the results are automatically translated in the standard **JSON** data format. An independent layer, the *DIM Context layer*, is then built on top of the different Service Providers: It aims at providing a high-level abstraction of the district model, by integrating and correlating the information received from the underlying Service Providers.

In the same way, IoT devices are integrated by exploiting different components: The *Service Catalog* and the *Resource Catalog* provide a comprehensive and detailed view of all the devices deployed in the district. The *Historical Datastore* **collects historical data** from the IoT devices and provides APIs to retrieve them.

The simulation of new energy distribution policies is tackled by the *Simulation Engine* component. This component is a **multi-thread, asynchronous, Web Service** enabled wrapper of a mathematical energy distribution network simulator, which is implemented using Matlab toolboxes. Through **REST** Web Service and **MQTT** interfaces, it is possible to configure and launch energy distribution network simulations, and retrieve results when they are published.

It is worth noting that each component of the infrastructure provide user authentication and authorization by using the **Central Authentication Service (CAS).**

4. Results

The kind of information which can be extracted from

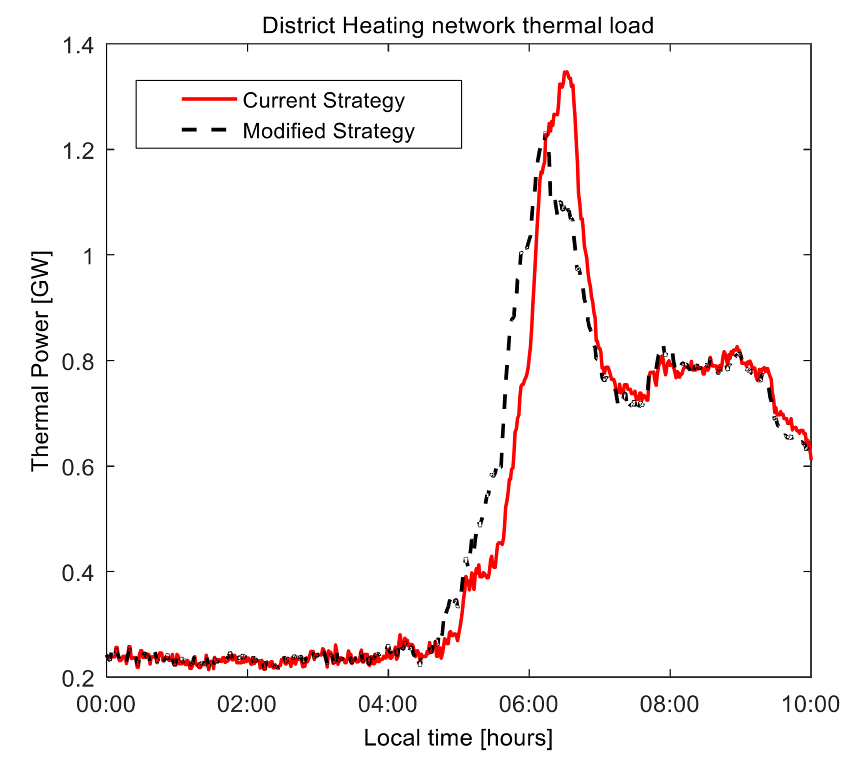

Figure 2: Energy distribution policy **simulation**

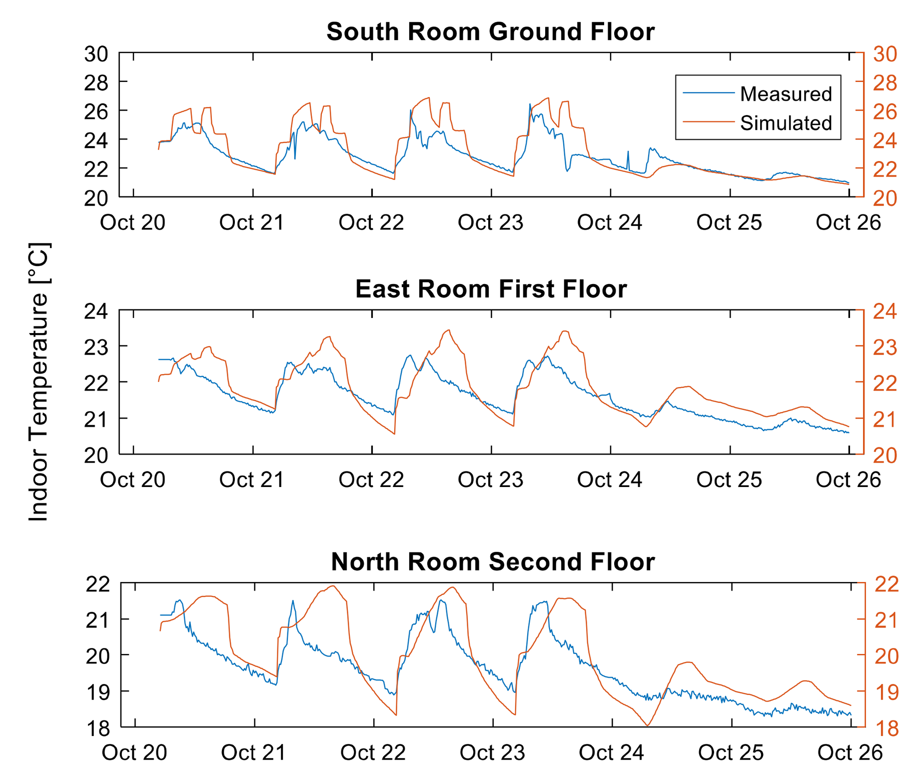

Figure 3: Energy policy **validation** on selected building

the infrastructure varies from the parameters of the different buildings of the districts (e.g., from BIM, orientation, surface/volume ratio, occupancy), the topology and the characteristics of the energy distribution networks (from SIM), and the geographical attributes of the district area (from GIS).

Further, district energy measurements such as heat loss and thermal mass coefficients of the buildings, and heat exchanger fouling can be retrieved.

This integrated system of heterogeneous information correlation has been exploited in two **real world demonstrators** (in Turin and Manchester). Specifically, in Turin, the system allowed the simulation of novel heating distribution strategies which are expected to save up to 2.1 MW (see Figure 2).

Using the information on the buildings provided by the infrastructure, the novel strategies can be **validated** by analyzing its effect on **user comfort** (see Figure 3).

5. Conclusions

The proposed infrastructure answers to a currently unmet need in energy distribution planning at city district scale. The use of **open standards of the Web** and **IoT devices** results in a complete interoperable ecosystem which allows an unprecedented fine-grained monitoring, control and simulation capability over district areas and energy grids.

6. References

1. Brundu, Francesco G., et al. "DIMCloud: a distributed framework for district energy simulation and management." Internet of Things. User-Centric IoT. Springer International Publishing, 2015. 331-338.
2. Brundu, Francesco G., et al. "IoT Software Infrastructure for Energy Management and Simulation in Smart Cities." IEEE Transactions on Industrial Informatics (2016).