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Wireless Sensor Network Based Web Enabled Application Framework for Fire Monitoring

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Abstract: This paper focuses on the implementation of Open Geospatial Consortium's (OGC) Sensor Web Enablement for developing innovative fire detection and control prototype for real estate infrastructures. The system consisting of number of low cost sensors installed on sensor nodes deployed over the region of interest so as to monitor the environmental parameters to reduce the numbers of false alarms. The prototype is implemented using wireless sensor network relying on sensor web which allows easy accessibility of sensor or sensor networks through internet. The main motive of behind this study is to develop web-based sensor network architecture to make all sensors and repositories of sensor data discoverable, accessible and controllable via the WWW thus allowing the users to take action in time for avoiding such catastrophes.

Key words: Sensor networks · Sensor Web Enablement · SOAP · Wireless Sensor Network (WSN) · Sensor Observation Service (SOS)

INTRODUCTION

Sensor Networks have emerged as significant tool and solution for number of applications used to monitor conditions like temperature, sound, vibration, pressure, humidity, light intensity, motion or pollutants. Many proprietary and web technologies are in use for observing, communicating, analysing and reporting of data between these applications. Because of existence of different types of sensor architectures, sensor protocols and sensor interfaces there is a need to have framework that is based on open standards to simplify application development and deal seamlessly with heterogeneous sensor networks.

We are particularly interested in OGC's SWE initiative which provides feature of interoperability by providing standard encoding models, web service interfaces and real time integration of heterogeneous sensor nodes to the web. The proposed prototype investigates the potential of SWE for real world application to monitor the conditions in real time for occurrence of fire in real estates. In this prototype we developed a web-based sensor network based on Service Oriented Architecture (SOA) for delivery services to the user by gathering observed values from the deployed sensor nodes [1].

This paper proposes a web service based architecture for Fire Detection and Control System using WSN. The system will focus on the detection of fire incidents by combining various types of sensors like Smoke, Humidity, Temperature and Carbon Monoxide for avoidance of false alarms and if the incident is detected it will trigger certain control measures automatic as well as manual. In case of automatic measures it will use actuators to open fire extinguishers and activates circuit breaker to cut the main power supply to the area. At the same time it will produce alarms and various alerts to the concerned people by various means like text SMS [2-6].

The remaining of the paper is organized as follows. In Section II, we discuss some related works. Section III describes the methodology used in this prototype. Section IV describes System Architecture and Section V describes Hardware and Deployment setup. We conclude the paper and discuss some future extensions of our current prototype in Section VI.

Related Work: The Sensor Web consists of a system of intra-communicating, spatially distributed sensor pods that can be deployed to monitor and explore new environments. Because of its ability to discern spatio-temporal phenomena, the Sensor Web provides a new way to think about environmental monitoring and creating

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a virtual presence. The Sensor Web is a new instrument concept, capable of being developed for a wide range of applications [1]. Wireless Sensor Network (WSN) is an active field of research due to its emerging importance in many applications including environment and habitat monitoring, health care applications, traffic control and military network systems [2].

The vision of the two related research fields Sensor Web and Sensor Web Enablement makes the realization of the concept of the Sensor Web by extending existing OGC services. The OGC's SWE provides standard web services and data model encodings which acts as a middle layer and provides the functionality to bridge the gap between the sensor layer and the application layer. The nature of middle layer is such that it abstracts the heterogeneous nature of the sensor networks and provides standard interfaces to the clients to access the real-time, reliable and accurate information of their interest from the sensor nodes and also facilitates the feature of controlling, discovering, querying, managing and configuring of these sensors.

SWE relies on SOA architecture and builds for developing accepted W3C standards. SWE service and information specifications are designed to realize scalable and interoperable SOAs of heterogeneous sensor assets and client applications. SWE enables easy accessibility and discovery of sensor as well as the dynamic deployment of distributed heterogeneous sensor networks by providing on-the-fly connectivity and Plug-and-Play of new sensors [3-8].

The rapid development of sensor networks due to the easy availability of low cost sensors along with the advanced development of standard web interface, made the concept of senor-web true. The sensor web allows easy accessibility of sensor and sensor network through Internet which makes the observations on web real time by making the easy accessibility of repositories of sensor data. OGC introduced the revolutionary approach for exploiting Web-connected sensors known as Sensor Web Enablement (SWE). The goal of SWE is to create the Web-based sensor network. That is to make all sensors and repositories of sensor data discoverable, accessible and controllable via the WWW.

Further, the prototype focuses on web service functionality and therefore provides a well-defined SOAP API based on HTTP for web enablement

MATERIALS AND METHODS

The diagram of the system is shown in Figure 1. The System is divided into four layers:

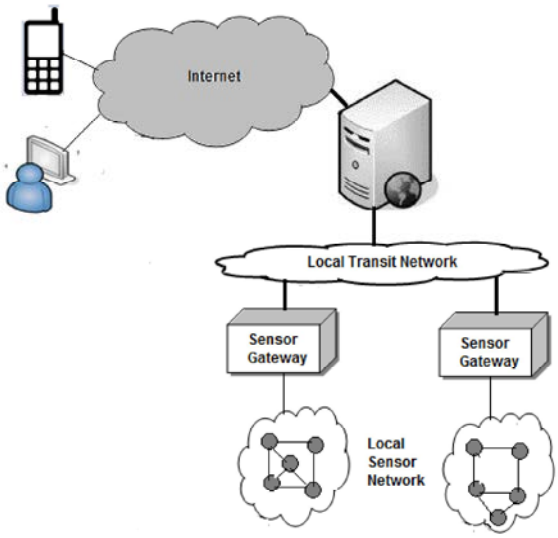

Fig. 1: General Architecture

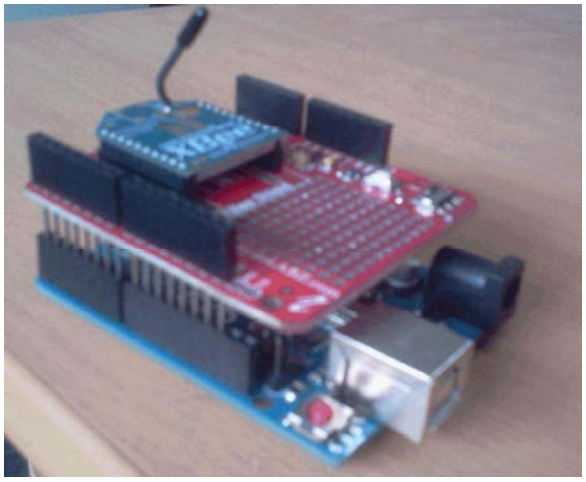

Fig. 2: Sensor Node Hardware

- Local Sensor network
- Sensor Gateway
- Web application

Local senor Network: The sensor network consists of one or more sensor nodes. Each senor node consists of two parts: Sensor Interface and Communication Interface. These two parts work in microcontroller Board, Zigbee radio and Sensors. The Sensor Interface receives data signals from the sensors via Analog Input pins of the microcontroller (as Analog to digital converter converts analog signals into digital values). The processed sensor value is encapsulated in a data frame along with other information (e.g. node id, Node Location) and is forwarded to Sensor gateway. Figure 2 shows the hardware platform of the Sensor node [9-11].

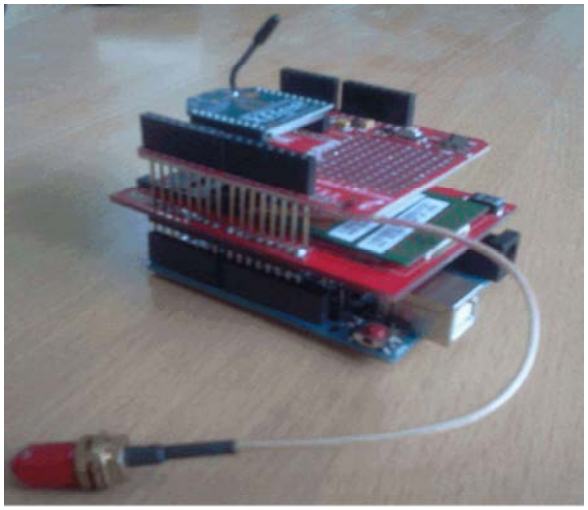

Fig. 3: Sensor Gateway Hardware

Sensor Gateway: The gateway is responsible to gather sensor readings from the sensor nodes and publish the readings to the web application interface using the Local Transit Network. In addition to that it provides control commands to the actuators (e.g Power Mains of the building, fire extinguisher controller) in case of any critical event of fire detected by it after processing the gathered sensor data. Thus the function of the gateway is divided into three parts: Web-Server interface to connect the network to web application through Local Transit Network, Zigbee Interface to the Local Senor Network and control module for actuation of circuit breakers. These three functions as implemented on the microcontroller board. The hardware of the Gateway consists of a microcontroller,Zigbee radio and GSM module, as shown in Figure 3.

Web Application: In order to provide data gathered by the Sensor Gateway to Web applications, a SOAP API for accessing measured observations is designed. In addition, the Web application along with publishing and managing the backend database for the system will contain the Alert Service and Notification Service. The purpose of Alert service is same as in OGC SWE Web Alert Service to register the authentic users for necessary alerts from the system. Similarly Notification service will act as OGC SWE's Web Notification service to send the alert to the registered users of the system (Typically by Text SMS and emails in our prototype). The purpose of the web application is to contribute our prototypic work to the initiatives like Sensor Web Enablement and Web of Things [12-15].

System Specification:

Network Specification:

Local Sensor Network: Star Topology was used for Local Sensor Network. The setup consists of a Sensor gateway as a center processing unit functions. It gathers sensor readings from all Sensor Nodes.

Sensor Gateway: Sensor gate way is connected to the web server using Local Transit Network.

Hardware Specification: A WSN node consists of a microcontroller, some sensors and a communication module :

Microcontroller: We use microcontroller board with Atmega 328P-PU as a processor, interfaced to the computer via USB port.

Sensors:

- Temperature Sensor (LM35)
- Smoke Sensor (MQ-2)
- Humidity Sensor (HSM -20G)
- Carbon Monoxide Sensor (MQ-7)

This paper discusses the issue of deploying different sensors and gathering data from these sensors using SOAP (Simple Object Access Protocol). The testbed developed will monitor the fire in the real estate infrastructures automatically depending on the data gathered from the sensors using SOAP based framework.

Software Implementation: The implementation is a Java-based web service package, requiring the components Java Runtime Environment (JRE) and Java Development Kit (JDK) Version 1.6.0, Glass Fish Version 3.1.1.and MySQL database as backend. All the Web services have been developed with Java web technologies using Simple Object Access Protocol (SOAP) architecture. The motivation of using the technology was due to the fact that SOAP is a standard web service middleware protocol [16-18]. It is a protocol based on eXtensible Markup Language (XML) means it can be easily integrated with different programming languages and platforms. For this reason we found it very effective for developing our prototype. Also Java provides a set of technologies which gives the facilities for development of portable applications along with easy development of XML-based Web services. The system has been developed in accordance with the OGC standard specifications. According to these specifications all the communications

shall be performed by exchanging XML messages. Means all the request operations must send the request messages in XML format and each operation response is also an XML document. That basically means that each XML schema is mapped into exactly one corresponding java class, which can be instantiated and treated like any other java object

Fire Monitoring Hardware and Deployment Setup: In this work, a kind of low power, multi-parameter composite fire detection node is designed, which can detect temperature, smoke and humidity concentration. This prototype is based on a microcontroller board with Atmega 328P-PU microcontroller, group of sensors, Zigbee 2mW Wire Antenna-Series 2 and SM5100B-D GPRS module to monitor the fire arising conditions. The web connectivity is established by the GPRS module so that all collected and processed data is available on the web in real time. The GPRS terminal is connected to the Zigbee central base station called gateway. The base station is responsible for transmitting data to the user via GPRS. The data is displayed to user through a web-based user interface. The data available within our architecture is derived from smoke, humidity and temperature sensors. Sensors used are MQ-2 Smoke sensor, HSM Bridge Humidity sensor and LM-35 temperature sensor. The microcontroller board hardware and the firmware programming language, is utilized to integrate the sensor components with the web enabled computing component [19-25].

System Architecture: This application focuses on reliable detection of fire threats in real estate infrastructures and buildings. In this prototype the special focus is towards implementing web service platform which binds web application to the sensor network gateway. In this scenario various types of sensors like Smoke, humidity as well as temperature sensors are embedded in the prototype which is covering all the aspects of the occurrence of any fire incident for high reliability and accuracy of fire detection. To add the feature of interoperability among these sensors the web service platform and the hosted services are located at the WSN gateway. In this prototype, the sensors communicate using their own proprietary protocols and frameworks. At the gateway, there is a mapping from proprietary frameworks to web services. Thus the services and data offered by WSN are exposed to application via web services. The end user application communicates with the gateway via SOAP by invoking a particular web service which we bind to the gateway. In its simplest form, the gateway does the mapping of the SOAP request to the format and protocol of the framework used by the rest of the WSN entities behind it. It also collects the responses from the network, builds the corresponding SOAP response and forwards them to the requesting application. In our prototype our web service based gateway does more than just mapping the request and responses. The web service do some processing of the collected raw sensor data and provide more meaningful information. For example, instead of merely providing actual temperature, smoke and humidity values as furnished by the temperature, smoke and humidity sensor, it could allow application to be alerted when the temperature, smoke humidity is above certain thresholds. The services offered by the web service based WSN gateway is published in the UDDI registry for the end user applications to find. General layout of the system is depicted in Figure 2.

Senor Observation Service: The SOS is a standard interface for accessing measured values from sensors and sensor systems including remote, in situ, fixed and mobile sensors. The SOS service provides an interface to make sensors and sensor data accessible via an interoperable web based interface. The SOS is based on standard data models, Observations & Measurements (O&M) and Sensor Model Language (SensorML) for exchanging the information between the clients and SOS servers. In our monitoring system SOS collects observation data from sensors and then uploads to SOS Server. The SOS interface comprises of GetCapabilities, GetObservation, DescribeSensor operations.

Layered Architecture:

Sensor Network Layer: Sensor layer is responsible for configuration and management of sensors in sensor layer and their organization in sensor networks.

Data Acquisition Layer: this layer is responsible for gathering sensor observation from the senor layer

Mediation and Processing Layer [MP]: The third layer performs the task of analysis and visualization of the sensor data and allows the decision maker to action in time at the time of crises management.

Application Layer: This layers abstracts the complexity of the underlying architecture and support the easy accessibility of the information that can be understood by the user. The information presented in this layer is in the form of maps, diagrams and reports such that they may be presented to the user in the user domain.

User Interface Layer: The functionality of the User Domain is to support the interface to the end user, typically in a graphical fashion

CONCLUSION

This work presents the innovative fire detection and control prototype for real estate infrastructures for monitoring and controlling the fire incidents based on a Wireless Sensor Network. The system focuses on an easy accessibility of real time data via the Web by following the frame work of SWE. The SOAP interface enables its integration to web applications. Applying the prototype in the described use case of fire monitoring and control has already shown satisfying results. In future, this use case setup will be refined, but also other use cases will be investigated to prove the genericness.

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