International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 18 (2015) pp 39558-39561

A Radiation Detection Wireless Sensor Networks in the Nuclear Power Plant

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Abstract
Wireless sensor network is an interesting technique that provides a tool to gather and analyze information from the real world. Since everything is now connected to the Internet, the introduction of the concept of wireless sensor network applications is more widely used. Radiation source from the nuclear power plant is one of the most important things that must be monitored. Unlike the conventional radiation detecting system that is huge and expensive, a new proposed radiation detector based on a wireless sensor network with a number of low-cost sensor installed that can monitor and detect the radiation source immediately in real time.

Keywords: WSN, MANET, Radiation Monitoring, Mobile Computing

1 Introduction

Nuclear power plant is very important to modern society which absolutely dependent on electrical energy. Nuclear power plant generates more energy than the fossil fuels power plant. For this reason, many countries uses nuclear power, but it should be operated safely to ensure safety to the population. Since the nuclear power plant's accidents are very fatal and the recovery is so difficult, the safety of nuclear power plant is utmost importance. Thus, many studies in nuclear power plant safety and accident prevention are being conducted.

A wireless sensor network (WSN) is a distributed computing system that can measure and collect environmental data through tiny and lightweight sensor nodes that can detect various data of the real world [1]. Sensor nodes are often called Mote with cheap price and small size, and can be deployed in various places. So, it is increasingly used in variety of applications such as agriculture, environment, defense, and security, etc. Recently, the application fields of the sensor node being expanded due to sensor nodes are used as infrastructure of Internet of Things [2, 3].

When sensor nodes are deployed as fixed mode around the nuclear power plant, each of the sensor node measures the level of radiation and the information transmitted to the base station or sink node by periodic or event-driven method. At this time, the fixed sensor nodes construct cluster for energy control, and then the radiation measurement values are passed to the sink node via multi-hop manner among cluster header [4]. Plant manager can monitoring the value of collected radiation data from a remote location through the gathered information. Also, it need to know the radiation level around a plant staffs immediately. These staffs bring variety of environmental sensors, including a radiation sensor that embedded into mobile tablet device and receives radiation measurements of his position. Also by the communication between tablet devices and the fixed sensor nodes in the vicinity, tablet device can know radiation level near a plant staff location in real time, instantly detect and respond if there is a crisis situation.

This study presents a real-time system design not only for plant staff to detect and respond a crisis situation nuclear power plant, but also provides capability of remote monitoring through the combination of fixed radiation sensor node and mobile one. We will collect empirical data by the simulation and then build a small pilot system of real nuclear power plant security system.

2 Operational Designs of Sensor Nodes

In order to measure the radiation level of the target of large site nuclear power plant, two kinds of sensor nodes are installed. A number of small radiation sensor nodes are fixedly deployed over buildings and mobile sensor node around the open spaces of the building, including plant layout and wind along the way that can measure radiation at the proper position. Since the node is fixedly installed, measured GPS coordination value will be stored at the server then it can retrieve the specified position of the radiation levels when needed. In order to install a large amount of sensor nodes in a fixed manner, it should be as light as possible in terms of minimum functions. In addition to data transmission in order to minimize the energy consumed, a low-power module such as IEEE 802.15.4/ZigBee is adopted as communication interface [5].

Mobile sensor node is equipment carried by manager or maintenance staff. A variety of smart phones or tablet devices are attached to radiation detection sensor and various environmental sensors. Each mobile radiation sensors node has a Wi-Fi of MANET to support mobile ad-hoc communication between mobile nodes and sink nodes, and also has low-power interface like IEEE 802.15.4 [6] to collects radiation sensing data from fixed sensor nodes. In addition to the radiation detection, mobile nodes have to assist to recognize overall situation, a user interface on the mobile sensor node should issue a warning to the user if the radiation

level reaches or exceeds the threshold. The threshold range could be consisted of warning, crisis, and several stages.
Figure 1 shows the diagram of a mixed deployment of fixed sensor nodes and mobile sensor nodes of the nuclear power plant. Fixed sensor nodes measure radiation data, transmits information through cluster that construct among near fixed sensor nodes to the sink node, and finally store the collected information at the remote server in the Internet. When mobile sensor node of tablet device approach to any cluster, it can hear beacon signal that cluster header periodically transmit, then the mobile sensor node can be joined to a cluster. The mobile node being a cluster member and can receive information that exchange between cluster header and member nodes. A plant staff with the mobile node can continuously monitor status of vicinity of him/her in real time. This means plant staff rapidly identify and deal with occurred situation than warning or alarm informed from remote monitoring site.

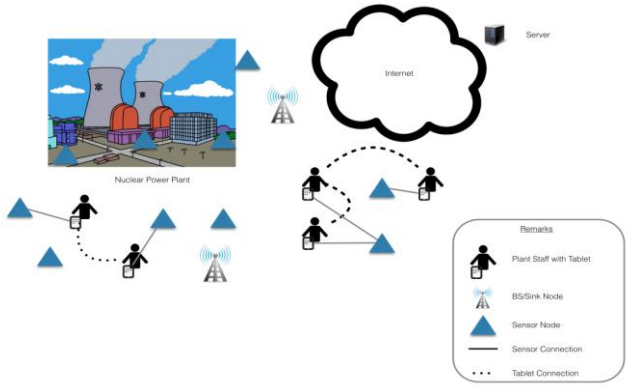

Fig. 1 Deployment of fixed sensor nodes and mobile nodes

3 System Architecture

Sensor networks for detecting radiation of the nuclear power plant is made up of two types of sensor nodes and sink node. First, a fixed sensor nodes are installed in the precinct of power plant, the radiation sensor is mounted, periodically transmits the measured data values to the sink node through the cluster header node. The second type of node is configured by a radiation detection sensor mounted on the smartphone or tablet device power plant staff in possession. Two kinds of sensor nodes, in order to support the communication channel with various applications, are configured in the structure of three layers as shown in Figure 2.

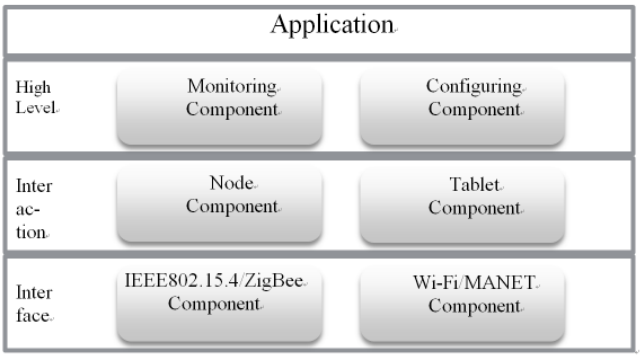

Fig. 2 Proposed 3 layers architecture of node

Nuclear power plants, for using large site, in view of the reach of the wireless LAN radio must variously consider the number of sink nodes. The fixed sensor node has measurement data mobile node exists near while moving the Power Station is collected via the channel of the IEEE802.15.4. Mobile node, the collected data are analyzed, after being displayed for the user, transmits to the sink node. In this case, depending on the state of the distance or obstructions between the mobile node and sink node, the communication state is changed. In this experiment, by installing 1 to 3 of the sync node, depending on the configuration of the network, the communication state is analyzed to change.

4 Results and Discussion

In order to understand performance of designed sensor network system for monitoring the radiation leakage of nuclear power plants, we perform simulation experiments. Simulation experiments show the communication performance in a mutual relation of the fixed node and the removable node, taking into account the size of the site of the power plant, the performance change due to the change of the sink node by installing 1 to 3 of the sync node was observed.
Simulation is using Qualnet5.0 [7], 90 pieces of fixed nodes, four mobile nodes and 1-3 sink nodes are used. With 10 CBR applications, simulation time of 1.5 days has been applied. To record the consumption time of the battery in fixed node, the capacity of the battery was artificially adjusted at low levels.
Figure 3 is a graph of throughput of 10 CBR applications. Since packet size of CBR used was very small size of 70 bytes experimental results of low-level throughput revealed in the experiment. Performance will vary depending on the change from Figure 3 of the sink node. In particular, when two of the sink node is used, it has shown better results. When one and three sink nodes have been applied, it has showed similar results. Two sink nodes are most suitable for the nuclear power plant environment that is used in the experiment through the variously adapted number of sink nodes.
Figure 4, data packets created by the 10 CBR applications shows the elapsed time until the arrival to the sink node. The value of the end-to-end delay, when the data of a nuclear power plant is considered a must characteristics to pass immediately when the emergency situation occurs, which is one of the important characteristics of the sensor network.

Looking at Figure 4 shows the results of observation according to the delay value of data packets to a change in the sink node, the sink node is the shortest delay value two days revealed. This is, without delay immediately when two sink nodes are arranged in a simulated power plant, shows that the data packet is passed. When the moving path and other conditions mobile nodes are the same, these experimental results, it means that the position and quantity of the sink node plays an important role.

Figures 5 and 6 shows the total energy of a fixed node has consumed in the simulation, each fixed node consume all the energy of the battery, also it displays the time the node has stopped working. A fixed node using battery power may need to be driven with low power consumption is to ensure the operation of the long network. Most of the fixed node, but consume the amount of energy similar, it was somewhat record the consumption of low-level in particular some of the node. Time graphs fixed node is down in Figure 6 was made to send a little more, the packet set artificially battery power amount lower for the experiment. Time fixed node is activated, are distributed in a very wide interval up to 120,000 hours at 20,000 hours. The advantage is that the energy evenly among the nodes which means that there must be carefully designed to operate so as to consume. In this way, non-uniform node stop time, it means that the operation of the network changes very unstable.

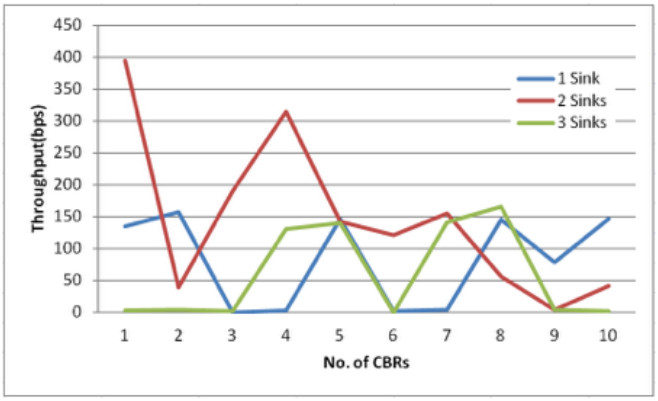

Fig. 3 Throughput performance over various sink nodes with 10 CBR applications

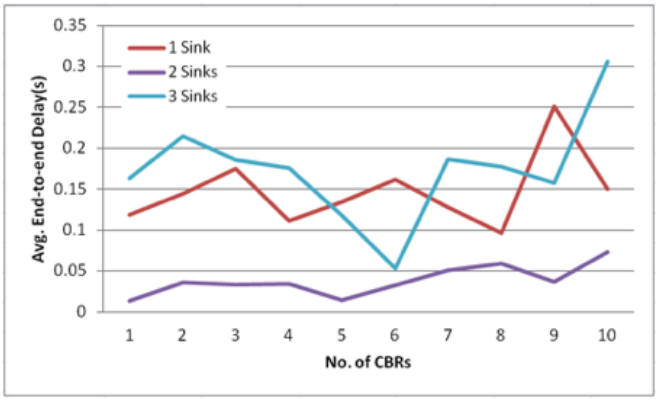

Fig. 4 Average en-to-end delay time of 10 CBR application over different number of sink nodes

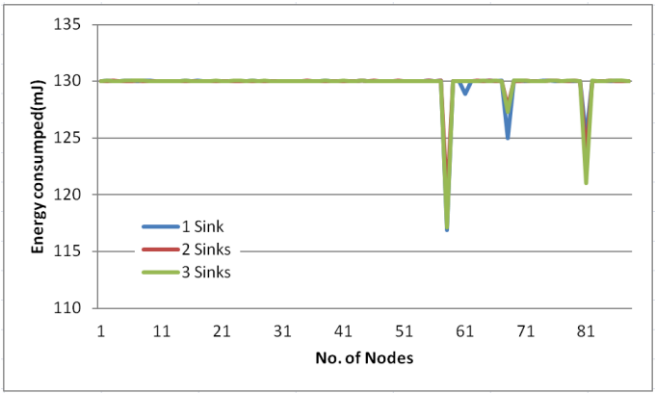

Fig. 5 Amount of consumed energy for 1.5 days simulation

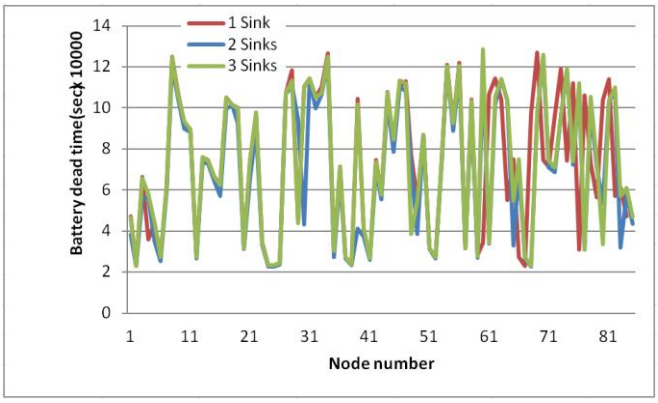

Fig. 6 Battery dead time for fixed nodes

5 Conclusion

In this work, we propose wireless sensor networks to detect radiation in the nuclear power plant. Wireless sensor networks receive much interest for many years. It has been studied promising areas and now is being expanded to the internet objects. The development of lighter and smaller sensor networks to be included in the various fields and has a sensor for measuring the radiation sensor. Nuclear power plants are playing an important role in the power supply in proportion of strict safety standards that are required for collateral. It is very important to utilize a wireless sensor network to satisfy those requirements. The flexibility of the wireless sensor network is usually required in all circumstances and risks for the radiation measurement data can be provided. We demonstrate through simulation experiments and pilot implementation is expected to proceed.

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Received: Month xx, 20xx