



Présentation / Intervention

2013

Open Access

This version of the publication is provided by the author(s) and made available in accordance with the copyright holder(s).

Syndesi: A Framework for Creating Personalized Smart Environments using Wireless Sensor Networks

Evangelatos, Napoleon-Orestis; Samarasinghe, Kasun; Rolim, Jose

How to cite

EVANGELATOS, Napoleon-Orestis, SAMARASINGHE, Kasun, ROLIM, Jose. Syndesi: A Framework for Creating Personalized Smart Environments using Wireless Sensor Networks. In: IEEE International Conference on Distributed Computing in Sensor Systems. Cambridge, Massachusetts (United States). 2013.

This publication URL: <https://archive-ouverte.unige.ch/unige:88896>

Syndesi: A Framework for Creating Personalized Smart Environments using Wireless Sensor Networks

Orestis Evangelatos, Kasun Samarasinghe and Jose Rolim
Department of Computer Science
University of Geneva, Switzerland
{Orestis.Evangelatos,Kasun.Wijesiriwardana,Jose.Rolim}@unige.ch

Abstract—Smart environments are places where different kind of embedded devices are interconnected in order to provide their occupants intelligent services improving their comfort and convenience. These smart environments are seen to be important for the future urban ecosystems in terms of user friendliness, quality of life, energy efficiency and sustainability. Lately such environments have become economically and technologically feasible due to the advancements in embedded and distributed technologies. Most of the novel infrastructures adopt smart technologies, while old infrastructures need a transition towards smart environments. Even though different technologies and devices are available, there is a need for an appropriate methodology and a system architecture for a smooth and profitable transition towards smart environments. In this paper we present a framework for creating personalized smart environments using wireless sensor networks. This framework, among other services that it provides, is able to identify people and take personalized actions such as control electrical devices based on their preferences and needs. We present, as a proof of concept, a real world deployment where two scenarios are implemented in two office premises.

Index Terms—Wireless Sensor Networks, Smart Environments, Internet of Things, Personal Awareness, Distributed Systems

I. INTRODUCTION

Computer and communication technologies have greatly affected day to day lives of human society. Especially, mobile and wireless devices have even increasing computation and communication capabilities and provide easy access to various and ubiquitous information services. Wireless Sensor Networks (WSN) is a technology which can be used to enhance accessibility and availability of such ubiquitous services. With recent advancements in IP enabled WSN, these services are further enhanced. WSN coupled with IP technology become a viable candidate for various applications in many domains such as health care monitoring, environment monitoring and smart infrastructure.

Smart infrastructure is an important area of concern especially in the face of climate change and the foreseeable energy crisis. With the use of smart technologies, designers and architects expect sustainability and maintainability of infrastructures while optimizing the utilization of resources. In this context of smart infrastructure, wireless sensor networks play an important role due to the balance between flexibility and complexity they offer.

Even though there are many of WSN technologies and devices available, combining these technologies remains a challenge. This is mainly due to the lack of developments in unified frameworks which can support combination of heterogeneous devices and services. Such a framework should mainly provide support for discovery, maintainability, user-friendliness and combination of services. Furthermore, it should support various auxiliary services which can be used to develop and integrate other applications.

The contribution of this paper is a framework for unifying heterogeneous devices and services in the WSN domain, which can be used to develop more advanced and integrated applications for creating smart environments with a support of personalization. Our framework consist of the hardware interfaces and software services to support combined WSN based application development, electrical and electronic integration and user identification. Furthermore we use the REpresentational State Transfer (REST-style) [9] web service abstraction based on Constrained Application Protocol (CoAP) [16]. As a proof of concept we transform an old traditional infrastructure into a personalized smart environment based on our framework, which is connected to the Web and to electrical appliances through our developed electrical-electronic interface.

In the following sections we present our framework as follows: in Section II we briefly describe the background material and what motivates the need of such a framework. In Section III we present the *Syndesi* framework, its architecture and layers. A proof of concept of our framework follows in Section IV where we implement two different real life scenarios in an office space. In Section V we present the performance results of the framework and finally in Section VI we present our conclusions.

II. BACKGROUND

The advantages of distributed sensor networks including but not limited to reliability, scalability, dynamicity, efficiency have brought the WSN systems into the next generation. WSN systems play an inevitable role in our everyday life. A smart environment is a small world where all kinds of smart devices are continuously working to make inhabitants' lives more comfortable [4]. The use of WSN in this context

has drawn a lot of attention due to the flexible nature of such networks. With the developments in IP technologies and web service standards in WSN further extends the capability to develop smart environment applications based on standard protocols. The challenges of next-generation WSN in the smart environments' domain can be overcome using state-of-the-art technologies. By exploiting them, we could reach a credible future in the development of smart buildings.

Smart environments should act based on the individual occupants and their preferences. Therefore it is important to identify and track the occupants in the environment as well as provide the necessary services to them so that they can control and monitor their environment. Besides, a smart environment should be able to take autonomous decisions in order to provide comfort and safety to the occupants as well as being energy efficient.

To be able to realize such systems that are auto organizing, easily accessible, efficient and energy aware, new protocols and standards have to be developed. The state-of-the-art protocol suite 6LoWPAN [12], [15], [13] deployed by the 6LoWPAN working group of Internet Engineering Task Force (IETF) has defined the frame format for transmission of IPv6 packets to be sent and received over IEEE 802.15.4 networks. The authors in [8] present an analysis of smart building systems design approaches and implementation with WSN to conclude that the IPv6/6LoWPAN prevails against the IPv4. The 6LoWPAN stack enables each device to be directly connected to the Web. Based on these IP packets, a RESTful API for sensor nodes has been developed. REST is a style of software architecture for distributed systems such as the World Wide Web [9].

Inside a smart environment many sensors and actuators are interconnected to form a control system. The deployment of such a control system is complicated due to different communication standards. In [14] the authors implemented an API to access services on sensor nodes following the architectural style of REST. An approach towards the integration of tiny wireless sensors or actuator nodes into an IPv6 6LoWPAN based network is presented. They propose the use of lightweight Web services based on REST and the representation of data in the JSON format together with the stateless address auto-configuration mechanisms provided by the IPv6 protocol.

In the home automation design field a wireless sensor network system using 6LoWPAN has proposed [17]. A vital part of an WSN architecture design is gateways. The gateway provides all the necessary interconnection schemes that makes a WSN able to connect to other WSN and to the Web. The design and the construction of a wireless sensor and actuator network gateway based on 6LoWPAN are shown in [5].

An application framework for Web-based smart homes is presented in [10]. RESTful services over HTTP to connect sensors directly to the Web is used. We go further than the results of this work that are limited in an 6LoWPAN WSN inside a home environment, by creating a general framework for smart environments which includes heterogeneous WSNs,

occupant identification and interconnection of electrical devices.

The authors in [6] are mentioning the capabilities of using NFC in smart home environments of the future IoT systems but their system is not yet connected with any WSN network for monitoring the environment and controlling appliances.

A framework to integrate sensors and actuators with IP networks based on the REST architecture is proposed in [14]. The authors propose a dynamic service discovery mechanism based on a REST API through which services provided by the WSN nodes can be discovered. Since both the architecture and the Web protocols are location transparent, we identify a need of a location based service discovery mechanism, especially in smart environment applications.

III. SYNDESI FRAMEWORK

The aim of the *Syndesi* framework is to create personalized smart environments using WSNs. It combines networks of sensors, nodes and actuators with different communication technologies such as Near Field Communication (NFC), Bluetooth, ZigBee, and 6LoWPAN along with an electrical interface.

By using state of the art technologies and communication protocols in the domain of distributed computing, the *Syndesi* framework can transform an old traditional infrastructure into a smart environment. Through this framework practically any electrical device can be controlled via the Internet, a smart-phone or automatically by the framework itself. The WSN that is deployed at the heart of the framework has the ability to monitor the environment of an infrastructure and to control it as well. Furthermore, this framework provides an external interface so that each individual node or the whole system can be operated through Web-based applications. Apart from the general management of the system, taking into account the preferences of the occupants of a smart environment, the framework leads to personalized and optimized system performance. In order to provide personalized services to the occupants it is necessary to incorporate tools for their identification, tracking and localization. In this context we interconnect within the framework NFC tags, NFC enabled smart phones and Bluetooth enabled devices which provide a better user experience to the occupants. Moreover, this framework eases the management and the maintainability of such an environment.

A. General Behaviour of the *Syndesi* Framework

The behavior of the *Syndesi* framework is twofold. On one hand the framework acts as a *centralized system*, where the system relies on centralized information so as to provide specific services. This centralized behavior of the framework is activated when the system requires, for example, the profile information of an occupant from the gateway in order to drive some actuators of the system. Specific examples include: when a user needs its personal heating to be turned on when it is cold outside or when the management of a building requires information about the status of the sensors via the Web.

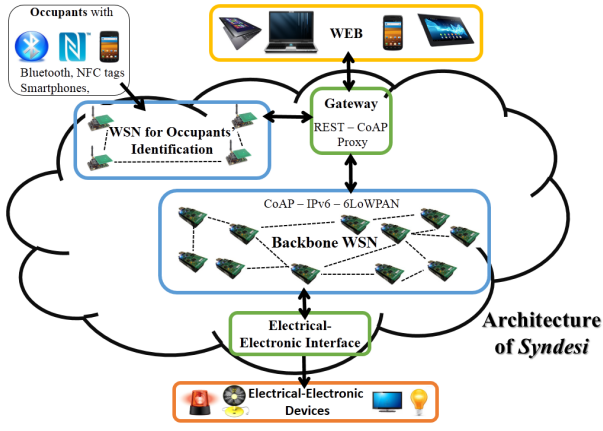


Fig. 1: Architectural Overview of the Syndesi Framework

On the other hand, the framework has a *distributed behavior*. The system reacts in a distributed manner when individual sensors perform autonomously. A descriptive scenario of such behavior is the case of an emergency situation when a fire breaks out in a room. In that case an alarm can be triggered directly and automatically by the fire detection sensor.

This twofold behavior of our framework allows for the realization of multiple and complex real life scenarios where a centralized and/or a distributed processing is needed.

B. Architecture of Syndesi

The overall architecture of the framework is illustrated in Figure 1, which presents the interconnections between the components of the framework. Following we describe each component of the framework in details.

1) WSN for Occupants' Identification

For the identification, simple tracking and localization of the occupants in our framework is dedicated a WSN which is deployed with the use of Wasmotes by Libelium [2]. The Wasmotes are sensor devices oriented for developers. They support ZigBee, WiFi, Bluetooth, NFC/RFID and GSM/GPRS communication interfaces, which makes them a good candidate for being used as gateway nodes between nodes that do not share a common communication interface. An inevitable part of a smart environment is its occupants, consequently it is crucial for the framework that controls this smart environment and provides smart services to its occupants to be capable of identifying and tracking them.

2) Gateway

The gateway of the Syndesi framework is interconnected with the *Backbone WSN*, the *WSN for Occupants' Identification* and the *Web*. It contains the two base-stations of the two different WSNs so as to provide connectivity with them. On the other side it provides a proxy server in order to make the whole framework accessible to the Web connecting both CoAP and HTTP enabled systems.

3) Backbone WSN

The *Backbone WSN* comprises the sensors which are responsible for the monitoring and control of the smart environment. These sensors are capable of communicating over the wireless medium. For the backbone WSN, TelosB [1] sensor nodes are used. The TelosB node is an open source platform designed to enable cutting-edge experimentation. These nodes form a wireless sensor network based on the 6LoWPAN protocol implementation available in the Contiki operating system. Therefore, the network is IPv6 addressable with optimized IP services such as routing for low power wireless links. Some of the WSN's motes are used as actuators taking part also in the *Electrical-Electronic Interface* which is connected to electrical and electronic appliances.

4) Electrical-Electronic Interface

As one end of our framework consists of electrical and electronic appliances, we developed an interface with which we are able to control them. An electrical or an electronic device can be powered either by Alternating Current (AC) or by Direct Current (DC) supply. For manipulating these two different types of current, we need two different types of relays: one for switching AC circuits being driven by DC and the other one for switching DC circuits being also driven by DC. Thus, to be able to control any AC or DC electrical or electronic device we use DC-DC and DC-AC relays which are driven by the General I/O (GI/O) of the sensors. We use solid state relays which have increased long-term reliability as a consequence of the inexistence of moving components. In this way, via the Syndesi framework, is feasible to control practically any electrical or electronic appliance, be it a light bulb, a fan, a LED array or a TV set.

C. Layered overview of Syndesi

Interconnection of heterogeneous networks has to be handled by standard messaging and communication protocols. As our framework comprises two different wireless networking technologies (Zigbee and 6LoWPAN), a service oriented architecture can be used to unify the different components. In other words, we define REST style services using COAP in the embedded domain, and mediate them with HTTP services using the proxy service. This mediation takes place in the gateway, which eventually connects both WSN with the web. Therefore it leads to an easy application integration of the framework. We use the light weight JavaScript Object Notation (JSON) as the message format, since it is preferred over XML, especially for the embedded domain applications. Figure 2 illustrates the layered overview of our framework across its components. The set of gray boxes illustrates the main services provided by the framework, which are described below.

1) Actuator Service

Sensors and actuators available in the sensor platform act as an interface between the physical environment and the framework. Such sensors provide readings of the environment parameters via the system software available in the Contiki

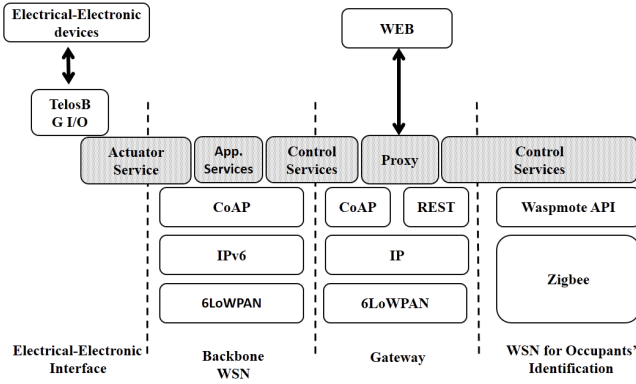


Fig. 2: Layered Overview of Syndesi Framework

operating system. Similarly we implemented actuator drivers in Contiki. Services can use these actuator drivers to make them available to the framework.

2) Control services for the backbone WSN

Control services provide auxiliary services to facilitate the control and monitoring of the application services. For example, these can be services defined to ensure the quality of service requirements of the framework. We define these services in such a way that the overhead added by them is compensated with the quality of service they provide to the system.

a) Application Services

Application services are the services required by specific applications intended to be built upon the framework. In general, these application services expose sensors as services, which are inputs to the framework or expose actuators as services, which control objects of the system. These individual services are combined to perform useful application tasks.

b) Localized Service Mapping

Most of the algorithms performed in smart environment applications need to have a knowledge of the physical locations of the sensors and actuators (nodes of the WSN). Moreover, such algorithms need to be aware of the physical correspondence of the nodes within a context of the considered space. In a smart building scenario nodes have to be mapped with the floor plan of the building. By contrast, IP networks do not maintain any knowledge of the nodes in the network. Therefore, to compensate the fact that IP addressing is location independent, there should be a service discovery mechanism based on the location. This ideally should maintain a mapping between the physical location of a node with its IP address and the services provided.

Due to the lack of low cost and accurate localization protocols implemented in practical settings, we implemented a centralized location mapping service. In other words, we assume a sensor is bound to a specific location and identified by a unique location identifier. We label the nodes of the network with this location identifier when deploying the individual nodes. These

labels form a logical tree structure which is rooted at the base station connected to the gateway. The framework maintains a centralized registry of these labels, essentially a tree structure of labels. Maintaining a tree topology is natural mainly since the objects needed to be considered in a smart infrastructure system can be modelled as a hierarchical structure. Especially in a scenario like a smart building system, whole system can be hierarchically modelled as a tree with the root being the central coordinator of the system.

c) Maintenance Services

As most of the smart environment systems are time and safety critical, there must be provisions to ensure such demands. Therefore, we designed additional services to ease the management and monitor the health of the system. We first define a periodic status update service which sends sensor readings and the status of a node to the central registry. In addition, each node exposes a service which can be invoked to check the presence of a node (namely, a "heartbeat" service). Furthermore a node maintains a state of itself and changes its state accordingly.

d) Proxy Service

Both application and framework services are COAP services, which are not possible to invoke over standard Web protocols. Therefore, to expose these services to the Web, we implemented a proxy service, which supports RESTfull interaction over HTTP with COAP service. We define RESTfull services interfaces to utilize both application and framework services, which can be used to develop required applications based on our framework. Due to its compliance with standard Web protocols, these applications are easily portable across all the platforms and devices.

3) Control services for the WSN for Occupants' Identification

As the scope of this work is not to deploy complex algorithms for user discovery, tracking and identification, we deploy a simple algorithm in the Wasmotes-WSN which is able to identify a user by the two following ways:

a) Bluetooth

The first way for the identification and simple tracking of a user is realized with the use of the sensing capabilities of a Bluetooth discovery sensor with which we are able to identify or track Bluetooth enabled devices in the proximity. The algorithm for this sensor is looking for Bluetooth devices and notifies the system once they are discovered. In this way we are able to make a one to one correlation of unique MAC addresses and specific users. The range of the sensor with a 5 dBi antenna allows us to scan devices in a range of few dozens meters around the sensor.

b) NFC

The other way to identify and locate the position of a person is done via the Near Field Communications sensor reader. This sensor is supporting read and write functionalities of several protocols. The maximum distance for a NFC chip to activate the NFC-sensor-reader is 7 cm. A simple touch of an NFC card on the sensor is enough to interact with the reader transmitting data with a maximum speed of 424kbps. Due to the short range

of transmissions the NFC is inherently secure [3]. This new emerging technology of the NFC communications creates a new and universal interface to existing devices through simple touch interaction.

With both of the above identification systems, the unique ID of a user is being transmitted from the identification sensors to the base-station of the Waspnotes-WSN and afterwards to the Gateway of the *Syndesi* framework. There are two ways by which we can transmit the data to the gateway: the first one is via a USB serial connection and the other one is via a Zigbee communication.

IV. PROOF OF CONCEPT

For the proof of concept of our *Syndesi* framework we implemented two real life scenarios in two rooms of our office. As our building is an old traditional infrastructure we use our framework, the WEB and some electrical devices to transform our office into a smart personalized environment. In both scenarios we focused on personalization, comfort, safety and energy efficiency.

A. Description of the environment

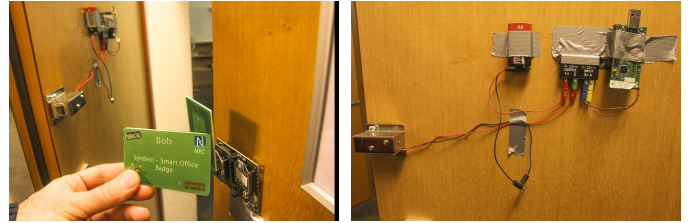
The implementation took part in two rooms of our office where 8 people work. We connected to our framework the existing electrical and electronic devices which are used every day. As it is shown in the 3D representation of our office (Figure 3) the electrical and electronic devices connected to the framework are marked with a "cross", and the sensors for monitoring the environment with a "star". Following we present the devices connected to our framework in more detail. We connected the 8 personal desk lamps placed on each desk. There are six floor lamps that are placed in between of the desks which produce enough light to cover with sufficient working light the two desks next to it and sufficient ambient light for the area around them. We have placed a fan and a heater in each room to maintain comfortable room temperatures in the office as our infrastructure is old and it has insufficient HVAC system. On top of one of the windows we placed a roll-curtain which we connected to an electrical motor for raising and lowering it. On the inside part of the doors we installed electric locks while on the top of the doors we installed a siren alarm together with an emergency red light.

B. Description of scenarios

The implemented scenario involved all the 8 person who work in these two rooms. For each person was created a profile account in a database which contains basic personal information about him/her such as: Name, Age, Sex, Profession, Desk Location, preferable Temperature and Lighting condition. Consider now an ordinary day when "Bob" is arriving to his office; he touches with his personal and unique NFC-tag the NFC-sensor on his office door (Figure 4a). Then the system identifies his unique ID in the database and it disengages the electrical door lock (Figure 4b). At the same time, if the luminosity inside the room is below the default threshold then

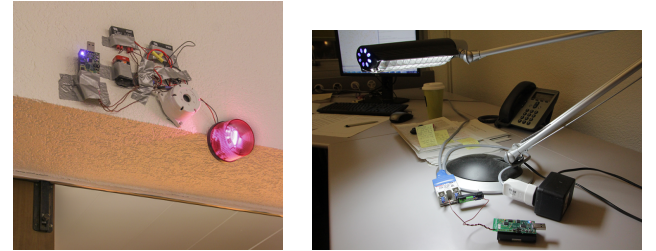


Fig. 3: Office Environment of implementation. The "cross" represents the electrical-electronic interface and the "star" the sensors for monitoring the environment.



(a) NFC sensor reader connected to the WSN for occupants' identification (b) Electric door lock connected with the Electrical-Electronic Interface

Fig. 4: Occupants' identification and door unlocking



(a) Siren and alarm light

(b) Desk lamp

Fig. 5: Alarm system and desk lamp connected to the Electrical-Electronic Interface

the system raises the curtains. In the case when the outside light is still below his preferences, then his desk lamp will switch on (Figure 5b). The same algorithms apply for the personalized temperature, heating and ventilation control. The above scenario represents an example of a centralized behavior of the framework.

On the other hand, the distributed behavior of the framework is presented in the following scenario: people are working at the office when suddenly a fire breaks out in a lamp in a room. The system then recognizing the extreme high temperature due to the fire, automatically cuts off the power to this lamp and triggers immediately the alarm system (Figure 5a). In that case the messages generated by the sensor are transmitted directly to the actuators and afterwards the gateway will be updated concerning the status of the environment.

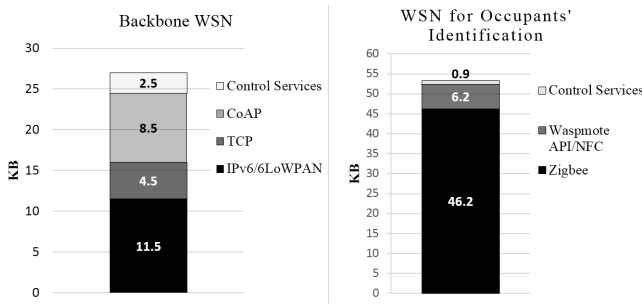


Fig. 6: ROM memory footprint of system software components and added ROM values by the *Syndesi* framework

V. PERFORMANCE

We evaluated the performance of our framework based on the distributed and centralized scenarios as described in section IV. We measured the response time in the two different scenarios and the ROM memory footprint of both WSN. In the first scenario, we define as response time the time between the moment that an NFC card is detected until the moment the door is unlocked. We found out that the average response time is 2.3 seconds. In the second scenario, as response time we define the time between the detection of the high temperature of a sensor until the moment the lamp switches off and the alarm triggers and we found out that the average response time is 0.7 seconds.

Considering the control services of the *Syndesi* framework in both WSN, the ROM memory footprints are illustrated in Figure 6 along with the underlying system software components [7], [11]. As shown, our framework adds 2,5 KBytes and 0,9 KBytes to the system software of the *Backbone WSN* and *WSN for Occupant's Identification* respectively

VI. CONCLUSIONS

In this paper we presented the *Syndesi* framework for creating personalized smart environments using diverse technologies, heterogeneous wireless sensor networks and state of the art communication protocols such as NFC and 6LoWPAN. We identify some of the shortcomings of existing frameworks based on WSN, and propose solutions for a comprehensive framework. We mainly identify the necessity of personalization in a smart environment and enable our framework with occupant identification capability. In order to control the electrical and electronic devices, we designed an electrical-electronic interface through which we make feasible the connection of such devices to the smart environment. Furthermore, we propose a location based service discovery mechanism where, the web services exposed by the sensors are mapped with their physical location. Finally we conclude that our framework reacts relatively fast to the user interactions and to the changes of the environment while at the same time it adds a small overhead in the software memory requirements.

Syndesi is a framework which can be used in several types of infrastructures such as hospitals, schools, parking lots and houses. It is a scalable framework which can be

easily expanded. Should someone need to connect more sensors/actuators and electrical appliances, the design of the framework allows for easy integration. Furthermore it provides energy efficiency, safety and convenience to the inhabitants, user-friendly interaction and accessibility over the Web.

As a future work we envision the extension of the *Syndesi* framework in such a way that it will provide an optimized energy consumption in smart environments. Moreover we believe that this framework could be integrated with social networks and crowdsensing applications for a better incorporation of personal information and user experience.

VII. ACKNOWLEDGMENT

This work has been partially supported by the IST Programme of the European Union under contract number ICT/FIRE/-STREP257466 (HOBNET) and Swiss National Science Foundation under the project number 200021 135516.

REFERENCES

- [1] Telosb motes datasheet. <http://bullseye.xbow.com:81/Products>.
- [2] www.libelium.com.
- [3] www.nfc-forum.org.
- [4] D. Cook and S. Das. *Smart Environments: Technology, Protocols and Applications (Wiley Series on Parallel and Distributed Computing)*. Wiley-Interscience, 2004.
- [5] Bruno da Silva et al. Design and construction of a wireless sensor and actuator network gateway based on 6lowpan. In *Proceedings of EUROCON 2011, International Conference on Computer as a Tool, 27-29 April 2011, Lisbon, Portugal*. IEEE, 2011.
- [6] M. Darianian and M. Michael. Smart home mobile rfid-based internet-of-things systems and services. In *Proceedings of the 2008 International Conference on Advanced Computer Theory and Engineering, ICACTE '08*, Washington, DC, USA, 2008. IEEE Computer Society.
- [7] M. Durvy et al. Making sensor networks ipv6 ready. In *Proceedings of the 6th ACM conference on Embedded network sensor systems, SenSys '08*, pages 421–422, New York, NY, USA, 2008. ACM.
- [8] O. Evangelatos, K. Samarasinghe, and J. Rolim. Evaluating design approaches for smart building systems. In *IEEE MASS 2012 Workshop on Internet of Things Technology and Architectures (IoTech'12)*, Las Vegas, USA, 2012.
- [9] Roy T. Fielding and Richard N. Taylor. Principled design of the modern web architecture. *ACM Trans. Internet Technol.*, 2002.
- [10] A. Kamilaris, V. Trifa, and A. Pitsillides. Homeweb: An application framework for web-based smart homes. In *Telecommunications (ICT), 2011 18th International Conference on*, 2011.
- [11] Matthias Kovatsch, Simon Duquennoy, and Adam Dunkels. A low-power coap for contiki. In *Proceedings of the 8th IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS 2011)*, Spain.
- [12] N. Kushalnagar, G. Montenegro, D. Culler, and J. Hui. Transmission of IPv6 Packets over IEEE 802.15.4 Networks. Technical Report 4944, RFC Editor, September 2007.
- [13] G. Mulligan. The 6lowpan architecture. In *Proceedings of the 4th workshop on Embedded networked sensors, EmNets '07*, New York, NY, USA, 2007. ACM.
- [14] L. Schor, P. Sommer, and R. Wattenhofer. Towards a zero-configuration wireless sensor network architecture for smart buildings. In *Proceedings of the First ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings, BuildSys '09*, NY, USA.
- [15] Z. Shelby and C. Bormann. *6LoWPAN: The Wireless Embedded Internet*. Wiley Publishing, 2010.
- [16] Z. Shelby, K. Hartke, C. Bormann, and B. Frank. Constrained Application Protocol (CoAP). Technical Report draft-ietf-core-coap-07.txt, 2011.
- [17] Dan Stefan Tudose et al. Home automation design using 6lowpan wireless sensor networks. In *Distributed Computing in Sensor Systems, 7th IEEE International Conference and Workshops, DCOSS 2011, Barcelona, Spain, 27-29 June, 2011, Proceedings*, 2011.