Dedication

This thesis is dedicated especially to my Parents for instilling the importance of hard work and higher education, for their guidance, support and extraordinary courage. To my Professors who have been my friends, guides and philosophers. To my best friends who have always assisted me and believed that I could do it. To my family who have always stood by me and dealt with all of my absence from many family occasions with a smile.

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CHAPTER 1

Introduction

Recent technological improvements toward the miniaturization and ubiquity of computing devices have lead to the emergence of Wireless Sensor Networks (WSNs) [1,2]. This type of networks consist of a huge number of small and low-cost wireless sensor nodes characterized by their limited resources in power, computational capacities and memory [3]. These small nodes are used to collect the environmental data such as light, humidity and temperature.

Due to its real-time detection and early warning applications (like fires, tsunamis and earthquakes), WSN has been useful in different application fields like environmental observations (include forest fire detection, air/water pollution, rainfall observation) [4], military monitoring, building monitoring [5],health-care monitoring [6], etc.

In spite of their useful applications, many challenges concerning the design and the implementation processes of WSNs are required. Especially those to enable users to remotely interact with the sensor nodes in their environment and make them interacting with each other. Achieving this challenge can improve the development of the WSNs by adopting the concept of the Internet-of-Things and exposing the device services and capabilities in the World Wide Web to provide functionalities similar to those available through the Internet. Hence, the idea of integrating WSNs with Service-Oriented-Architecture (SOA) has been raised [7] by emerging the concept of "‘Sensor Web"’ [8]. This latter aims mainly to achieve a collaborative, consistent, and consolidated sensor data collection, fusion and distribution system, typically used in environment monitoring applications. This new earth-observation system opens up a new avenue to fast assimilation of data from various sensors and accurate analysis and informed decision makings [9]. In fact, the key challenge in building the Sensor Web is how to remotely retrieve, discover and inertact with data observed by heterogenous sensors via the Internet.

To realize an efficient sensor Web, the Open Geospatial Consortiums (OGC) have recently established Sensor Web Enablement (SWE) initiatives that enable the creation of web-accessible sensor assets through common interfaces and encodings by developing a suite of specifications related to sensors, sensor data models, and sensor Web services.

In this Thesis, we poposed a seamless approach based on combining the OGC' s SWE services with the lightweight REST architectural style. Moreover, to trigger a good extension to our approach, we proposed the usage of JavaScript Object Notation (JSON) format as an alternative to the verbose XML format of the SWE standards.
In fact, our work is mainly based on the approach described in [10], which improves the feasibility of using RESTful Web services to integrate SOA with IP-based WSNs and presents sensors and actuators as resources accessible via the Internet.

1.1 Motivation

1.1.1 WSNs Overview

WSN is considered as one of the main topics in Computer science researches. This was motivated by the fact that these networks can improve the quality of life by providing various applications in the favor of different fields such as environment monitoring, home automation, traffic control and helath-care control.

WSN consists of deploying thousands of tiny nodes to make an efficient coverage of the monitored field. In spite of their useful applications, to make an efficient interaction of the WSNs with their environment, many factors should be taken into consideration such as:

- **Ad hoc deployment:** The sensor nodes should identify its connectivity and distribution when they are deployed in no infrastructure regions.

- **Unattended operation:** There is a possibility that after being deployed, sensor networks have no human intervention. That makes the nodes responsable for reconfigurating themselves in case of environmental changes.

- **Untethered:** Because of their limited resources in power depending on the batteries, the sensor nodes try to use optimally this resource by minimizing the communication as much as possible.

- **Dynamic changes:** The sensor network should be adaptable to system connectivity and environtmental changing.

These factors join the low power and small memory of sensor nodes to represent an impediment on the development and design of architectures and protocol stacks for WSNs.

1.1.2 IPv6-based Low-Power Wireless Personal Area Networks (6LoWPANs)

The Low-power wireless personal area networks (LoWPANs) have been raised with the emergence of the IEEE 802.15.4 radio-based devices with their limited resources.

Although it has a vital roles in the pervasive environments, the usage of LoWPAN presents a number of challenges especially in terms of interoperability between the constrained Networks and the other Networks like IPv6.

To overcome these shortfalls and ensure the concept of Wireless Embedded Internet, the 6LoWPAN standard has been emerged [11,12]. Indeed, it presents the key advantage of enabling IPv6-users to remotely and seamlessly access low power embedded devices [13], such as wireless sensor nodes, through the Internet.

This new paradigm opens the door to several new challenges for adapting/adopting legacy Internet solution in the LoWPAN area, and these challenges are inherited from the resource-constrained nature of low-power devices. Among these challenges there is the integration of Service-Oriented-Architecture (SOA) with LoWPANs to provide services accessible via the Internet and achieve interoperability at the application Layer.

1.1.3 Service-Oriented-Architecture (SOA)

SOA is one of the core mechanism for service deployment in the Internet that has been adapted in WSNs for making easier and more effective service deployment [14,15,16]. In fact, it possesses an architectural style encompassing a set of loosely coupled services that are defined out of any execution context and interact on the fly without prior collaboration agreement.

This technology enables to access and share the services, data, computational and communication resources in the network for multiple users. It also allows rapid and cost-effective composition of interoperable and scalable systems based on reusable services exposed by these systems.

Applying the idea of SOA into LoWPANs and especially for WSNs has been emerged in order to present sensors as reusable resources that can be discoverable, accessible, shared and even controlled through the World Wide Web [17,18]. It also supports heterogeneous infrastructures and allows to link distributed resources in order to create a sensor grid, enabling the advantages of a computational grid that offers reliable and accessible services to end users [19].

1.2 Problem Statement

The increasing complexity of device networks consisting of up to thousands of devices is demanding new technologies for simple device interaction and interoperability. Indeed, sensor networks are currently developed around different communities of sensor types and user types, with each community typically relying on its own system, its on metadata semantics, its own data formats, and its own software.Thus the ability to discover and utilize a new sensor asset is typically hindered by incompatible encodings and services.

To overcome this incompatibility, a coherent infrastructure is needed to treat sensors in an interoperable, platform-independent and uniform way using lightweight format for data and exchanged messages. In addition, the architectural style of this infrastructure should be based on a lightweight web service mechanisms that require a minimum processing power and communication bandwidth to take into consideration the limited resources of WSNs.

1.3 Objectives & Proposed Solutions

To ensure an efficient and distributed infrastructure for publishing, discovering and accessing sensor resources and to tackle, to some extent, the challenge of data fusion, we propose to adapt the Open Geospatial Consortium' s Sensor Web Enablement (OGC' s SWE) initiative, which was designed to enable the creation of web-accessible sensor assets through common interfaces and encodings [20,21].

On the other hand, the use of the OGC' s SWE initiative, as any other technology, is accompanied by some limitations and challenges that should be avoided to provide an efficient services for WSNs. Among these shortcomings, SWE has the limitation that it only provides rudimentary support for the required data conversion. In addition, we address the problems related to the data format of the SWE services that are mainly based on the verbose XML format, and the architectural style followed by the implementation of the SWE services.

Indeed, we propose the adoption of the Representational State Transfer (REST) [22,23], which is a lightweight instantiation of the web services concept that is particularly well suited to the properties of sensor networks by reducing the overhead imposed by traditional Web Service technologies. Moreover, we raise the idea of using the lightwight JavaScript Object Notation (JSON) format as an alternative to the verbose XML one.

1.4 Outline

After introducing the problem and explaining the issues of motivation, the remainder of this thesis will be structured as follows:

In the second Chapter we give an overview of the main research efforts and models that contributed to feature the integration of Wireless Sensor Networks (WSNs) with Service Oriented Architecture (SOA) in a 6LOWPAN area.

Chapter 3 lays the foundations of the proposed model that adapts the SWE services to the REST architectural style. We start by introducing the ingredients of this approach. Then, the system architecture and the adaptation features are detailed.

The implementation of the proposed approach, described in the previous Chapter, is explained in Chapter 4. The results of the experimentation and the performance evaluation are also depicted in this Chapter and some interpretations of these results are given too.

Finally, we conclude the thesis and outline the open challenges and future work.

Integration of SOA and Wireless Sensors Networks: A RESTful Approach

Abstract: The large diffusion of wireless sensors in our contemporary life, with their numerous applications, has led to a huge heterogeneity. Indeed, each type of sensor tends to be accompanied by its on its own system for discovery and accessing observations, its own metadata semantics, its own data formats, and its own software. Thus, the ability to discover and analyze a new sensor asset within the Wireless Sensor Networks (WSNs) is typically hindered by incompatible encodings and services.

Therefore, a coherent infrastructure is needed to reflect the concept of Service-Oriented-Architecture (SOA) in Low Power Wireless Personal Area Networks (LOWPANs) and enable to treat sensors in an interoperable, platform-independent and standard way for sharing, finding, and accessing sensors and their data across different applications.

To overcome these shortfalls, we adopted the technique of integrating a representational state transfer (REST) APIs into the sensor nodes that will be accessible to the Web-user by using RESTful Web services via Internet. Moreover, we tried to extend this concept by designing an architecture that combine REST architectural style with the Open Geospatial Consortiums Sensor Web Enablement (OGC's SWE) standards within a 6LoWPAN area. The main contribution of our thesis is this combination, which takes into consideration the limited resources of the WSNs and makes an efficient communication between the different components of the system through a JSON messages instead of the XML ones in order to trigger a good extension to the concept of "'Sensor Web"'.

Keywords: WSNs, 6LOWPAN, SOA, REST, OGC's SWE.