Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Emergency Stations in the Grand Mosque of Mecca Using Wireless Sensor Network (WSN)

A Thesis Submitted in fulfilment of the requirement for the Degree of

Master of Engineering

By

MOHAMMED AMER AL NIZARI

School of Engineering and Advanced Technology (SEAT)

Massey University
Palmerston North,
September 2011

Emergency Stations in the Grand Mosque of Mecca Using Wireless Sensor Network (WSN)

MOHAMMED AMER AL NIZARI

2011

Abstract

The Hajj is one of the five pillars of Islam. Every year Muslims from all over the world gather in the two Holy Mosques, Mecca and Medina, in the Kingdom of Saudi Arabia to make the pilgrimage. The kingdom of Saudi Arabia has therefore invested heavily over the years in the security and emergency services for the comfort of pilgrims. While it is a great spiritual experience for all the pilgrims, at the same time it poses a range of series challenges to the authorities responsible for facilitating the Hajj. Security and emergency issues cause most difficulties and challenges.

Today, there are more than 2.5 million pilgrims with different languages, different ages and level of education gathering in a particular place at a specific time. A significant number of pilgrims die due to both accidents and natural causes and a large number get lost in this extremely crowded gathering. In fact, it is very common for some pilgrims to lose contact with their groups or friends during the rituals and this situation may be critical for certain pilgrims such as women children, the elderly, the sick, etc.

The use of recent technologies in the Hajj season could help in monitoring and tracking the pilgrims. Specifically these technologies could help in congestion, tracking missing pilgrims, discovering who is walking in reverse direction at peak times, re-detection etc. technologies may be found in Wireless Sensor Networks (WSNs). However; Wireless Sensor Networks (WSNs) are not easy to implement and some of them are costly.

This project to make the mission much easier, we made Wireless Sensors Network Stations as emergency fixed stations. These stations will be spread around the holy mosque to support local rescuers and aid the retrieval of missing pilgrims. Each emergency station has a button switch to press if the pilgrims get lost or if they need to request services. The range of the sensor, power consumption and the price are important in choosing the sensor. To meet these criteria we have used RF Engines from Synapse there have a range of up to 5 Km, and the lowest power consumption (IEEE 802.15.4 module running 2.4GHz Frequency, Up to 250 Kbps Data Rate).

Acknowledgments

Firstly I would like to thank, Professor Dr. Subhas Mukhopadhyay, for giving me an opportunity to do my Masters under his supervision. His wisdom, knowledge and continued support has always inspired and motivated me. Without his help, advice and expert guidance, this work would not have been possible, and, above all, I thank him for his technical and emotional support.

I extend my sincere thanks to the Custodian of the Two Holy Mosques King Abdullah bin Abdulaziz, for the support he gives to the scholarship program. King Abdullah provided an opportunity for me and my brothers to get the best level of education.

I will never forget the efforts of the Ministry of Higher Education in the Kingdom of Saudi Arabia, represented in the Saudi Cultural Mission in New Zealand in facilitating the process of scholarship and supervision on this project.

Finally, words will not describe all of the sacrifices and emotional supports made by my parents, my wife and my children as well as by my brothers and sisters. Without them my success would have no meaning. Thank you from the depths of my heart.

Table of Contents

Abstract i

Acknowledgments ii

Table of Contents iii

List of Figures vii

List of Tables xi

CHAPTER 1 Introduction

1.1 Mecca and Hajj……2

1.2 Problem definition……4

1.3 Problem statement……5

1.4 The Objective……7

1.5 Thesis organization……7

CHAPTER 2 Literature Review of Wireless Sensor Network

2.1 Existing WSN technologies and applications……10

2.1.1 Bluetooth or IEEE 802.15.1……10

2.1.2 UWB or IEEE 802.15.3……10

2.1.3 Wi-Fi or IEEE 802.11a/b/g……10

2.1.4 ZigBee or IEEE 802.15.4……10

2.2 Exiting WSN Applications ……11

2.2.1 Recent WSN applications in health section ……11

2.2.1.1 Monitoring System: Early Detection Of Alzheimer's Disease……11

2.2.1.2 Wireless Patient Monitoring System……13

2.2.2 Exiting WSN Project in Mecca and Hajj Season……14

2.2.2.1 Group of Pilgrims Monitoring (GPM) ……14

2.2.2.2 An RFID-Based Pilgrim Identification System……17

CHAPTER 3 Specification of the System and Design

3.1 Introduction……20

3.2 System structure……20

3.2.1 Station nodes……21

3.2.2 A bridge node……21

3.2.3 Graphical user interface (GUI) ……21

3.3 RF Engine……21

3.4 Evaluation kit ……24

3.4.1 SN132 SNAPstick……24

3.4.2 Synapse Portal software……25

3.4.3 SN171 SNAP Node ProtoBoard……25

3.5 Station design……25

3.6 Station nodes' Python scrip……26

3.7 SNAPconnect……28

3.8 Graphical user interface (GUI) ……29

3.8.1 Events……30

3.8.2 Connect button……30

3.8.3 Check station button……31

3.8.4 Pull up menu……32

3.8.5 Messagess Box……32

3.8.6 Statistics Frame……33

3.8.7 Map……34

CHAPTER 4 Simulation

4.1 Introduction……37

4.2 IEEE 802.15.4 Standard OPNET simulator ……38

4.3 Types of Wireless Sensor Network Topology……38

4.3.1.1 Star Network Topology……39

4.3.1.2 Cluster Tree Network Topology……39

4.3.1.3 Mesh Network Topology ……40

4.4 Node types……40

4.5 Simulation setup……40

4.6 Simulation Results ……41

4.6.1 Throughput……41

4.6.2 The Average Delay and Packet loss……42

4.6.3 Total number of received and sent packets……43

4.7 Conclusion……44

CHAPTER 5 Experiment Set- up and results

5.1 Introduction……..46

5.2 Field Experiment……46

5.3 Positioning of the sensors (draw the map network) ……47

5.4 Tools of the Experiment……51

5.5 Distance VS. Signal Strength RSSI……53

5.6 Signal Path……..56

5.6.1 Main Node……..57

5.6.2 Sensor Node One……..58

5.6.3 Sensor Node Two ……59

5.6.4 Sensor Node Three……..60

5.6.5 Sensor Node Four……61

5.6.6 Sensor Node Five……62

5.6.7 Sensor Node Six……63

5.6.8 Sensor Node Seven……64

5.6.9 Sensor Node Eighth……..65

5.6.10 Sensor Node Nine……..66

5.6.11 Sensor Node Ten……..67

5.7 Discussion on the signal paths test ……68

5.8 Battery life……70

5.9 Conclusion……71

CHAPTER 6Summary of Findings and Discussion

6.1 Introduction……73

6.2 The Project's prototype ……73

6.3 Project's hardware and Software……74

6.3.1 Hardware ……74

6.3.2 Software……74

6.4 Field Experiment……75

6.5 Positioning of the sensors (draw the map network) ……75

6.6 Tools of the Experiment……75

6.7 Results and Discussion……76

CHAPTER 7 Conclusion and Future work

7.1 Conclusion and Recommendation……78

CHAPTER 8 REFERENCES

APPENDIX A - Python script……85

APPENDIX B – The GUI code ……87

Appendix C – SYNAPSE Data Sheets……98

List of Figures

Figure1.1: Mecca location. ……..2

Figure 1.2: The Grand mosque. ……..3

Figure 1.3: The Grand mosque doors. ……..3

Figure 1.4: Number of pilgrims ……..4

Figures 1.6: Use of Medical Services during 15 Day Period of Hajj 2010……6

Figure: 2.1 Wireless sensor network…….. ……9

Figure 2.2: illustration of the proposed Bluetooth-enabled in-home patient monitoring system…..13

Figure 2.3: Remote Monitoring System……..14

Figure 2.4: A base station and gateway board …… 15

Figure 2.5: Pilgrim Navigator indicates ……..16

Figure 2.6: RFID-Based Pilgrim Identification System. ……17

Figure 2.7: RFID tag……..18

Figure 2.8: Wristband RFID tag. ……..18

Figure 2.9: GUI on the PC unit……..18

Figure 3.1: System structure. ……..20

Figure 3.2 : RF Engine……..21

Figure 3.3 Physical Dimensions of RF Engine……22

Figure 3. 5: Evaluation kit……..24

Figure 3. 6: SN132 SNAPstick [17] ……..24

Figure 3.7 : The circuit structure of the station. ……25

Figure 3. 8: start-up function code……..26

Figure 3. 9: (Set pin) Function……27

Figure 3. 10 : (onPin) function call. ……..27

Figure 3. 11: check(),(checkstations) and (localAddr()) function call. ……..28

Figure 3. 12: Message Exchange (SNAP node initiated) ……28

Figure 3. 13: Message Exchange (client application initiated) ……29

Figure 3.14: Graphical user interface (GUI) of the system. ……30

Figure 3.15: Connect button code. ……30

Figure 3.16: check station button example. ……31

Figure 3.17: Check station button code. ……31

Figure 3.18: Pull up menu. ……32

Figure 3. 19: messages box code. ……33

Figure 3. 20 : Statistics Frame……33

Figure 3. 21: statistics frame code. ……34

Figure 3. 22 MedicalStations code……35

Figure 3. 23 Security Stations code……35

Figure 4.1: Opnet simulation environment……37

Figure 4.2: The structure of the IEEE 802.15.4 simulation model. ……38

Figure4.3: Types of Wireless Sensor Network Topology……39

Figure4.4: Simulation scenario layout……40

Figure 4.5: Average throughput of the network……42

Figure 4.6: Network average delay……42

Figure 4.7: Data loss rate……43

Figure 4.8: Network collision ratio……43

Figure 4.9: Total number of received and sent packets……44

Figure 5.1: Dimensions of the Grand Mosque in Mecca……46

Figure 5.2: Dimensions of the Victoria Esplanade Garden……47

Figure 5.3: Positioning of the sensor nodes in Mecca……48

Figure 5.4 Positioning of the sensor nodes in Victoria Esplanade Garden……48

Figure 5.4: Distance from the main station node in Mecca……49

Figure 5.6: Distance between nodes……50

Figure 5.7: SYNAPSE Wireless, Inc.....51

Figure 5.8: A snapshot of Portal.....51

Figure 5.9: RF Engine network address.....52

Figure 5.10: A snapshot of Link Quality.....53

Figure 5.11 Signal Strength from Main node.....55

Figure 5.12: Distance from Main node.....57

Figure 5.13: Signal Strength from Main node.....57

Figure 5.14: Distance from node 1.....58

Figure 5.15: Signal Strength from node 1.....58

Figure 5.16: Distance from node 2.....59

Figure 5.17: Signal Strength from node 2.....59

Figure 5.18: Distance from node 3.....60

Figure 5.19: Signal Strength from node 3.....60

Figure 5.20: Distance from node 4 61

Figure 5.21: Signal Strength from node 4.....61

Figure 5.22: Distance from node 5.....62

Figure 5.23: Signal Strength from node 5.....62

Figure 5.24: Distance from node 6.....63

Figure 5.25: Signal Strength from node 6.....63

Figure 5.26: Distance from node 7.....64

Figure 5.27: Signal Strength from node 7.....64

Figure 5.28: Distance from node 8.....65

Figure 5.29: Signal Strength from node 8.....65

Figure 5.30: Distance from node 9.....66

Figure 5.31: Signal Strength from node 9.....66

Figure 5.32: Distance from node 10.....67

Figure 5.33: Signal Strength from node 10.....67

Figure 5.34: The Strongest Path……..69

Figure 5.35: Battery Life during 24 hours……..71

Figure 6.1: The Project's prototype……..73

Figure 7.1: The four floors Map of The Grand Mosque ……80

Figure 7.2: The four floors Map of The Grand Mosque……80

List of Tables

Table 2:1: Comparison of the Bluetooth, Uwb, Zigbee, and Wi-Fi Protocols [14] 11

Table 3.1: RF Engine Specifications 23

Table 3.1: icons criteria..... 35

Table 4.1: Nodes parameters..... 39

Table5.1: Distance from the main..... 49

Table 5.2: Distance between nodes 50

Table.5.3: the network address of each node..... 52

Table 5.4: Distance and signal from Main node..... 54

Table 5.5: Distance and signal from Main node.....57

Table 5.6: Distance and signal from node 1.....58

Table 5.7: Distance and signal from node 2.....59

Table 5.8: Distance and signal from node 3.....60

Table 5.9: Distance and signal from node 4.....61

Table 5.10: Distance and signal from node 5.....62

Table 5.11: Distance and signal from node 6.....63

Table 5.12: Distance and signal from node 7.....64

Table 5.13: Distance and signal from node 8.....65

Table 5.14: Distance and signal from node 9.....66

Table 5.15: Distance and signal from node 10.....67

Table 5.16: Number of paths.....68

Table 5.17: Battery Life during 24 hours.....70