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EMERGENCY STATIONS IN THE GRAND MOSQUE OF MECCA AS AN APPLICATION FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

During the annual Hajj pilgrimage, a large number of pilgrims suffer death as a result of misadventure and natural causes. Others, unfamiliar with the location, become lost in the crowds. As the demands of catering to the needs of ever-growing numbers of pilgrims visiting the Sacred Mosques increase, crowd control and communication between pilgrims and those responsible for the provision of services remains a significant issue for both the local authority and the pilgrims themselves. This paper reports how, in order to alleviate some of these problems, wireless sensor network stations should be established as emergency fixed stations. Such stations should be strategically situated throughout the holy mosque to assist rescue teams in locating and recovering lost pilgrims. Important factors in selecting the type of sensor are the power it consumes, its range and financial cost. The best combination of these factors can be found in the "RF Engines" sensor produced by Synapse. In modelling the network characteristics of this sensor in a variety of circumstances, the results demonstrate stability in sending and resaving packets with low rates of delay and dropped packet. In view of these results and due to the limited size of the network, high network performance can be anticipated.

Keywords: *Crowds, Wireless sensor network, Station, RF Engines, Dropped packet*

1. INTRODUCTION

Visitors to Mecca and the Grand Mosque, especially those visiting from abroad, women, children and the elderly, are prone to getting lost in what to them is an unfamiliar environment [1]. These pilgrims typically become lost in the crowd when they are inadvertently separated from their families or pilgrimage groups. Many pilgrims, unable to speak the local language or the languages of the many visitors to Mecca during the Hajj, are unable to request assistance [2]. Due to the extent of the Mosque complex, prevalent arrangements are not conducive for timely and efficient provision of medical assistance by the emergency services and, as a result, some pilgrims die who could otherwise have been saved. There is, therefore, an urgent need for an accurate system of communication with the emergency services. The employment of modern technologies during the Hajj season could facilitate monitoring and tracking of pilgrims thereby mitigating congestion, assisting in tracking missing pilgrims, detecting those who are moving in the wrong direction at peak times and generally facilitating redetection. Technologies that are applicable to these requirements include wireless sensor networks (WSNs). WSNs consist of networks of inexpensive battery-powered sensors, which are capable of performing integrated sensing, computing, and wireless communication functions [3, 4]. The WSN concept is based on each node possessing power suitable for one or more microcontrollers, CPUs or DSP chips. They may consist of a number of types of memory program,

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data and flash memories. WSNs contain a power source, usually consisting of batteries or solar cells, and various sensors and actuators [5, 6]. WSNs typically comprise base stations or gateways that are able to communicate with a network of wireless sensors by means of a radio link. Data is acquired at the wireless sensor node, compressed, and then transmitted to the gateway directly or, if necessary, by means of other wireless sensor nodes that forward data to the gateway. The transmitted data is then input to the system via the gateway connection. There is no limit to the number of nodes that can be included in the WSN, so it is possible to build systems that consist of 1,000 or even 10,000 nodes. It is also possible for a system to operate over a number of locations [7, 8]. WSNs have been used in a wide variety of scenarios including environmental monitoring [9], early detection of forest fires [10], real-time target tracking [11], security surveillance [12], multimedia [13], structural monitoring [14] and healthcare [15]. WSNs are, however, typically difficult to implement and can in some cases be expensive. The aim of the research that is reported in this paper is to design a WSN using sensor nodes based on the IEEE 802.15.4 standard and RF technology, in order that rapid response to any emergency occurring in the Grand Mosque and the mosque's environs in Mecca may be facilitated. The design includes fixed stations, each consisting of two switches: one to be used in summoning medical help, the other to be used by those who are lost. This will be of substantial assistance in the cost-effective and timely meeting of needs of pilgrims requiring medical treatment and in facilitating basic security, such as informing the authorities of the location of missing children and the elderly during Hajj time. This paper consists of five sections. Section 2 presents a review of existing literature concerned with tracking and monitoring systems that use the WSN concept. Section 3 describes the design and specification of the proposed system, explicating the devices that have been used in this system. Section 4 presents a network simulation and its outcomes. Finally, the research conclusions are presented in Section 5.

2. LITERATURE REVIEW

Research by Mohandes [16] presented in a paper by that author described a means of implementing RFIDs for pilgrim identification and tracking during the Hajj. This method utilized radio frequency identification devices (RFIDs) for pilgrim identification. This means of pilgrim tracking, however, was not implemented on a large scale. Mohandes' [17] prototype RFID-based Pilgrim Identification System proved the efficacy of RFID systems in alleviating bottlenecks compared to traditional authentication systems, although his system requires further research, particularly in the area of improving the design of the antennae, location of readers, and the communication frequency.

Yamin et al. [18] also suggested using RFID tags connected to a central database as a means by which pilgrims may be tracked. One suggestion has involved the devolution of data collection during Hajj to the pilgrims themselves. This approach offers the prospect of gathering detailed information regarding the movement of pilgrims during the Hajj at low-cost. This system is known as Hajjdoc. It utilizes the Ushahidi platform and through a bespoke mobile application with a web server set up on Ushahidi's web-hosted CrowdMap site. The web server enables reporting of data from all Hajjdoc pilgrim application users. The reports obtained deliver data regarding a number of aspects concerning the Pilgrims' Hajj experience and their use of the various facilities provided. Yamin [19] also used RFID tags for identification and sensor devices in combination with database systems, such sensor devices being used to track the movements of pilgrims during the Hajj period.

The research conducted by Mitchell et al. [20] used a number of types of scanner including those that gather data on pilgrims' palms, fingers, eyelids, retinas and faces in order to establish the identities of people who are lost and to identify cadavers. The research concentrated on the combined use of various mobile technologies in crowd management and people tracking using location-based services. They offered a solution whereby pilgrims could be tracked using RFID technology, a location-aware mobile technique. These is a solution that could be provided to pilgrims with smart phones, enabling enhanced accuracy and tracking time of pilgrims, and provide pilgrims with location-based services during the Hajj period. They also identified situations where a solution using modern and industry-accepted technologies may be required, such those relating to medical and emergency situations.

F. Abdessemed [21] proposed a means of Hajj management through integrating pilgrimage transportation control by tracking shuttle buses from the beginning of their routes through to their destinations. This process identifies individual shuttle buses by means of individual RFID tags.

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Passengers boarding or alighting from the bus are identified on the basis of their RFID cards and their finger identification.

Tracking and identifying people in large congregations is difficult. This difficulty is exacerbated where a multitude of languages, ethnicities and beliefs are involved. RFDS offer the means by which such difficulties may be ameliorated, although they are unlikely to offer a complete solution. A complete solution may, however, be found by using advanced, efficient and effective technologies.

3. SYSTEM STRUCTURE

3.1 The Proposed System

The system proposed in this paper consists of three main types of component: first, the Station nodes, secondly the Bridge node and finally the Graphical User Interface (GUI). These are shown in Figure 1. RF Engine as shown in Figure 2 is the backbone of the proposed system. It offers potential for a new generation of battery-driven systems. Table 1 illustrates the performance of SNAP RF engine.

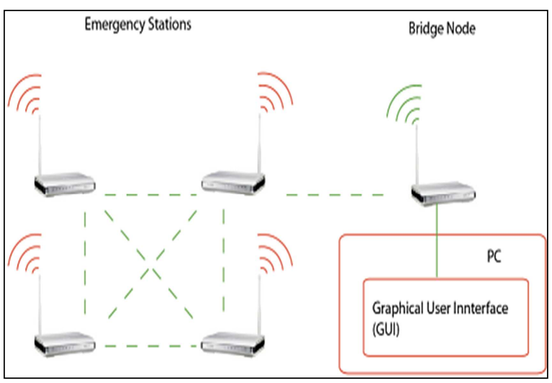

Figure 1: System Structure

Figure 2: RF Engine

Table 1: Performance of SYNAPSE RF Engine

Parameter	Value
Model	RF200
Standard	IEEE 802.15.4
Network Topology	SNAP
Transmit Power	15 dBm
Receiver Sensitivity	-103 dBm
Data Rate	Up to 2 Mbits/sec
Frequency	2.4GHz
Cost	Low
Cover Distance	3 miles
Transmit Current	80mA
Idle Current	20mA
Power-down Current	1.6 µA
Supply Voltage	2.7 - 3.6 V

3.1.1 Station Design

Wireless connections are used between station nodes. Each of the station nodes has two switches. A wireless signal is sent to the bridge node when one of the switches is turned on. The station components are: RF Module, Proto Board switches, 3V power adapter and 2x1.5 A batteries (in case of power failure). Station's circuit arrangement is shown in Figure 3.

• The first switch is linked to GPIO3 on the board and is dedicated for the provision of medical support. The switch next to it is linked to GPIO4 on the board and is used for security purpose. These two switches are denoted as input pin 3 and input pin 4, respectively. In the startup function, pin 1 is labelled as output. On pressing any of these switches, an RPC signal is transmitted to the bridge node by the station node.

• In addition, the station node confirms working status of the node. Client node's server receives RPC on triggering of the function which uses node's network address as a parameter.

• The role of middleware between GUI software and bridge is performed by SNAPconnect. It allows SNAP wireless network to be easily accessed via GUI applications by the client. Also, it facilitates interaction between client programs and distant station nodes by providing a terminal.

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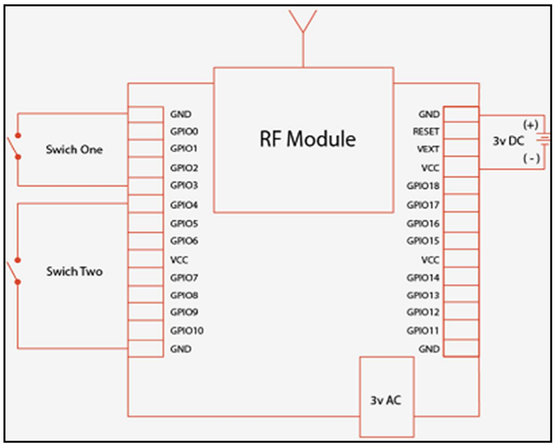

Figure 3: The Circuit Structure Of The Station

3.1.2 Bridge Node

The bridge node is linked to PC-based receiver. On receiving the signal from the station node, the bridge node directly sends it to the PC.

3.1.3 Graphical User Interface (GUI)

The Graphical user interface (GUI) takes the data obtained from the bridge node via an interface program and displays the results. The GUI is divided into four sections:

• Events: There are three buttons in the event box: Connect button, check station button and pull up menu button. The connect button connects PC and the bridge node via SNAPconnect server. The status of each node is checked by using the check station button. By using the third button i.e. pulls up menu button, all station nodes can be listed. Also, an active station node can be deactivated by the pull up menu button.

• Messages: The selected station node, request type, date and time are shown by message box.

• Statistics Frame: It tells about nature of the generated request if it is for provision of medical support or security. Also, every station's accumulative request number and number of the station are shown.

• Map: It shows construction and design of the mosque including main entrance doors which will be equipped with station nodes in real implementation scenario.

3.2 The Network Topology

The network topology used in this system is mesh network which allows communication amongst all nodes of the network if they are in the radio range of each other. If one of the communication links between nodes fails, the information can still reach the gateway by traveling through other network nodes. There are three types of nodes in IEEE 802.15.4: Coordinator, Router and End device. In our system, coordinators and routers are used. Coordinator node, which serves as the main device, initiates and synchronizes the network whereas routers serve as relaying nodes and help in information circulation between nodes.

4. SIMULATION RESULTS AND PERFORMANCE EVALUATION

The simulation conducted in this research used 10 routers and 1 coordinator as shown in Figure 4, and the simulation scenario had dimensions of 720m x 220m, matching the ground area of the mosque. The simulation runtime was 5000 seconds. Some modifications needed to be made to the nodes' parameters in order to meet system requirements. The OPNET modeler simulator was chosen for its accuracy, ease of use and due to the fact that it supports IEEE 802.15.4 standard.

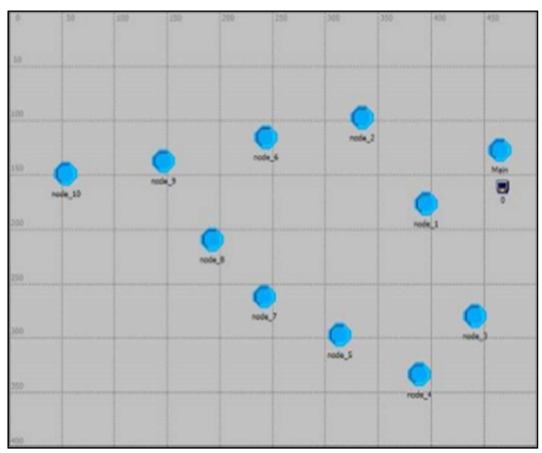
Figure 4: Simulation Scenario

The results obtained are:

- **Throughput.** Number of nodes and size of network have direct effect on throughout. Figure 5 provides the average throughput for this scenario using 10 nodes. It's clear from the figure, the network capacity is relatively high so which leads to high network performance. The throughput (transmission packets) increased dramatically with the time.

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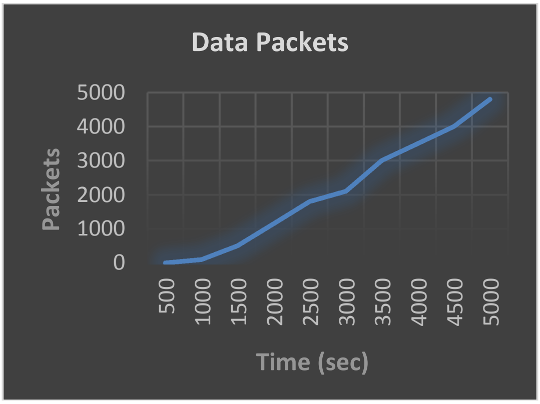

Figure 5: Average Throughput Of The Network

- **End to End Delay and Dropped Packets.** Network delay specifies the time taken by the packets to travel across the network. Dropped packets occur when packets do not reach their destination. The end to end delay and dropped packets for this scenario are provided in Figures 6 and 7. From the figures, the results indicate low in delay and dropped packets.

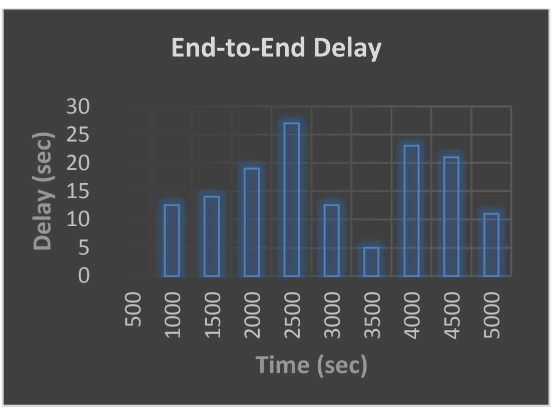

Figure 6: End To End Network Delay

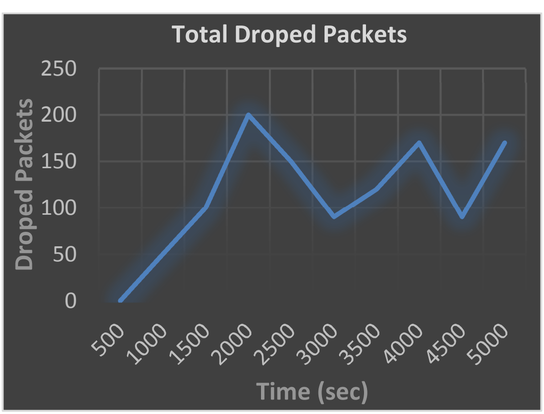

Figure 7: Dropped Packets

- **Total number of received and sent packets.** Figure 8 shows the total number for both sent and received packets in our scenario. It's clear from the figure; the difference between the number of sent packets by the ten nodes and received packets arriving at the coordinator is very small. This difference is caused by the delay and dropped packets in the network. The total number of sent and received packets is increased significantly with the time.

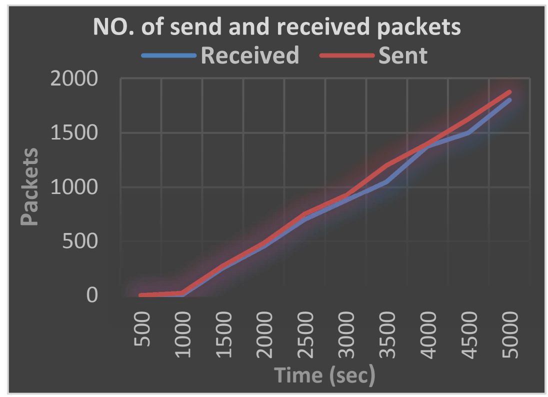

Figure 8: Total Number Of Received And Sent Packets

5. CONCLUSIONS

The proposed solution aims to secure the advantages afforded by advanced technology by setting up fixed station nodes using WSNs within the corridors of the Grand Mosque in Mecca. This will assist pilgrims in respect of their security and timely access to emergency medical services. The locations of services are established in advance and made known to pilgrims in the event that they require help or wish to enquire about any problem that could occur during Hajj time. This proposal's implementation in the Grand Mosque of Mecca is potentially cost-effective and reliable. This proposal represents a solution to the pressing need for emergency support of pilgrims during Hajj. The SNAP RF Engine module was chosen as the main device to be used in implementing the proposed method. Its selection was based on its four significant features of latest technologies, range, price, and power consumption. Various programs of differing degrees of sophistication are used in the system, each engendering specific objectives in system operation; for example, python programing language has been used to set up the codes of the two medical and security switches on the RF Engine node, C# language has been used to design the GUI which monitors the status of the station nodes and obtains a wide variety of information from each station node. The simulation tools of the OPNET modeler simulator have been used to test

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the network's behavior under a range of conditions. The results obtained have demonstrated stability in sending and resaving packets with low rates of delay and packet loss. In view of these results and the network's small size, high performance can be expected from it. For future enhancements, the implementation of the proposed model in real world scenarios (in Mecca) is needed to test the proposed model and to add several features such as geolocation and the protocols for to implement it.

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