DEVELOPMENT OF AN EMBEDDED WIRELESS SENSOR NETWORK PLATFORM BASED ON SBC APPLICATION

By

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LIST OF ABBREVIATIONS

App	Application
BD	Band Rate
DSP	Digital Signal Processor
DVI	Digital Visual Interface
FPGA	Field Programmable Gate Array
GPIO	General Purpose Input Output
GUI	Graphic User Interface
HDMI	High Definition Multimedia Interface
LCD	Liquid Crystal Display
OS	Operating System
R/W	Read/Write
RAM	Random Access Memory
Rasp Pi	Raspberry Pi Device
RS	Register Select
SBC	Single Board Computer
SD Card	Secure Digital Card
SDHC	Secure Digital High Capacity
SDXC	Secure Digital Extended Capacity
USB	Universal Serial Bus
Vdd	Positive Voltage Supply
Vss	Negative Supply Voltage
WPAN	wireless personal area network
WSN	Wireless Sensor Network
Xbee	ZigBee

Membangunkan Rangkaian Sensor Tanpa Wayar Terbenam Berdasarkan Aplikasi SBC

ABSTRAK

Lebih dari sedekad penyelidikan dan pembangunan pesat dijalankan, teknologi rangkaian sensor tanpa wayar telah muncul sebagai satu penyelesaian kepada pelbagai aplikasi. Tesis ini mengenai reka bentuk sistem rangkaian sensor tanpa wayar yang telah dibangunkan menggunakan platform perkakasan sumber terbuka iaitu ZigBee dan Raspberry Pi. Reka bentuk ini mempunyai kelebihan yang mana ia memerlukan penggunaan kuasa yang rendah, kos rendah dan boleh skala untuk pelbagai jenis sensor serta bilangan unit sensor yang membolehkan ianya sesuai untuk pelbagai aplikasi berkaitan dengan menghantar dan menerima data. Walau bagaimanapun, fungsi Raspberry Pi dalam reka bentuk ialah menjadikannya lebih fleksibel, murah dan peruntukan penuh. Kod Python telah digunakan dalam komponen pengaturcaraan untuk mendapatkan kod yang lebih kecil dan mengelakkan ralat dalam pengaturcaraan serta boleh dibangunkan dengan pesat pada masa akan datang. Walau bagaimanapun, pilihan sistem operasi Raspbian untuk Raspberi hendaklah mempunyai satu system berkualiti tinggi, stabil dan boleh skala yang mana disokong oleh syarikat pengilang Raspberry. Raspberry Pi bertindak sebagai stesen pangkalan untuk protokol ZigBee dalam rangkaian sensor tanpa wayar dan mengumpul data dari sensor yang berbeza serta menyediakan perkhidmatan multi-clients termasuk paparan data. Walau bagaimanapun untuk perkembangan masa depan, data boleh dipantau dari jauh di stesen pangkalan melalui laman sesawang.

Development of an Embedded Wireless Sensor Network Platform Based on SBC Application

ABSTRACT

With more than a decade of dense researches and development, wireless sensor network (WSN) technology has been appearing as solution to many applications. This thesis concerns of designing a wireless sensor network system which has been developed using open-source hardware platforms, ZigBee and Raspberry Pi. This design has advantages of low power consumption, low-cost and scalable in terms of the type of sensors and the number of sensor units that makes it well suited for a wide range of applications related to sending and receiving data. Although use of Raspberry Pi in the design, make it flexible, cheaper and full allocation. Python code has been used in programming the components to get a smaller code and avoid errors in programming and can be developed rapidly in the future. The choice of Raspbian operating system for Raspberries was to have a high-quality, stable and scalable operating system in which supported by Raspberry manufacturer company. Raspberry Pi act as a base station for ZigBee protocol in the wireless sensor network and collects the data from different sensors, and provide multi-clients services including data display. As future development, data can be seen remotely at the base station via website.

CHAPTER 1

INTRODUCTION

1.1 Overview

Embedded systems play an important role in our lives every day. It is a fast growing industry, which affect our daily life directly. In fact they are tools used to control, monitor or assist the operation of equipment, machinery or plant (Fischmeister, 2014). These systems perform pre-defined tasks, usually with very specific requirements, although they could be optimized in terms of size and cost. Optimization even of a small piece could be such cost effective due the mass production of embedded systems which include millions of pieces (Kopetz, 2011). However the advantages of embedded systems are lower power consumption, small size, low cost, small weight and Lower Electromagnetic interference. On the other hand, the disadvantages are, difficulty in design process, faster obsolesce, low mean time failure, unmanageable heat loss, repair and maintenance are not possible (Kopetz, 2011). Embedded systems can be manipulated in different applications such as telecommunication, missiles, smart cards, and satellites, digital consumer electronics, computer networking, and automotive.

Sensors convert the physical data receive from the ambient to a readable electrical or numerical data, however several sensors could integrated to a single sensor to collect many information from the same place, therefore these info could be used to perform a specific task based on the information received. When several sensor nodes work together indoor or

outdoor and done a task, these call sensor network. If the communication through them is without wire and use radio transceiver this call wireless sensor network.

In recent years the use of wireless short range technologies such as ZigBee, Bluetooth, Wi-Fi and 6LoWPan become common. These devices have different range power consumption and data band width and other features and they could connect to small computers such as Raspberry to make an embedded wireless sensor network.

1.2 Problems Statement

- SBC integrate with WSN will close the gap and bring SBC for new applications area and got accumulative advantages.
- Advantages of these technologies push towards building more devices that can achieve true interactive of phenomena under visions.
- Design and implement small in size embedded wireless sensor network using Raspberry which is low cost and lower power consumption compared with propeller board, beagle board and other SBC device. However it is cost and consume more power than Arduino but include 700 MHz processor, Operating system, 1GB RAM, Ethernet and micro SD RAM which considered advantage of Raspberry over Arduino.

1.3 Aims and Objectives

The purpose of this research is to design and implement a solution that capable to handle in an efficient way to reach specific goals like, low consumption and low-cost in a

wireless transmitter to ensure that the technology can be used with common elements such as temperature, humidity, movement, speed sensors, measures and surveillance. To accomplish these goals, this research work opted into the following objectives:

1. To design and develop a cost effective ZigBee sensing based SBC with Raspberry Pi.
2. To implement a network for data transmission base SBC.
3. To validate the performance of the system.

1.4 Brief Methodology

The embedded WSN based raspberry is designed with ZigBee that offer data rate and high reliable communication link for specified distance. The proposed system is composed mainly of two categories hardware and software parts.

1.4.1 System Hardware

1. Raspberry pi 2 B+
2. ZigBee 4214A
3. LCD 1602A
4. Accessories (Keyboard, Mouse and HDMI Cable)

1.4.2 System Software

The proposed system is based on Raspbian operating system as a software platform. The software mainly is based on client/server, where the clients represent the end nodes and server represented by the link node. However the software will monitor and collect clients' information and offer flexibility to process data as required.

1.5 Scope of Study

Embedded systems are efficient platforms that prove high advantages over various applications. WSNs have gained crucial demands last decades due to their positivity in sensing and data collection through network based protocols. The WSN based SBC has been design and developed by utilization of available tools, also the necessary applications that have been used are described.

Nowadays, Wireless Sensor Network has gained much attention of the new generation of networks. This research is focusing on the design and implementation a cost effective WSN system. The targeted WSN that will designed and discussed, is smart to perform tasks based on information received from sensors, although it characterized by high speed. As well as, the system manage sending and receiving information via ZigBee and raspberry devices, its small size make it suitable for a small network, the advantages above make a good reason for developers to enhance these type of networks.

1.7 Thesis Outlines

The thesis includes four chapters, discussing the design and operation of an embedded wireless sensor network system. Below is the brief detail of each chapter.

- Chapter 1 shows an overview on embedded systems and WSNs, research motivation and problem statement, aim & objectives, scope of study, brief research methodology, as well as thesis outlines.
- In chapter 2 the background of Single Board Computer, Linux, Raspberry Pi, ZigBee Standard, Raspbian, Python and literature review of the project has been discussed.
- Chapter 3 will discuss the methodology of the work, results and their analyses.
- Chapter 4 will include an overview, a brief summary of the work has been done, conclusion and future works.

CHAPTER 2

LITERATURE REVIEW

2. 1 Overview

Nowadays, researchers and developers have produced numerous embedded systems that used for remote monitoring, alerting, controlling and many other functions which led to profitable works and tasks. The embedded systems are specially hardware and software designed in one component to perform a certain task comparably with general computers. Embedded systems invade with applications such as airplanes, monitory, control, home appliances and medical devices.

Wireless sensor networks (WSN) have important applications such as environment monitoring and tracking. They composed from sensors which equipped with wireless interfaces to communicate with each other. However a wireless sensor network based SBC is cost effective, low power, well utilize and efficient system. These systems could monitor several activities in real time (Yick, Mukherjee & Ghosal, 2008).

2.2 Single Board Computer (SBC)

Many computers represent different units with variant functions on a single circuit board, these devices known as single board computers or as SBCs. These devices specified with a centered microprocessor for analyzing data and a memory to make it faster and more

functional, however these computers need input and output port to communicate with other devices and achieve the ability to receive and transfer the information in different types.

SBC embedded system has been design as a general purpose processor module and can work as an independent unit (Ethernet, SD card and USB/Serial converter are all on the board), these features in design allow initial development done without affecting the main part of the module.

The proposed of the SBC board that has been used in this project is that these SBC boards are integrated with all basic system interfaces and that needed in Education and Industrial laboratories (Nduka, 2012). Small size, low power consumption, versatile and low cost, are characteristics of single board computers (Open Embedded, 2016).

The common types of SBC computers could be summarized as PICMG, VXI, VME bus, Compact PCI and PXI. The internal processors of these small computers differ in structure and processing and power consumption such as RISC and SPARC types. In addition to that, Single board computers allow their several boards to connect via several connectors. Some of SBCs include PC/104, PC/104-Plus, EBX, EBX, PCI-104, EPIC, and PC/104. These boards are available for use in control systems. Although SBCs have memory cards such as DIMMs and SIMMs, although the HDD could be connected to the SBCs boards as mass storage unit for saving data (journalist, 2010).

2.3 Linux

One of the forms of UNIX operating system is Linux which was used by engineers and scientists in programming, whilst it was not familiar to the public and other small

projects. The first major operating system that implemented in TCP/IP protocol Internet also was UNIX, and that led to the public notice of this operating system. Although the Macintosh operating system was based on Unix and the android operating system is based on Linux (Matloff, 2013).

The first OS which developed by Berkeley was Unix 3BSD, followed by version 4.0, 4.1, 4.2 and 4.3 , these versions of OS add more features such as virtual memory and TCP/IP. This OS is still considered one of strongest operation system in the world, the simplicity of OS makes more development for foreign organizations, as an example of these organizations is contributors from University of California at Berkeley. Moreover, this modern OS success as a worldwide operating system, due to its simplicity, good design, support demand paging, shared libraries multithreading ,TCP/IP network support and virtual memory features (Love, Are, Linus, Kernels & Begin, 2005).

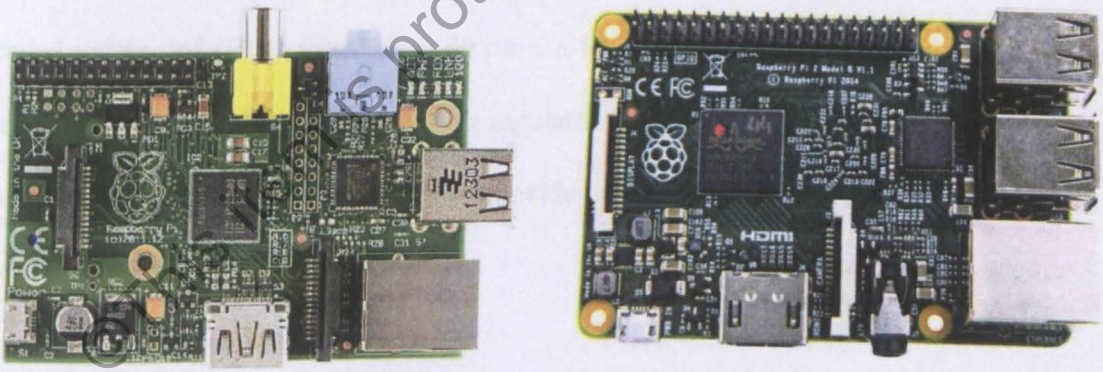
Linux OS these days become familiar in large desktop markets, such as offices, universities and businesses due to its lower rate of virus infection compared with Windows and its lower cost and reliability. Today Linux considered one of reliable and stable operating system and its major corporation in Web. Although it is free and several developing companies found that it is cheaper because this OS need less maintenance (Matloff, 2013).

This OS improved and developed for computers that use Intel 80386 microprocessor by Linus Torvalds. The speed and time to perform the instructions was very quickly, and due to its license and its available to changing by developers, gain collaborative to many projects. Compiler, toolchain, C library, basic system utility, kernel and shell are fundamentals of Linux system. There are thousands of free programs which work for small

and large machine. In addition to that Linux OS includes a modern X window with perfect desktop environment and is not commercial product (Love, Are, Linus, Kernels & Begin, 2005).

2.4 Raspberry Pi

Raspberry Pi has two generations which known as Raspberry Pi and Raspberry Pi 2 as shown in Figure 2.1. These devices are single board computers (SBC) with size of small credit card. The idea of developing a small computer begun in 2006 by realization that the young generation have not enough information about computers and their operation therefore a group of academics, develop a small computer in which any person can buy it with cheap price to provide all people with programming environment (Pomyen, 2015).



(a) Raspberry Pi model B (b) Raspberry Pi 2 model B

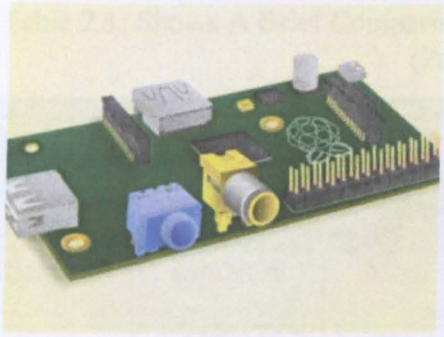
Figure 2.1 Raspberry Pi's Generation 1 and Generation 2 (Pomyen, 2015).

The first generation of Raspberry (Raspberry Pi) developed in four models as shown in Figure 2.2. the first model was known as model B which followed after model A. after

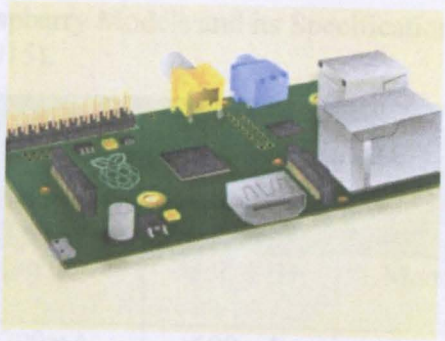
these two models model B+ and model A+ have been released which upgraded to be more efficient and more convenient to users by reducing power consumption and adding more USB ports to perform more functions, whilst the second generation have only one model which called Raspberry Pi 2 model B which its specification is based on Raspberry Pi model B+ but with faster CPU and more memory.

Raspberry Pi model B, as shown in Figure 2.2(b), released in 2012 with the specification of 256 MB RAM, two USB ports and one Ethernet port. Later in the same year, model A as shown in Figure 2.2(a) released, the RAM size increased to 512 MB. These first generation computers use Broadcom SoC, BCM2835, which integrates 700 MHz single-core ARM1176JZF-S.

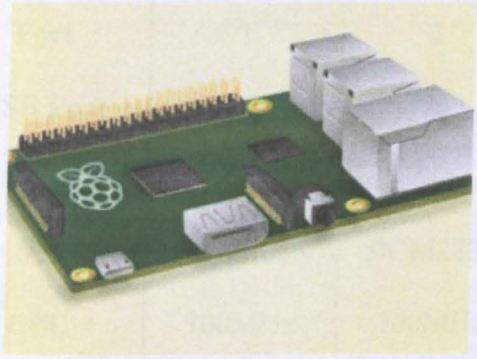
In 2014, an upgraded version of the two previous models released, called B+ and A+, as shown in Figure 2.2(c) and 2.2(d). The two new models have same CPU, GPU and RAM as their previous versions, a micro SD memory socket replacing an SD card slot, an upgraded version of GPIO from 26 to 40 pins, a low noise audio and a 0.5 to 1 W lower power consumption by having a switching regulator instead of a linear regulator. Moreover , model A+ is 2 cm shorter and model B+ provides four USB ports instead of two in model B (Pomyen, 2015).



(a) Raspberry Pi model A



(b) Raspberry Pi model B



(c) Raspberry Pi model B+

(d) Raspberry Pi model A+

Figure 2.2: Raspberry Pi models (Pomyen, 2015).

In early 2015, The Raspberry Pi 2 model B was released as the latest Raspberry Pi model with updated hardware. The Raspberry Pi 2 B specifications include four USB-ports, a quad-core CPU processor running at 900MHz, 1024 Megabytes of memory and one micro-SD card slot for storage. The Raspberry Pi 2 model B is faster compared with previous model with twice amount of memory, One 10/100 Megabit/s Ethernet-port and now has a quad-core processor which is speculated to make the Raspberry Pi 2 model B up to six time faster than the previous models (Aspernäs & Simonsson, 2015). Table 2.1 summarizes the specification of each model.

Table 2.1: Shows A Brief Comparison of Raspberry Models and its Specifications (Pomyen, 2015).

Raspberry Pi	Generation 1				Generation 2
specifications	Model A	Model B	Model A+	Model B+	Model B
Power	300mA	700mA	200mA	600mA	900mA
Ethernet	No	Yes	No	Yes	Yes
Port	1	2	1	4	4
USB Port	26	26	40	40	40
SD Card Slot	SD	SD	Micro SD	Micro SD	Micro SD
Soc	BCM2835	BCM2835	BCM2835	BCM2835	BCM2835
CPU	700MHz	700MHz	700MHz	700MHz	700MHz
	ARM11	ARM11	ARM11	ARM11	ARM11
	Single-core	Single-core	Single-core	Single-core	Single-core
RAM	256 MB	512 MB	512 MB	512 MB	1 GB

2.5 ZigBee Standard

ZigBee is a simple, efficient and low power consumption standard of wireless technology which use to create or built small low power digital network. It is based on IEEE 802.15.4 level. The low consumption, limits its distance for communication to 10-100 meters. By using a mesh network ZigBee could transfer the data over long distances. Usually ZigBee used for low data rate which need long battery life and secure network. ZigBee has defined a rate of 250 Kbit/s for transition from sensor or input device. The