Efficient SOA-based Network Management Architecture in Wireless Sensor Networks

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ABSTRACT: During the past few years there has been an explosive growth in the research devoted to the field of wireless sensor networks (WSN).These networks use hundreds to thousands of inexpensive wireless sensor nodes over an area for the purpose of monitoring certain phenomena and capture geographically distinct measurements over a long period of time. The pervasive interconnection of such nodes has given birth to a broad class of exciting new applications in several areas of our lives, including environment and habitat monitoring, healthcare applications, home automation, and traffic control. Up to now most of the works focused on designing routing protocols to address energy consumption issue, fault tolerance of WSN. In our work we designed a model which is based on service oriented architecture (SOA) for the management of WSN through internet mainly. Our model builds a standardized interface between a WSN and external IP network. Designed gateway that offers a synthesis of web services offers by the WSN assuring its entire management. Furthermore, Authentication, Authorization and Accounting mechanism has been implements to provide security services.

Keywords: Service-Oriented Architecture, Web services, Wireless sensor networks, AAA

1. INTRODUCTION

A wireless sensor network is composed of a large number of nodes in each of which there are a number of sensor nodes. These sensor nodes are placed manually or by random at desired locations; but sometimes no definite pattern is followed in placing the sensors so that they can be put in inaccessible or dangerous locations. These sensor nodes evaluate conditions such as temperature, light intensity, pressure, etc. and the processed information is sent through sink node to base stations (BS) in order to be used in the application operations. The BS stores and/or processes data according to the application. WSN can be used in a couple of areas ranging from military tracking and surveillance to civilian applications in home automation (smart home), agriculture, intrusion detection and so on.
In sensor networks environments, it is more useful form the applications point of view to have nodes identified by the type of sensor node or by their geographical location. Several works [5, 6] WSNs need to be interconnected with the existing IP networks and mainly Internet. In the data-centric approach, nodes are addressed by the type of data they provide, or by their interest in some type of sensing data. Current works [5, 6] consider sensor networks as being designed for specific applications, with data communication protocols strongly coupled to the application. In fact, the network requirements, organization, and routing behavior change according to the application. In spite of the application specific behavior of the current sensor networks, many authors [10] envision the future sensor networks as being composed of heterogeneous sensor devices and assisting to a large range of applications. To achieve this goal, a new architectural approach is needed, where application specific requirements are separated from the data dissemination functions. In such architecture, the components should be loosely coupled, having well defined interfaces for WSN and traditional IP networks.

Data Services are published and accessed using the Web Services technology [3] i.e. SOA. By adopting the Web Services paradigm, we propose a novel architecture for sensor networks, in which the Web Services Description Language (WSDL) [15] is used to describe data and functionalities of sensor nodes. Sink nodes are Web Services that offer a standard interface for accessing services provided by the network. Queries submitted by user applications from the IP networks are accomplished through such a gateway interface.

In this perspective, we designed a SOA based model that offers standardized level gateway interface between a WSN and external network. Gateway that offers a synthesis of web services offers by the WSN assuring its entire management. The designed model gives access for user and application to manage the WSN in secure fashion with the aid of encryption and signature of the exchanged SOAP messages. Furthermore it offers Authentication, Authorization and Accounting services. We designed a generic architecture independently from any application. Here we have taken home energy automation

The article is organized as follows. Section 2 covers the background concepts. Section 3 presents the detailed architecture. Next, Sections 4 gives an application instantiation of the model description. Section 5 gives the instantiation results Finally, Section 6 outlines the conclusions.

2. BACKGROUND

2.1 Overview

Wireless sensor networks have certain unique features which must be accounted for in any data dissemination methodology designed for such networks. The gateway through which sensor networks communicate with the external world (e.g., IT network, a monitoring terminal or the Internet) is called an access point. We use the term access path to refer to the set of data paths from the sensor nodes to the access point. In a typical scenario, we can expect these access points to have higher communication load than other sensor nodes. In a high-traffic scenario, such access points can become a bottleneck point in the sensor sink. An essential design requirement, then, is to minimize the peak amount of traffic owing through these access points.

Prior research [1, 4] has shown that the tight energy constraints of wireless sensor networks can be more efficiently achieved by using an attribute-based naming system than by commonly used topological naming schemes (e.g., IP). Such attributes could be pre-defined to reduce the overhead during actual communication. For example, we could classify all sensor data in an environmental sensing network as being of types “temperature", “pressure" and “humidity" and name all such data by including these pre-defined event attributes in the data itself. At the lowest level, when an event occurs the sensors record and store the event data locally, and name this data based on its attributes. The low-level output from sensors (observations) is named based on the attributes of the associated data. Application requesting data send out interests through some sink in the network. These interests are also represented as a set of attributes.

Despite of the advantages of data-centric addressing in sensor networks, recent works [5, 6] assume that the data representation is application-specific or offer schemes with low flexibility and expressivity. Such approaches require strong coupling between the data or interest representation model and the application querying the network. We can envision a class of future sensor networks as being accessed by several different applications submitting queries through arbitrarily localized sinks. To enable such scenario, the network should be accessed through a common and application independent gateway interface.

The present work suggests a services oriented approach for architecting wireless sensor networks.

2.2. Service Oriented Architecture

Concept for designing and implementing distributed systems such that functionality is encapsulated into inter-operable services. The main goal is to partition business functionality in a way that it can be orchestrated in a loosely-coupled and re-usable fashion. Also, the integration into workflow systems is facilitated by this architectural style. Currently, no clear and concise definition of SOA exists.
In this respect, service oriented architectures provide a model in which each network node offers its functionality through independent services accessible in a standardized manner. SOA implies that all the different elements that form the system are related with each other as services. This service orientation is the next evolutionary step from the traditional client-server model with *Service Providers* instead of servers and *Service Consumers* instead of clients, but decentralizing the whole process by introducing the *Service Broker* as a new element, whose function is to keep the record of all services offered throughout the system and describe its use. There are currently a set of standard technologies which make SOA based applications possible: XML language and WSDL languages to describe services, SOAP to provide services and UDDI services to register them. The conjunction of these technologies constitutes the basis of Web Services (WS).

3. GLOBAL MODEL

Our Model compromised with three major levels

- Business level
- Monitoring level
- Client application level

3.1. Business level

The business level serves to realize all the functionalities necessary that the network management required. Gateway and UDDI registry gathers processes and stores the information delivered by different client application in terms of web services. The Gateway it insures the AAA to protect the WSN and insures the translation of the requests (made by the users through Web Services) into requests according to the operating system and technology run by the sensors, and vice versa for the responses. These processes are termed as *publication and discovery phases.*

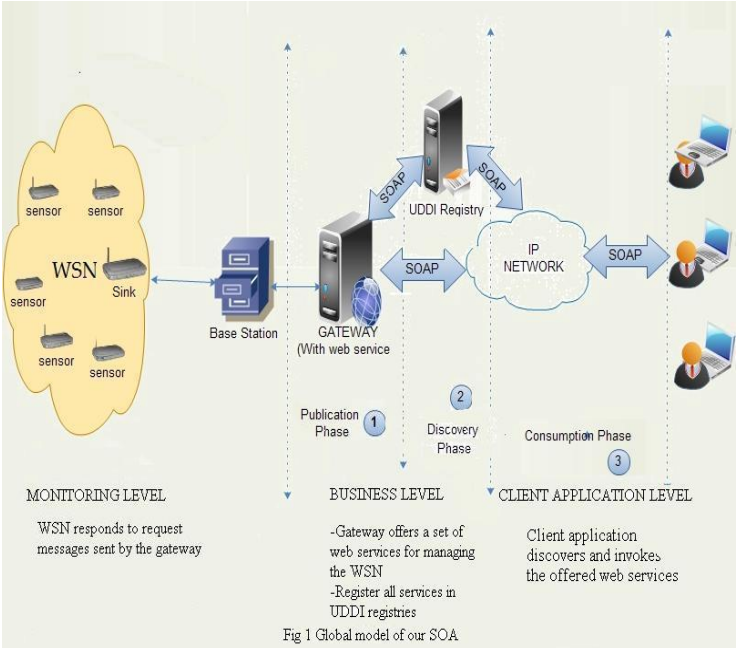

Fig 1: Global model of our SOA

Web Services offered by business level:

- *Web Services for WSN real time interrogation:* they are services that request a real time data from the sensors or a particular sensor. It could be, for instance, *"The temperature in my bed room* sensors Operating System and technology and sent to the appropriate sensor. The response, given by the sensor, is sent back to the user.

- *Web Services for the WSN management:* they are services that deal with the management of the WSN. It could be turning on/off some sensors, modifying the sensing interval of a sensor, launching and stopping the capture-store function
- *Web Services for subscription to events:* they are services that could be invoked by users or applications that want to subscribe to some events in the WSN.
- *Web Services for administration:* they are services dedicated to the administrators. They help them to set, modify and remove users and authorizations. They focus on the management of the AAA functionalities.

3.1.1 Gateway Modules

The gateway as a whole is divided into four main modules. These modules are interconnected in a mesh structure to simplify the design and for better efficiency. The different modules and the interconnections between them are shown in Fig. 2. They are:

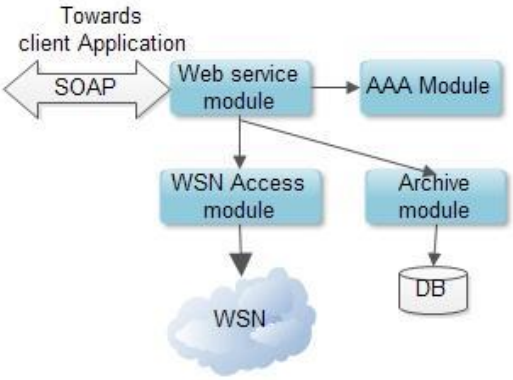

Fig 2.Various Gateway modules

a) *Web Services Module:* it represents the different Web Services offered by the Gateway. It assures the interface with the Internet and handles the requests coming from the clients (user applications).. It is also responsible for the advertising of the offered Web Services (in UDDI registries).
b) *AAA Module:* it is responsible for the implementation of the Authentication, Authorization And Accounting functionalities. It is coupled with a dedicated AAA server. It is a critical part in the gateway since it checks the security credentials related to the user, mainly a user name and a password.
c) *Archive Module:* it is responsible for storing and retrieving the captured data. It assures
the interface with the underlying storing technology which could be a relational data base, files, a cloud storage system.
d) *WSN Access Module:* it is responsible for the interface with the WSN. Depending on the Operating System run in the sensors, it sends the appropriate request messages and handles the response messages.

3.2. Monitoring Level:

This level deals with the WSN part; it is composed of the deployed sensors that capture the measurements to the monitored phenomenon. The WSN part is composed of the deployed sensors. It implements the usual protocol stack of WSNs. It uses a routing strategy that does not impact the way our platform behaves. However, according to the taxonomy of the Web Services we have given earlier
(see Section 3.1), it is to note that the routing should be done according to the three ways of collecting data from the WSN: Query Driven (In case of WSN real time interrogation and management services), Event Driven (In case of subscription to events services) and Time Driven (In case of functionalities like capture-store).

3.2.1 A Service Oriented WSN and Directed Service Oriented Diffusion

In this section, we present our Service Oriented data gathering scheme for WSN. This scheme is implemented on the WSN side and extends naturally the SOA approach implemented on the gateway. We refer to this approach as being a Low Level Service Oriented Architecture to make a difference with the Web Services and the SOA at the Gateway level (High Level). The sensors in this case offer services (we call them Low Level Services) that could be invoked by other sensors or external nodes by means of Service Invocation Messages (Requests) and the responses (If they do exist) are given in Response Messages [7]. Hence, the exchanged messages carry services invocations and responses as illustrated in Fig.3. A service invocation (from a sink) toward a node (destination) is translated into a Service Invocation Message. Each node that receives the message checks its local table called *Registry* Through our work, we have designed and implemented a Service Oriented routing protocol. It is a proof of concept of the possibility of implementing an SOA in the WSN part
.

Fig 3:Message structure in the low level SOA in WSN

The protocol we have designed is called Directed Service Oriented Diffusion (DSOD).

3.3. Client Application Level:

It is the part made of the users and the IP networks (Internet) that transport the requests (SOAP messages) from the users to the gateway and vice versa. This process is termed as *consumption phase*
They could be any kind of application that can send, receive and process SOAP messages. We have designed, for example, applications in Java, C# , PHP. They are much more like user friendly Graphical interfaces. In the context of our work, they are more a proof of concept of interoperability.

4. INSTANTIATION OF OUR GLOBAL MODEL

4.1 Home Energy management:

In the SOA architecture, the wireless sensor network (WSN) provides the basic tools for gathering information on user behavior and his interaction with home appliances. Moreover, the WSN provides measurements of some physical parameters like temperature and light that can be used by the system to perform some automatic adjustment of the energy management system in terms of service representation. For this purpose we implemented a web service based architecture that's called SOA for wireless sensor network management for home energy [4]. This architecture is composed by section III. WSN is managed by a Gateway and is able to communicate with it using a SOAP message in order to retrieve all home management services.

This SOA model for monitoring environmental Parameters, such as user presence, temperature and light. This information is aggregated and processed in order to create three different types of profile (user presence profile, temperature profile and light profile) that represent user's habits. All these profiles have been register in UDDI registry in terms of web services

5. INSTANTIATION RESULTS

The presence, temperature and light profiles can be used
To optimize the using time of home appliances and to minimize the home energy consumption. In Figure 2 and 3 we present an example of the automatic temperature management benefits. The management system allows some energy savings turning off the cooling system of the rooms that are not required to be air conditioned because the user will not enter those rooms with high probably and turning it off in the whole house if the user is not present and probably will not return for a long time.

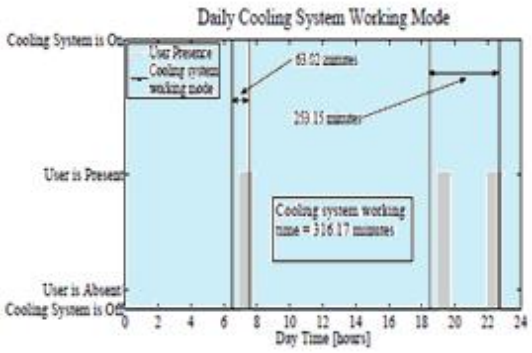

Fig 4: Home cooling system working mode without home energy management

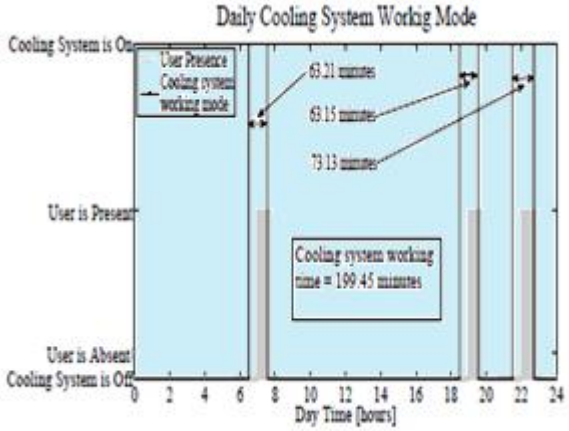

Fig 5: Home Cooling system working mode with home automation

In the test scenario, we consider a grid topology. A number of invocation messages (real time interrogation Web Services) is sent to the Gateway from a user application. The Targeted node is always the same as illustrated in Fig. 6. We measure the total number of exchanged messages in the entire network and in the nodes located near to the diagonal.
The amount of exchanged messages gives us an idea on the load and energy consumption in the WSN.

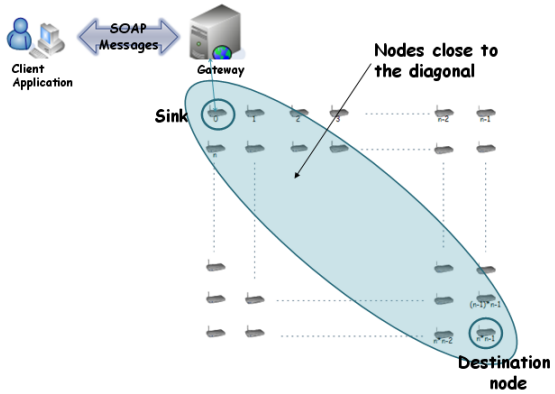

Fig. 6: Test scenario

6. CONCLUSION

Through our work, we have given an architecture that integrates the WSN in IP networks, mainly Internet. Our approach is based on Web Services implemented in a gateway. The usage of Web Services provides opportunities due to the fact that they are standardized and widely used in Internet today. The offered services are augmented by Authentication, Authorization and Accounting (AAA) functionalities to insure filtering clients and requests at the gateway level. We have given a global overview and detailed decomposition of the design of our framework. Furthermore, it was thought to be generic, not limited to some applications. Then, we instantiated it into sample applications home energy management to provide a proof of concept. We have seen that the interoperability is always insured through the different client applications we developed. Moreover, we have given an implementation of a SOA in WSN which we called Low Level SOA. We have also designed and implemented a Service Oriented routing protocol for WSN called Directed Service Oriented Diffusion (DSOD). It is the first routing protocol in this new paradigm for WSN and the results we obtained are promising.

7. ACKNOWLEDGEMENT

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