Middleware services for network interoperability in smart energy efficient buildings

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Middleware Services for Network Interoperability in Smart Energy Efficient Buildings

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***Abstract*—One of the major challenges in today's economy concerns the reduction in energy usage and CO_2 footprint in existing Public buildings and Spaces without significant construction works, by an intelligent ICT-based service monitoring and managing the energy consumption. In particular, interoperability between heterogeneous devices and networks, both existing and to be deployed is a key features to create efficient services and holistic energy control policies. In this paper we describe an innovative software infrastructure to provide a web-service based, hardware independent access to the heterogeneous networks of wireless sensor nodes, such as smart plugs for measuring energy motes for temperature, relative humidity and light monitoring. The proposed infrastructure allows easy extension to other networks, thus representing a contribute to the opening of a market for ICT-based customized solutions integrating numerous products from different vendors and offering services from design of integrated systems to the operation and maintenance phases.**

I. Introduction

One of the higher priorities for research investment in the last years concerns smart ICT-based services for building management. In particular, key challenges regards the development of energy performance monitoring and control of Heating, Ventilation, Air Conditioning (HVAC) and lighting services in existing building and open public spaces without significant construction works. This requires enabling the interoperability between heterogeneous networks and devices.

In this work, we propose a web-service oriented software infrastructure, which enables the abstraction of network and hardware details thus promoting interoperability among the heterogeneous monitoring devices.

In the rest of the paper we describe the proposed infrastructure and we show a case study of a building-monitoring infrastructure.

II. Middleware/DB infrastructure

The main purpose of this work consists in the development of an innovative software infrastructure to handle heterogeneous wireless sensor nodes of different WSNs through web-services, leveraging on the LinkSmart Middleware (earlier called Hydra) [1], [2]. To achieve it, the access to the motes must be hardware independent. Hence, the software should to associate a virtual end-node to a real physical device and then export it to the higher layers.

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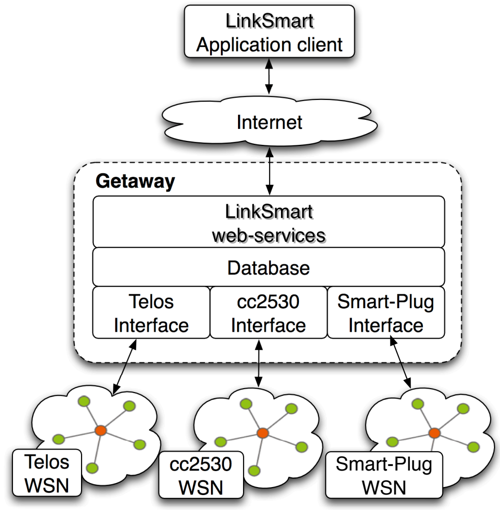

Fig. 1. Software infrastructure scheme to handle heterogeneous wireless sensor networks.

As shown on Fig. 1, the heterogeneous networks communicate directly with our software infrastructure, which runs on a PC-Gateway (GW). All the information coming from the WSNs, regardless of the adopted communication protocols, hardware or the network topology, is sent to a dedicated *Interface*, that is the lowest layer of our proposed stack. Each WSN needs to have a specific software *Interface*, which interprets the data and stores them in an integrated database (DB), which makes the whole infrastructure flexible and reliable with respect to back-bone network problems, since data are locally stored. As Database Management System (DBMS) we adopted SQLite [3], a DBMS easy to use and to install. Moreover, the stored data can be easily exported to others DBMS or to others standards formats. The web-services layer has been implemented using LinkSmart. It interfaces the WSNs to the web, making easy a remote management and control. Furthermore, it exports to the application-client layer all the environmental data stored in the database, collected by the wireless sensor nodes. At the application-client layer, the information is available to the end-user and ready to be shown or to be post-processed.

Particular emphasis was given to the possibility to reconfigure each node, changing, for instance, some parameters about power management. Thus, the end-user sends the new configuration via web-services to the GW and stores it in the DB. Then, the new settings will be automatically send to the receiver mote, when it will wake up from the sleeping period, through the specific WSN software *Interface*. The configurable parameters change depending on the hardware and the Operating System running on the end-node. However, using this software infrastructure, the user can choose the appropriate settings without knowing the real physical hardware related to the virtual device.

In a nutshell, the proposed web-based infrastructure is a software that makes transparent to the end-user the underlying WSNs, abstracting all the information about the hardware, the protocol stack and embedded operating system. Furthermore, by the use of web-services, it makes easy the interoperability with third-party software.

III. Case study

In this work, three different networks made of three commercial wireless sensor devices, have been considered as case study, namely: i) Crossbow Telos rev. B mote [4], ii) customized mote built on Texas Instruments' CC2530 system on chip [5] with two additional sensors: a Texas Instruments TMP125 temperature sensor and an Avago ADPS-9300 photodiode sensor and iii) Smart-Plug developed by ST Microelectronic that provides details of energy consumption per appliance connected to the mains.

The Telos runs TinyOS [6], which implements a 802.15.4 protocol stack. On the other side, cc2530 nodes and Smart-Plugs run a ZigBee 2007 protocol stack.

The WSN's application has been developed to be independent of the adopted network topology. In this case study, it has been implemented a star network, consisting of a Coordinator (CO), one for every device network, always connected to a PC-Getaway (GW) via USB, and several End-Node (EN). The information flow is only from the EN to the CO and vice versa. There is no communication between different motes. Unlike a peer-to-peer or a mesh network topology, there are no routers, so there is an only single hope between sender and receiver.

Considering the opportunity to configure remotely, these parameters are an example of the type of settings that can be made:

- *sampling period:* it represents the time interval between two consecutive sampling and transmission of environmental information;
- *radio wake up interval:* it indicates the time interval between two consecutive wakening of the radio module to check for possible incoming packets;
- *active sensors:* they represent those sensors that must be activated depending on the environmental information to be collected. Concerning cc2530, the user can choose between Temperature and Light; Humidity and Battery level are added for Telos motes.

On cc2530, *sampling period* and *radio wake up interval* are coincident. These setting will be transparently exported as a virtual End-Node from the GW to the upper layers through web-services. Therefore, the user can choose only the right settings without knowing the real physical hardware related to the virtual device.

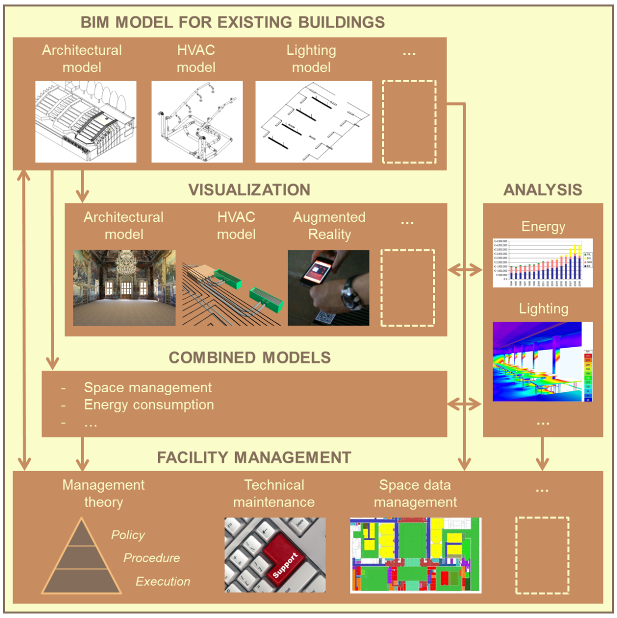

Fig. 2. Data management structure on a Building Information Modelling architecture.

IV. Integration into Building Management Systems

This work is included in the context of an European founded project whose objective is to implement an energy-intelligent control service based on a Building Information Modelling (BIM - shown on Fig. 2) to achieve improvements in energy yield by automatic energy regulation and data communication. At the end we expect also a Building Management System that incorporate 3D BIM-like aspects to allow facility managers to visualize and understand the complex interactions within their buildings. Augmented reality will be coupled to sensing networks to improve awareness in end users. In this way 3D models of mechanical and electrical systems will be augmented with real time data from sensors and it will be possible start to have tools to manage high performance buildings.

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