AUTOMATIC APPLICATION PROGRAMMING INTERFACE FOR MULTI HOP WIRELESS FIDELITY WIRELESS SENSOR NETWORK

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JULY 2015

To my beloved mother and father,
to my lecturers, for their guidance and encouragement.

ACKNOWLEDGEMENT

Thanks ALLAH for allowing me to finish my thesis for my master degree. I would like to take opportunities here to express my sincere appreciation to my supervisor, Assoc. Prof. Dr. Sharifah Hafizah Syed Ariffin for her encouragement, patience, and guidance toward finishing this project.

I also want to wish thank you all the researchers of the Telekom Laboratory especially Abdul Hadi Fikri, Mohd Rozaini, and Hamdan for helping me a lot in programming and hardware problem related to TelG.

Lastly, I would like to express my special thanks to my family for their moral support and encouragement to overcome my problem.

I also want to acknowledge many people that involve directly or indirectly in my project, especially to my friends Muhammad Affandy in making this thesis successful.

ABSTRACT

Wireless Sensor Network (WSN) is a network that consists of low rate devices, to sense, collect and transmit collected data using wireless communication. IEEE 802.11 (Wi-Fi) is another communication standard that is rapidly being implemented in smart devices like laptops and mobile devices. IEEE 802.11 has faster data rate, wider coverage area and bigger data per packet compared to IEEE 802.15.4. This makes IEEE 802.11 suitable for big data transmission, such as multimedia data. However, there is a limitation in IEEE 802.11 which only able to send data in the same Service Set Identifier (SSID). The original IEEE 802.11 is infrastructure based which does not allow multi-hopping transmission between distributed nodes. Implementing IEEE 802.11 standard to WSN node requires new software or Application Programming Interface (API) to handle communication between the node and transmitter. In this thesis, an API is developed based on Serial Interface Protocol provided by transmitter firmware. The API includes all the configuration parameters that need to be configured when operating the transmitter for normal operation such as sending and receiving packet data. An Auto-configuration API is introduced to allow multi-hop transmission. Wi-Fi WSN node can use Auto-configuration API to disconnect from current network and connect to other nearby network and forward its data. This allows the data to be collected from the nearby network and indirectly extends the coverage area. The end-to-end delay for sending a picture in one hop transmission using Wi-Fi WSN is 20% faster compared to IEEE 802.15.4 WSN. The Wi-Fi WSN is also able to transfer data from a network to other network using Auto-configuration API using two methods which are One Joiner and All Creator (OJAC) and Some Joiner and Some Creator (SJSC) in two and three hops transmission. Result show OJAC performs 22% better in two hops transmission while in three hops transmission, SJSC performs 18% better.

ABSTRAK

Rangkaian Sensor Wayarles (WSN) adalah satu rangkaian yang terdiri daripada peranti berkadar rendah, untuk mengesan, mengumpul dan menghantar data menggunakan komunikasi wayarles. IEEE 802.11 (Wi-Fi) adalah komunikasi piawaian yang sedang pesat digunakan. IEEE 802.11 mempunyai kadar data yang cepat, kawasan liputan yang luas dan kapasiti data yang besar berbanding IEEE 802.15.4. Ini membolehkan IEEE 802.11 sesuai untuk penghantaran data yang besar, seperti data multimedia. Walau bagaimanapun, terdapat kekurangan pada IEEE 802.11 yang hanya boleh menghantar data di dalam rangkaian Pengecam Set Pengenalan (SSID) yang sama. IEEE 802.11 yang asal adalah berasaskan infrastruktur tidak membenarkan penghantaran berbilang hop. Pelaksanaan piawaian IEEE 802.11 untuk nod WSN memerlukan Aplikasi Pengaturcaraan Antara muka (API) untuk menangani komunikasi antara nod dan pemancar. Dalam tesis ini, API dibangunkan berdasarkan protokol antara muka bersiri yang disediakan oleh perisian pemancar. API termasuk semua konfigurasi pemancar yang perlu untuk operasi normal seperti menghantar dan menerima data paket. Auto-konfigurasi API diperkenalkan untuk membolehkan penghantaran berbilang hop. Nod WSN Wi-Fi boleh menggunakan Auto-konfigurasi API untuk memutuskan sambungan rangkaian semasa untuk bersambung ke rangkaian lain yang berdekatan dan menghantar data. Ini membolehkan data yang dikumpul dari rangkaian berdekatan dan secara tidak langsung memperluaskan kawasan liputan. Masa hujung-ke-hujung bagi menghantar gambar dalam satu hop penghantaran menggunakan Wi-Fi WSN adalah 20% lebih cepat berbanding WSN IEEE 802.15.4. WSN Wi-Fi ini juga dapat memindahkan data dari rangkaian ke rangkaian lain menggunakan Auto-konfigurasi API yang menggunakan dua kaedah yang Satu Penyambung dan Semua Pencipta (OJAC) dan Beberapa Penyambung dan Beberapa Pencipta (SJSC) penghantaran hop dua dan tiga. Prestasi OJAC adalah lebih 22% baik semasa penghantaran dua hop manakala semasa peghataran tiga hop, prestasi SJSC adalah 18% lebih baik.

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LIST OF ABBREVIATIONS

WSN	-	Wireless Sensor Network
IEEE	-	Institute of Electrical and Electronics Engineers
TCP/IP	-	Transmission Control Protocol/Internet Protocol
API	-	Application Programming Interface
IEEE	-	Institute of Electrical and Electronics Engineers
UTM	-	Universiti Teknologi Malaysia
BSS	-	Basic Service Set
AP	-	Access Point
MAC	-	Media Access Control
SSID	-	Service Set Identifier
IP	-	Internet Protocol
RSSI	-	Received Signal Strength Indication
UART	-	Universal Asynchronous Receiver/Transmitter
SPI	-	Serial Peripheral Interface
RF	-	Radio Frequency
OS	-	Operating System
WBSN	-	Wireless Biomedical Sensor Network
CMOS	-	Complementary metal–oxide–semiconductor
MANET	-	Mobile Ad Hoc Network
Mbps	-	Megabit per second
WWSN	-	Wi-Fi for WSN
APIID	-	API Identifier
IDdata	-	ID specific Data
IBSS	-	Independent Basic Service Set
ASCII	-	American Standard Code for Information Interchange
DHCP	-	Dynamic Host Configuration Protocol
OJAC	-	One Joiner and All Creators

SJSC	-	Some Joiner and Some Creator
P2P	-	Peer to Peer

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CHAPTER 1

INTRODUCTION

1.1 Overview

Wireless sensor network (WSN) is a network of wireless sensor nodes that are used to monitor and collect data in any remote area. This technology is widely used around the world and it enables monitoring system at low cost which is easy to maintain compared to wired system. WSN can be easily deployed in the most difficult places. Nowadays, all systems are required to be intelligent and flexible. It is hard to implement if wired system is used because it will not be cost effective just to make a system with several sensors.

IEEE 802.11 (Wi-Fi) is a standard that is well-known across the world. It is one of the main feature in mobile devices such as mobile phones, laptops, and tablets. Wi-Fi standard became so popular due to its abilities to send bigger data in a single packet and the abilities to integrate with Transmission Control Protocol/Internet Protocol (TCP/IP) protocol. It also has bigger data rate transfer thus is is an alternative for WSN because it is able to support more nodes or intermediate device at the same time compared to WSN with IEEE 802.15.4 standard.

1.2 Motivation

Currently the implementations of most of WSN systems are using IEEE 802.15.4 as its standard to communicate with each other. With IEEE 802.15.4, all

nodes are able to directly transmit the data to the base station. The base station will be connected to a computer which will transfer all the data collected. Without the base station, there is no other way to send the data from the source to the destination. WSN with IEEE 802.15.4 only able to send small data because IEEE 802.15.4 can support data rate up to 250 kbps with coverage range of 10 meters. Thus, it is usually impossible to send any captured picture to the base system because it will take a lot of time with many packets for only one picture.

IEEE 802.11g[1] is a popular standard that is able to support up to 54Mbps with range 100 meters. This standard is also being used in many wireless devices such as laptops, and mobile phones. Using IEEE 802.11 standard, the WSN do not need any base station and the laptop can directly connected to the WSN to collect data. IEEE 802.11 standard also enables the WSN node data to be retrieved over the Internet using TCP/IP standard.

Both IEEE 802.11 and IEEE 802.15.4 communication standards have their pros and cons. IEEE 802.15.4 has small coverage range with lower data rate. IEEE 802.15.4 standard is suitable to be used in small data transmit. Even though IEEE 802.15.4 is an alternative to send small packet, IEEE 802.11 has better coverage range, and faster data rate. It is more suitable in a situation that requires big data (large number of packet) to be sent from one point to another, with larger covering area. IEEE 802.15.4 can handle big data but data could be loss in the middle of a transmission.

There are also other advantages of IEEE 802.11 in WSN is that it has good non-line-of-sight transmission, very cost-effective, can be easily expanded, robust and small disturbance of links[2]. Wi-Fi has a good transmission through the barrier (i.e. walls) compared to IEEE 802.15.4 and it also has the ability to communicate in non-line-of-sight. Wi-Fi is very cost effective because it deployment can be done using the existing network. The high data rate allows Wi-Fi to support up to 100

[1] IEEE 802.11g is the only data rate the particular hardware (TelG) can support in ad-hoc mode
[2] L. Li, H. Xiaoguang, C. Ke and H. Ketai, The applications of wifi-based wireless sensor network in internet of things and smart grid, Industrial Electronics and Applications (ICIEA), 2011 6th IEEE Conference on, IEEE, 2011, pp. 789-793.

wireless connections at a time. This will make the network can go large and have many nodes at a single place. The ability to handle network better and to recover fault in the network make it more stable compared to IEEE 802.15.4. It also has advantages in the architecture support. Multi-channel in Wi-Fi helps to reduce interference due to single channel transmission, even though there are many networks in one place.

TelG mote is an in-house wireless sensor mote based on IEEE 802.15.4 developed by the Telematics Research Group Universiti Teknologi Malaysia (UTM). The drawback of the low rate IEEE 802.15.4 is that the delay in sending multimedia data is high.

1.3 Problem Statement

A sensor node is a self-developed node that is specifically design to transmit data from the source node to sink node. The node is equipped with IEEE 802.15.4 radio frequency (RF) transmitter. The characteristic of IEEE 802.15.4 is that it is able to transmit small packet data and the sensor nodes are easy to communicate with each other using multi-hopping transmission. However, IEEE 802.15.4 has a small coverage area and have a slow transmission rate. These limitations will lead to many packet losses and require more nodes to deliver large data in a bigger area. Handling big data like multimedia data would require large bandwidth and fast data rate to avoid data loss. This can be done by using IEEE 802.11 based WSN which has wider coverage area, higher bandwidth and fast data transmission rate at the expense of higher power requirement per transmission.

There is an in house sensor mote called TelG Sensor Mote. As mention in previous section, this sensor mote is based on IEEE 802.15.4. The TelG sensor mote require improvement to increase it’s performance. In order to add IEEE 802.11 transmitter to the TelG mote, Application Programming Interface (API) is required to handle its communication between transmitter and sensor node operating system. API is similar to a driver where it will bridge software-to-software while the driver is

a bridge between hardware-to-software. However, there is a limitation in IEEE 802.11 that it only allows communication between nodes in the same SSID.

This limitation caused by the hardware configuration in IEEE 802.11. IEEE 802.11 can support both infrastructure and ad-hoc mode, however, both modes are constraint to the network mode configuration. There are two network/infrastructure mode which are creator mode and joiner mode. The problem with these mode is that the node will be in a joiner mode, when it is sending data and at the same time if any other node needs to send data and scanning for a creator mode, it will not able to locate the nodes that are in joiner mode. Creator mode will host the network and joiner mode will connect to the network. The limitation can be overcome by using an auto configuration API that work together with the TelG IEEE 802.11 API. The auto configuration API is expected to provide IEEE 802.11 based WSN to do multi-hops transmission.

1.4 Research Objectives

There are three main objectives of this research in order to solve the problems.

1. To develop the application programming interface (API) code to support communication between IEEE 802.11 RF module firmware with the operating system.
2. To develop an auto-configuration API to support multi-hops operations.
3. To analyze IEEE 802.11 based sensor node to verify the workability and measure the end to end delay for multi-hop operation.

1.5 Scope of Work

This research has involved programming and test-beds experiments. The programming language used in the research is C programming language and it uses a lot of pointers and interrupt technique. The programming structure is based on object-oriented programming where all codes are being grouped in specific function based on its purpose.

Test-beds experiment is conducted using TelG sensor node as the main device. TelG is equipped with XBEE IEEE 802.11 b/g/n RF module and operating system. Some experiment involves laptop as a sink node for data final destination target. Most of test-bed experiments are conducted in an indoor environment. The experiment of multi-hopping is using static routing where the data transmission path is manually configured.

1.6 Significant Contribution of Research

The contribution of the research is the design of the API for TelG operating system to support IEEE 802.11 transmitter. The design of the API provides TelG sensor to fully utilize the transmitter and allows multi-hopping transmission. The significant contribution of research are as follows:

- The API for WiseOS to support IEEE 802.11 b/g/n transmitter. With IEEE 802.11 transmitter, TelG mote is able to transmit many packets over 20 meter distance at the expense of high current usage.
- The Auto-configuration API to support multi-hopping transmission in Wi-Fi TelG. Multi-hopping transmission allows the data transmission range extend from a network to another nearby network.

1.7 Organization of the Thesis

This thesis consists of five chapters and is organized as follows:

The first chapter discuss on the problem of the research, the objective of the research, the scope of the research and the significance of the research.

The second chapter presents related work and facts related to the research. The research is related to wireless sensor network, IEEE 802.11 wireless standard and multi-hop operation. The details on the advantages and disadvantages of those keywords are also discuss.

The third chapter discuss the design of IEEE 802.11 based WSN. This chapter provides the detail on the design of the API code and auto-configuration API for the multi-hop operation. All flow charts explaining the flow of the code and design are also included.

The fourth chapter presents the experimental test-beds. There are two experiments conducted. The first experiment is to verify the working of the API code by sending data in single-hop transmission using ad-hoc mode. The second experiment is to verify the workings of the auto - configuration API in sending data in multi-hop manner. Multi-hop are done in two methods and they are explain in detail in this chapter. The results of experiment are also present in this chapter.

The final chapter discuss on the conclusion of the research, the limitation and problem occured in the research. This chapter also suggest the future works to overcome the limitation.

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