ENHANCEMENT OF DESIGN AND DEVELOPMENT OF RADIO FREQUENCY IDENTIFICATION (RFID) ZIGBEE MESH NETWORK FOR MATERIAL FLOW SYSTEM

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ABSTRACT

Methods of manually recording data, using barcodes and tracking distance constraints are problems encountered during handling of materials inside a manufacturing facility. However, Radio Frequency Identification (RFID) technology is not new but now as an effort to automate the operation and process of the mill to achieve optimum production. The aim of this study is to develop a production line monitoring system to track the current location of processed products where it underestimates and takes time to be tracked clearly by traditional methods. This proposed system is named Smart Material Flow System (Smart MFS) is to improve the efficiency of locating product in real time in the industrial plant. This novel system was developed based on the Waterfall model. The research methodology involves two parts namely hardware and software. The hardware combines passive RFID and active RFID while the software a General User Interface (GUI) for users to interact with electronic devices through graphical icons and visual indicators. The system WAS implemented in the Wireless Mesh Network (WMN) environment whose performance is assessed in terms of maximum read range for indoor environment, output power level versus read range, multi tags communication efficiency. The results of the assessment indicate that the maximum reading range is 2.45 meters for passive wireless communication, while 95 meters for active wireless communication. The power level for active wireless communication indicates that as output power increases, the distance of active wireless communication readings also increases. The communication efficiency of various tags can reach 100% of data received at a distance of 15 meters. The findings show that Smart MFS can be used to improve product location accuracy in real-time where Smart MFS has the ability to detect and track material flows from warehouse until shipping to overcome uncontrolled manual tracking and reduce labor costs.

PENAMBAHBAIKAN REKABENTUK DAN PEMBANGUNAN RANGKAIAN ZIGBEE MESH UNTUK SISTEM ALIRAN BAHAN

ABSTRAK

Kaedah merekodkan data secara manual, menggunakan barcode dan kekangan jarak pengesanan merupakan masalah yang dihadapi semasa pengendalian bahan di dalam sebuah kilang pembuatan. Namun begitu, teknologi *Radio Frequency Identification (RFID)* bukanlah sesuatu yang baharu namun kini sebagai usaha untuk mengautomasikan operasi dan proses kilang bagai mencapai pengeluaran yang optimum. Tujuan kajian ini adalah untuk membangunkan sistem pemantauan barisan pengeluaran untuk mengesan lokasi semasa produk yang diproses dimana ia meremehkan dan memakan masa untuk dijejaki secara nyata oleh kaedah tradisional. Sistem yang dicadangkan ini dinamakan *Smart Material Flow Sytem (Smart MFS)* adalah untuk meningkatkan kecekepan kebolehkesanan lokasi produk dalam masa nyata dalam gudang industry. Keaslian pembangunan adalah berdasarkan model Air Terjun. Metodologi kajian melibatkan dua bahagian iaitu perkakasan dan perisian. Perkakasan yang dibangunkan menggabungkan antara *Radio Frequency Identification (RFID)* pasif dan *RFID* aktif manakala pembangunan perisian pula membangunkan *General User Interface (GUI)* supaya pengguna dapat berinteraksi dengan perkakasan yang dibangunkan melalui ikon grafik dan petunjuk visual. Sistem ini dilaksanakan dalam persekitaran *Wireless Mesh Network (WMN)* iaitu prestasinya dinilai dari segi julat bacaan jarak maksimum yang dibaca di dalam persekitaran tertutup, tahap kuasa terhadap jarak bacaan, kecekapan komunikasi pelbagai tag yang dicadangkan. Keputusan penilaian menunjukkan bahawa julat bacaan maksimum adalah 2.45 meter untuk komunikasi tanpa wayar pasif, manakala 95 meter untuk komunikasi tanpa wayar aktif. Tahap kuasa untuk komunikasi tanpa wayar aktif menunjukkan bahawa apabila kuasa output meningkat, jarak bacaan komunikasi tanpa wayar aktif juga meningkat. Kecekapan komunikasi pelbagai tag mampu mencapai 100% data yang diterima pada jarak 15 meter. Penemuan ini menunjukkan bahawa *Smart MFS* ini boleh digunakan bagi menambahbaik kebolehkesanan lokasi produk dalam masa nyata di mana *Smart MFS* berkeupayaan untuk mengesan dan mengesan aliran bahan bermula dari gudang sehingga penghantaran untuk mengatasi penjejakan manual yang tidak terkawal dan mengurangkan kos buruh.

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LIST OF ABBREVIATIONS

AP	Access Point
API	Application Programming Interface
APP	Application Layer
APS	Advanced Planning and Scheduling
ASRS	Automated Storage and Retrieval System
CCA	Clear Channel Assessment
COM Port	Communication Port
CSMA-CA	Carrier-Sense Multiple Access with Collision Avoidance
DHCP	Dynamic Host Configuration Protocol
DSL	Digital Subscriber Lines
DSSS	Distributed Sequence Spread Spectrum
ED	Receiver Energy Detection
EmRFID	Embedded RFID Reader
EPC	Electronic Product Code
EPC C1G1	EPC Class One Generation One
FFD	Full-Function Devices
G1	Generation one
GPS	Global Positioning System
GUI	General User Interface
HF	High Frequency
ID	Identification Number
IIoT	Industrial Internet of Things
IP	Internet Protocol

ISM	Industrial, Scientific, and Medical
ISO	International Standards Organization
JDBC	Java Database Connectivity
LED	Light Emitting Diode
LF	Low Frequency
LLCP	Logical Link Control Protocol
LOS	Line-of-Sight
LQI	Link Quality Indicator
MAC	Medium Access Control
MCDAS	Managerial Control and Data Acquisition System
MLME	MAC sub layer management entity
MPDU	MAC protocol data units
NFC	Near-field communication
NLOS	Non-Line-of-Sight
NWK	Network Layer
PAN ID	Personal Area Network Identification
PC	Personal Computer
PHY	Physical Layer
PIE	Pulse Interval Encoding
PLME	Physical Layer Management Entity
PLME-SAP	Physical Layer Management Entity-Service Access Point
PPDU	Protocol Data Units
PSSS	Parallel Sequence Spread Spectrum
RF	Radio Frequency
RFD	Reduced-Function Devices

RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indicator
RTF	Reader-Talks-First
SAP	Service Access Point
SDP	Service Discovery Protocol
Smart MFS	Smart Material Flow System
SSI	Smart Sensor Interface
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TOTAL	Tag-only talks-after-listening
TTF	Tags talks First
UART	Universal Asynchronous Receiver/Transmitter
UDP	User Datagram Protocol
UHF	Ultra-high Frequency
UPC	Universal Product Code Standard
USB	Universal Serial Bus
USM	Universiti Sains Malaysia
UTHM	Universiti Tun Hussein Onn
WMN	Wireless Mesh Network
WSN	Wireless Sensor Network
WTO	World Trade Organization
ZDO	Zigbee Device Object

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CHAPTER 1

INTRODUCTION

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1.1 Background Study

Radio Frequency Identification (RFID) was recovered during the World War II in 1935. Due to its feasibility in many applications, the tracking system covers from high-end business sectors to mid-range (Anir, Nizam, & Masliyana, 2008). Tracking, anti-theft, inventory monitoring, control asset monitoring and management and electronic payments are among several popular RFID applications. In Malaysia, market observation reported that RFID has been used in 2009 reached approximately $9.5 million and by the end of 2016 roughly increase to $33.8 million (Khor, Ismail, Kamarulazizi, & Rahman, 2012). Furthermore, researcher has explored the various aspect of implement the RFID system with other technology.

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These days in broadened undertaking, constant assembling material stream assumes an imperative part and plans to accomplish an ideal generation administration. RFID innovation and Wireless Sensor Network (WSN) are awesome arranging and supervision of assembling exercises to guarantee that will be delivered on time at the most minimal conceivable cost (Luis Ruiz-Garcia, Lunadei, Barreiro, & Robla2, 2009). It contributes to making information flow fluent and the extended enterprise model more practical. There are three important elements in this research which is about Zigbee, WSN and also mesh network. Other than that, most of the application including Security and privacy related to RFID technology become increasingly important (Vladimir Modrak, Peter Knuth, 2010).

In this research focusing an embedded of active RFID and passive RFID are developed which able to detect in short and long distance. Zigbee is another remote system standard in the field, for example, IEEE 802.15.4 brought an innovation out of the examination centre and empowered the improvement of various business items (Huang & Park, 2009). Zigbee is another individual zone arrange radio correspondence standard which has been configuration to serve low data rate (S. H. Yang, 2013).

This thesis addressed the important issues that related to the worldwide retail and distribution in RFID. Unlike barcode technology, RFID is able to identify the object from a distance in line of sight and non-line of sight. RFID framework comprises of three essential parts: a transponder (tag), a transceiver (reader) and an information gathering device.

1.2 Research Motivation

RFID is an automatic identification and data capture technology which is composed of three elements: a tag, antenna and a reader. Active and passive RFID both fall under the RFID and are often discussed interchangeably. However active and passive RFID are essentially different technologies. Even though the difference may seem trivial on the surface but its impact on the functionality of the system is significant. However neither provides complete solution to the supply chain asset management. By combining both technologies give impact to the communication range, tag cost and business process impacts. Table 1.1 shows the complementary use of active and passive RFID.

Table 1.1

Complementary Criteria of Active and Passive RFID

Requirement Criteria	Active RFID	Passive RFID
Tag Cost	High	**Low**
Tag powered	Continuous	**Only when in range of the reader**
Communication Range	**Long Range (100 m or more)**	Short range (3 m or less)
Business Process Impacts	Minimal	**Extensive**
Boxes Individual Items Luggage/ Unit Load Device	- Unstructured movement throughout airport facility - Requires Security	**- Structured** **- Orderly process for conveyors**

The idea of integrating RFID and WSN to enhance the reader capability by having routing functions that able to forward information to and from other readers. Tags are able to be read from distance 100 m – 200 m that is beyond normal range of readers. In addition it gives RFID to work in multi jump to stretch out utilization of RFID to work in more extensive zone. Mesh network topology is a network topology where every node will transfer information for the system and every other node collaborate in the conveyance of information in the system.

By adopting the WSN technology for tracking application gives extraordinary points of interest over customary wired framework since information section and report planning are extremely dreary and tedious. In this manner they require a mechanized of material stream and constant criticism to expand uptime, lessen vitality and enhance profitability. This issue is featured from the business themselves which require answer for the control of materials developments in their processing plant.

Utilizing the RFID, extensive number of assembling information could be gathered progressively. The execution of Advanced Planning and Scheduling (APS) is to accomplish real-time production (Zhong, Huang, Zhang, Luo, & Lin, 2014). Other usage of RFID in Malaysia is in Universiti Tun Hussein Onn Malaysia (UTHM) where analysts build up the framework for experienced in research facility hardware monitoring (Helmy, Wahab, Kadir, & Tukiran, 2006). Researchers in Universiti Sains Malaysia (USM) build up the new arrangement of incorporate ongoing Managerial Control and Data Acquisition System (MCDAS) for modern mechanization (Zulkifli, Abdulla, & Ismail, 2012a). RFID develop additionally into nourishment industry (Anir et al., 2008) creating framework for halal sustenance following. The proposed venture is to build up the execution of uninvolved and dynamic RFID framework with Zigbee innovation for modern assembling minimal effort, long range and bolster substantial system.

Figure 1.1 demonstrates that, by 2014, the quantity of WSN devices will represent 15% of the whole modern estimation and control hardware detecting focuses, and 33% by 2016. From the research , by 2018, WSN will grow the aggregate market for mechanical field instruments by more than 20% and new markets or applications that cannot be wired and will make up 60% as of now (Richardson, 2011).

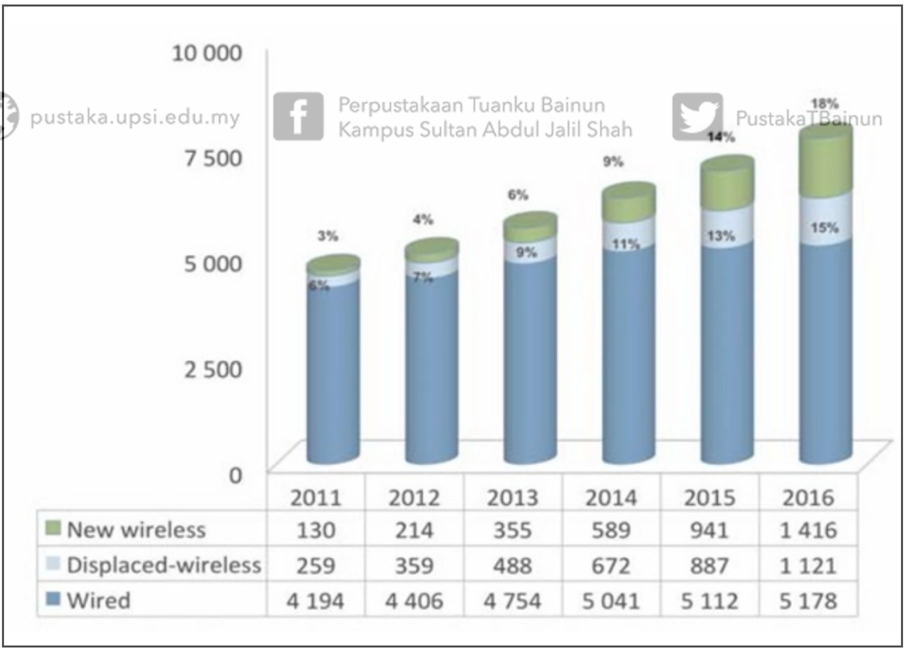

Figure 1.1. Global industrial field instrument shipments wired and wireless (ON WORLD, 2015)

1.3 Problem Statement

Pallet/bin is the decision for labourers to physically screen the track of development on the processing plant floor. The recklessness of human that cannot nearly screen the development materials comes about the correct materials are not accessible at the season of demand. Along these lines bringing about loss of time, vitality and cost because of human unequipped for concentrating on the rehashing work (Rosli, Hashim, & Jamaludin, 2013). An effective framework recognizes and consequently tracks the developments of these materials are wanted with a specific end goal to enhance proficiency.

The procedures of information section and report readiness are exceptionally tedious and it is extremely critical for organization's reference, perception and intercession. As indicated by an Industrial Report (Source: CANON (M) Sdn. Bhd.) a distribution centre director need to spend about five hours in a move to simply enter in the information and an additional 2.5 hours to set up a material following report. Since the manager invest more energy in achieving these undertakings, the chief will invest less time in observing the creation line action and it will influences the profitability yield. The traditional manual tracking and label for materials control used in the industry is shown in Figure 1.2.