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Wireless Sensor Network Based Early Warning and Alert System for Radioactive Radiation Leakage

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Abstract: One of the greatest threats to earth's survival are radioactive radiations which contaminates the environment. The main sources of the radioactive radiations are nuclear power plants. Measures need to be taken to protect the environment and the individuals affected by them. This paper aims at introducing the automated detection system for radiation leakage and alert system in the nuclear power plant by implementing wireless sensor network. The automated system comprising of array of sensor nodes, distributed spatially over a region of interest in power plant to detect the radiation leakage. The radiation detection system collects real time data from the surrounding environment which is to be monitored and analysed, so that proper action can be taken in time when threat arises. Hence transmitting the data on time is of utmost importance. This paper leverages on Open Geospatial Consortium's (OGC) Sensor Web Enablement (SWE) standard web service interfaces, Sensor Observation Service (SOS) for retrieving observations from sensor systems, Sensor Alert Service (SAS) and Web Notification service (WNS) for delivering alerts to the registered users and notifies them when an event triggers. The two services, SAS and WNS provides the standard interfaces for providing alert functionality using publish/subscribe mechanism and determines the alert conditions and finally notifies the subscribed users at the time of crises management. The paper mainly focuses on implementation details of the SAS and WNS for introducing early warning and alert system in nuclear power plant.

Key words: Wireless Sensor Network (WSN) · Sensor Web Enablement (SWE) · Sensor Alert Service (SAS) · Web Notification Service (WNS) · Sensor Observation Service (SOS)

INTRODUCTION

Nuclear power generation have always been a risk for contamination of the environment which keeps the life of workers of nuclear power plant and people living near the area to plant in danger. The emission of the radioactive radiations has potential hazards on human health and ecosystem. It contaminates everything like air, water, eatables etc. Therefore there is a need to have a comprehensive monitoring for leakage detection in power plants to safeguard the life of people. Keeping the above fact in consideration we developed an automated radioactive leak detection system for nuclear power plant which keeps on check for radiation leakage to prevent a catastrophe to happen. The developed automated system relies on wireless senor network.

The growing field of wireless sensor networks has been proven tremendously efficient for real time surveillance and control as each sensor node is having the feature of sensing, computation and communication. Sensors being smaller, power efficient and reliable made it possible to deploy them in any possible environment to monitor the conditions where human intervention can cost life. In such environments WNS can be used to investigate the environmental parameters, such monitoring systems are composed of number of sensor nodes which are deployed over the region of interest to observe the environmental conditions.

In our prototype, the application of wireless sensor networks was explored and implemented in our use case called radioactive leak detection in nuclear power plants. The sensor system composed of sensor nodes were

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installed in radioactive leakage suspected regions to observe the surrounding environment. The sensor nodes collect data from the regions under observation and transmit in real time. The observed data is collected and analysed and then information is transmitted to the sensor gateway via ZigBee radio which installed onto the sensor nodes. The gateway has internet accessibility using GPRS module installed on it. It acts as an interface between the sensor network and internet, so that the observations gathered by sensor nodes can be communicated to the web service interface. The observation values received by the user are accurate and reliable thus allowing decision makers to take action in time when the event triggers and also provide alert mechanism to the people working in those conditions. The development of such automated systems have been proven excellent in number of exciting application areas such as environmental monitoring, green house monitoring, disaster management, early warning system etc.

In this scenario two standard web services interfaces, SAS and WNS were implemented for developing an early warning and alert system. The duo service provides the standard interface for specifying the conditions of alerts and notifying the same to the users at time of the occurrence of the event. SAS allows delivering the data to the subscribed users collected from the sensors while WNS allows notifying the registered users when an event triggers. In this paper we presented the implementation details of the two services for developing an early warning and alert system in nuclear power plant for radioactive leak detection.

Related Work: Number of architectures based on OGC SWE has been developed for providing interoperable early warning and alert system in various applications domains like air, water, flood, fire, landslides etc. One among them was developed by Markovic *et al*. for monitoring river water pollution and early warning system using OGC SWE Standard services, the automated system retrieves data from sensor system, performs spatial queries and takes decision on some predefined rules (Markovic *et al* 2009) [1]. Similarly Henneböhl, *et al* proposed architecture based on OGC SWE web services for monitoring air quality for Europe which implemented using OGC's Web Processing Service and Web Coverage Service. The system measures the pollution level in the air by acquiring data from the sensors which is then transferred into the base station where analysis of data is performed to measure every pollutant constituent of the air. The air quality index is extracted from the retrieved observations and emergency situations are discovered and notified to the concerned authorities (Henneböhl *et al* 2009). Another architecture based on health monitoring was developed by Everding *et al*. for combining geospatial data and real-time sensor data for calculating an Integrated Health Index (IHI) (Everding *et al*. 2010). In this architecture they integrate SWE and geoprocessing services by using two Sensor Event Service (SES) instances and a WPS for determining of the IHI in certain areas [1].

Wireless Sensor Network: In order to develop the automated nuclear radiation leakage detection system for nuclear power plants, real time data acquisition and effective transmission of data should be focused. The acquired data needs to be delivered efficiently near real time. The proposed architecture fulfil these issues which is constructed by number of self customised sensor nodes; each node is having its own transmission and receiving unit, micro-controller, internal memory and power supply. Sensor nodes are deployed along the field of interest where the leakage of the nuclear radiation is suspected. The deployed nodes monitors the environment, samples and collects the data from the region under observation and then transmits the data packets to the sensor gateway which is the fundamental gateway for controlling entire system. The data received by sensor gateway is transmitted in real time web service interface. SOAP API is designed to provide the data gathered by the Sensor Gateway to Web applications where the processing and the evaluation of the data are done. Each node of the network is installed with Geiger Counter, detecting the number of alpha and beta particles per minute [2]. The number of particles detected by the sensing module is compared with predefined threshold; if the number exceeds the threshold the nuclear radiation leakage is assumed to be triggered. On receiving this information the alarm is raised and the subscribed users are notified via SMS and email. In this prototype OGC SWE's Sensor Alert Service and Web Notification service are implemented for facilitating early warning and alert system.

Sensor Node: Wireless sensor network is a network of sensor nodes deployed over a field under observation to investigate the environmental parameters. Each node in the network acts as a full-fledged sensing unit which has its own senor module, processor modules and wireless

communication module for sensing, computation and communication respectively. In our prototype the sensor module is composed of a radioactive radiation leakage detection sensor along with functions of analog to digital converter. The sensor used in the sensor module is the Geiger counter. Next is the processor module which is based on microcontroller board with Atmega 328P-PU as a processor and the firmware programming language used to integrate the sensors. The microcontroller board provides the capability to connect and configure the sensors and to preprocess the sensor outputs. Finally the communication module which comprises of wireless transceiver unit based on ZigBee 2mW Wire Antenna-Series) and SM5100B-D GPRS module and GTPA010 GPS module to track the present location and time awareness. As for as such prototypes are concerned, long battery life, low data rates, secure communications and less complexity is required. Therefore we designed the sensor node based on ZigBee technology which focuses in the above mentioned issues to provide accurate and reliable information in near real time, operating on 2.4GHz bandwidth based on the IEEE 802.15.4 standard. The ZigBee also provides the standardized protocol stack which simplifies the task of the designers at low level network issues. Another interesting feature of the ZigBee is[29], it provides the self organisation of the networks and also the cost of using ZigBee radio is very less as compare to other technologies.

Geiger Counter: Geiger Counter is a sensor which detects the nuclear radiation emission. It is actually the particle detector that measures the ionizing radiation. It measures the number counts per minute which are actually alpha or beta particles being detected, indicating the radiation emission. In this prototype we used Geiger Counter deployed in the sensor node which behaves as sensing unit to detect radiation leakage. The leak detection can be assumed on the basis of number of counts detected by the Geiger Counter compared to the predefined threshold, if the count crosses the threshold nuclear radiation leakage is assumed to be happened. To secure the life of the people the alarm is raised indicating the radiation leakage in the nuclear power plant. Below Fig 1 demonstrates working of Geiger Counter.

Early Warning and Alert System: The early Warning alert system in this scenario leverages on OGC SWE frame work.

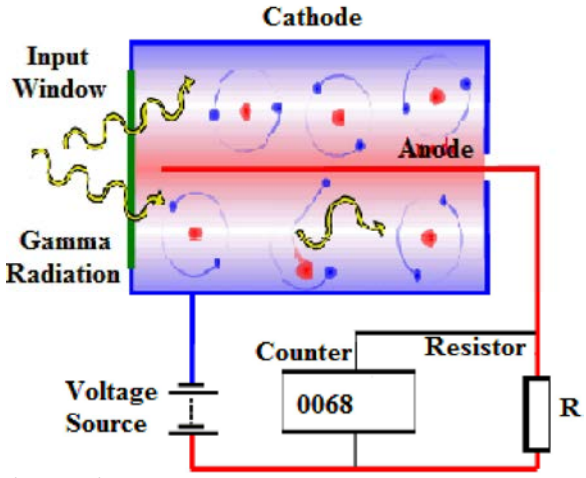

Fig 1: Geiger Counter

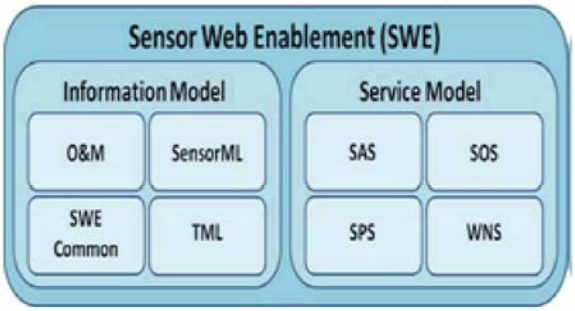

Fig. 2: Sensor Web Enablement

Sensor Web Enablement: Sensor Web Enablement an initiative of OGC provides two standard models called information model and service model. These models define the standards formats for representing sensor data and metadata as well as sensor service interfaces. Together, these standards form a framework which allows fulfilling the goals of the Sensor Web [2]. The sensor web provides easy accession to the sensor and sensor observation via World Wide Web using standard web services interfaces.

This paper will focus on the service model of the SWE which constitutes Sensor Alert Service (SAS), Sensor Observation Service (SOS), Sensor Planning Service (SPS) and Web notification Service (WNS).

- Sensor Observation Service(SOS):- The SOS is an standard interface for retrieving observed values from sensors and sensor systems including remote, in situ, fixed and mobile sensors. The service provides an interface to make sensors and sensor data accessible via an interoperable web based interface [3].

- The Sensor Planning Service (SPS):- This provides standard interface for tasking and planning sensors by setting their measured parameters. It's also intermediary between a client and a sensor collection management environment [4].
- Sensor Alert Service (SAS) – Standard Web service interface for publishing and subscribing alerts from sensors. Users outside this system who would like to receive observation information and alerts can subscribe to this system using SAS [5].
- Web Notification Service (WNS) –This service is useful when many collaborating services are required to satisfy a client request and/or when significant delays are involved in satisfying the request. It provides a means to alert people, software, or other sensor systems of results or alerts regarding phenomena of interest [6].

In particular we will mainly focus on implementation details of SAS and WNS for developing automated early warning and alert system.

Sensor Alert Service: The Sensor Alert Service provides the standard interface to send alerts to the subscribed users via XMPP (extensible messaging and presence protocol). The subscribed users themselves specify the alert condition and then join the corresponding MultiUserChat (MUC) [7]. This architecture enables the sensor and sensor nodes, clients (subscribing and receiving the alerts) and web service to be discoverable through OGC GetCapabilities interface. The sensor nodes publish and advertise the sensor data and measured values using HTTP POST requests. It provides a framework to make sensor observations available on real time.

The following figure illustrates the workflow of SAS:

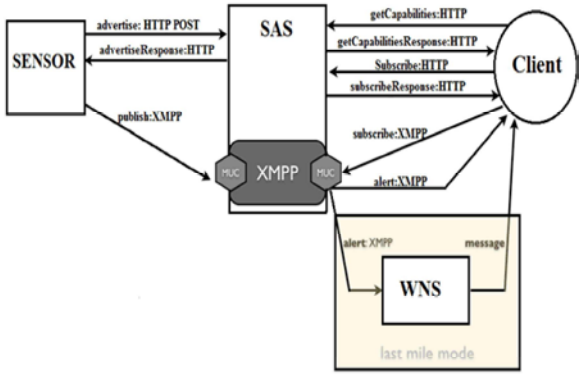

Fig. 3: Working of SAS

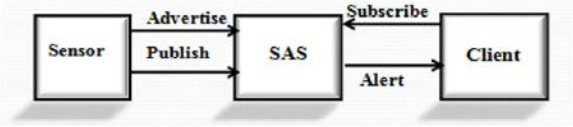

Fig. 4: SAS

The steps followed for implementing while Sensor Alert Service are:

- The initial step of SAS implementation is user calls the GetCapabilities operation in order to subscribe sensors.
- Capabilities document is returned by the SAS service indicating the capabilities of SAS service, in this particular prototype the SAS provides alert notification of number counts per minute which are actually alpha or beta particles being detected.
- After receiving the capabilities document the user is able to subscribe the sensor of the interest by acquiring the knowledge of sensor observation offering. Therefore[8], the user is able to choose a certain SubscriptionOffering and defines by means of the Subscribe operation the subscription condition (e.g. send me an alert if number of particles detected per minute is more than 50).
- The SAS returns the Subscription end point (MUC).
- Finally the user registers with the received MUC in order to receive alerts [9-15].

If the sensor observation meets the conditions predefined by the user, the SAS will publish alerts to the MUC to which the client has subscribed. If the subscriber is not interested any more in receiving alerts, he can cancel the subscription by means of the CancelSubscription operation.

Web Notification Service: The main functions of the WNS are Managing User Account and Notifications so as to notify the user that particular event has been triggered [16-20]. For subscribing such notifications user needs to know the capabilities provided by WNS, mainly communication channel. In this automated system two communication protocols have been used i.e. Email and Shot Messaging Service (SMS). To find out the mode of communication getCapabilities operation is invoked, after having the knowledge of the communication protocol the client select the communication mode he is interested in and register an account in WNS, SPS may request to register user via WNS, which asks the Account Manager to manage the user account in the data base for which

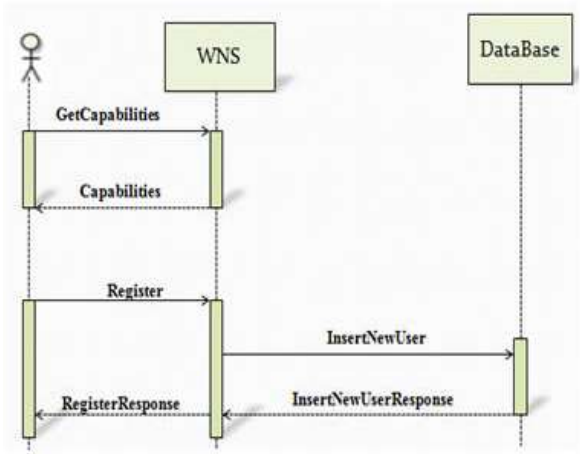

Fig. 5: Working of WNS

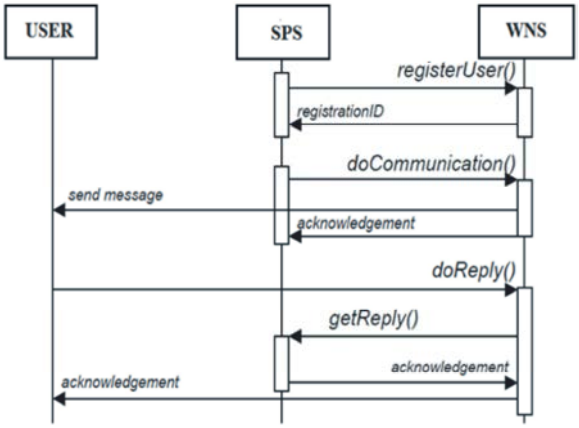

Fig. 6: WNS procedure

user needs to provide his name and way to receive notification. Register response will provide registrationID to the user [21-25]. The Notification is used to create a specific communication protocol and send the messages via the protocol to which the user has been registered in the database. Below fig demonstrates the sequence.

Once the user have been registered the next step is to send notifications to the user by invoking the doNotification( ) operation. On invoking the particular operation, the message is sent to the user and the acknowledgement is sent to the OGC SWE's SPS service indicating the status of the operation like notification send successfully, unsuccessfully or notification time was out.

Finally, WNS provides the interface to receive notification responses from the registered user by invoking the doReply() operation to establish a virtual asynchronous communication between the WNS and the user. Fig 6-demonstrates this procedure [26-28].

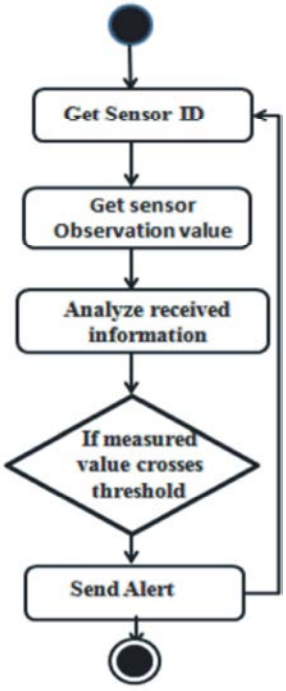

Fig. 7: Activity Flow

Activity Flow: During the development of automated early warning and alert system decision making unit developed at client application performs series of activities to keep the information up-to-date so as to avoid the disaster. The automated system keeps on requesting measured sensor values to determine their parameters. The received observations are monitored and analysed to check that parameters are within the predefined threshold so as take a proper action in time if the threat is detected. If analysed data indicates about some threat the alerts are dispatched to the intended users [29-31].

Prototype Architecture: This prototype is an automated system providing early warning and alert system in the nuclear power plant for preventing disasters by detecting nuclear radiation leakage. Following are the steps for providing early warning and alert to the user.

- The first step is user registers itself to the SAS through web–client registration interface.
- In second step GetCapabilities( ) function is invoked by SAS feeder to receive capabilities document, mentioning the all advertised sensors. If new sensor is added to the sensor system its descriptions are retrieved by invoking DescribeSensor( ) operation. The newly added sensor is registered to SAS by calling RegisterPublisher( ) operation.

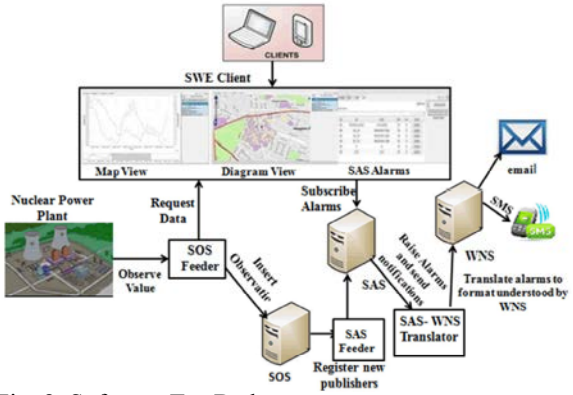

Fig. 8: Software TestBed

- After publishing the sensor by SAS user can subscribe the particular sensor by specifying filtering conditions for example user is interested in receiving notifications only when some criterion meets so as to restrict others
- To retrieve the observations from the SOS the SAS Feeder keeps on surveying to SOS for new observations. If new observation are found, sensor data is retrieved from SOS by invoking GetObservation( ) operation and is finally inserted into the SAS.
- If the event detected from the retrieved observations, notifications are sent to WNS translator which is responsible to processes and translate them in to requests which are understood by the WNS. WNS translator notifies new translated notifications to WNS by invoking DoNotify( ) operation.
- WNS dispatches these notifications to the user by sending an email or SMS.

CONCLUSION

The objective of this prototype was to create a new generation of interoperable early warning and alert system by implementing standard web service interfaces i.e. sensor alert service and web notification service which relies on the Sensor Web for data acquisition. This system investigates the OGC SWE compliant sensor systems for the rapid detection of radioactive radiation leakage in nuclear power plant. The Sensor Web architecture implemented in this prototype provides active monitoring for measuring parameters and timely responses in cases of crises management so as to prevent catastrophe to occur. In future this system will be extended for monitoring the people living near the area of nuclear power plant by attaching a Personal Digital assistant to them [32-35].

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