AUTOMATED PRODUCTION LINE MONITORING SYSTEM USING EMBEDDED RFID

by

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Che Zalina Zulkifli

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LIST OF ABBREVIATIONS

ACK: Acknowledge

ADC: Analog-Digital-Converter

AODV: Ad-hoc On-demand Distance Vector

API: Application Programming Interface

BD: Baud rate

BFSA: Basic Framed Slotted Aloha

BFSK: Binary Frequency-shift Keying

CKE: Clock Edge

CKP: Clock Polarity

CMOS: Complementary Metal-Oxide Semiconductor

CPU: Central Processing Unit

CRC: Cyclic Redundancy Check

CS: Chip Select

CST: Computer Simulation Technology

DBMS: Database Management System

DC: Direct Current

EEPROM: Electrically Erasable Programmable Read-Only Memory

EIA: Electronic Industries Association

ERFIDC: Embedded Counter System with RFID

FFD: Full Function Device

GND: Ground

GSM: Global System for Mobile

GPS: Global Positioning System

GUI: Graphical User Interface

HF: High Frequency

IC: Integrated circuit

H2M: Human-to-Machine

ID: Identification

I^2C: Inter IC

ICSP: In-circuit Serial Programming

IDE: Integrated Development Environment

IEC: International Electrotechnical Commission

I/O: Input/Output

ISO: International Organization of Standardization

ISM: Industrial, Scientific and Medical

JDBC: Java Database Connectivity

KPI: Key Performance Indicator

LCD: Liquid Crystal Display

LED: Light-emitting Diode

LF: Low Frequency

LOS: Line-Of-Sight

LSB: Least Significant Bit

MCU: Microcontroller Unit

MCDAS: Managerial Control and Data Acquisition System

M2M: Machine-to-Machine

MIS: Management Information System

MySQL: Microsoft Structured Query Language

NLOS: Non-Line-of-Sight

OC: Organization Chart

OS: Operating System

PA: Power Amplifier

PAN ID: Personal Area network Identification

PC: Personal Computer

PCB: Printed Circuit Board

PHY: Physical Layer

PIC: Programmable Interface Controller

RAM: Random Access Memory

ROM: Read Only Memory

RF: Radio Frequency

RFD: Reduce Function Device

RFID: Radio Frequency Identification

RREQ: Route Request

RREP: Route Reply Packet

RSSI: Received Signal Strength Indication

RTC: Real-time Clock

RTF: Reader-Talks-First

RTL: Real Time Location

RX: Receive, Receive Mode

SCLK: Serial Clock

SCK: Serial Clock

SDI: Serial Data In

SDO: Serial Data Out

SCI: Serial Communication Interface

SO: Serial Out

SPI: Serial Peripheral Interface

SPBRG: Synchronous Baud Rate Register Generator

TRFB: The First Response Byte

TRLB: The Last Response Byte

TTF: Tag-Talks-First

TTL: Transistor Transistor Logic

TX: Transmit, Transmit Mode

TXIF: Transmit Interrupt Register

TXREG: Transmit Register

TXSTA: Transmit Status and Control

UHF: Ultra High Frequency

URL: Uniform Resource Locater

USART: Universal Synchronous and Asynchronous Receiver Transmitter

USB: Universal Serial Bus

WISP: Wireless Internet Service Provider

WLAN: Wireless Local Area Network

WSN: Wireless Sensor Network

WMSN: Wireless Mesh Sensor Network

ZC: ZigBee Coordinator

ZED: ZigBee End Device

ZMN: ZigBee Mesh Networking

ZR: ZigBee Router

SISTEM PEMANTAUAN BARISAN PENGELUARAN OTOMATIK MENGGUNAKAN RFID TERBENAM

ABSTRAK

Di dalam industri pengeluaran, rangkaian tanpa wayar kebanyakannya digunakan dalam rantaian bekalan, pengurusan bekalan runcit, kunci keselamatan elektronik dan pencegahan kecurian. Industri pengeluar memerlukan teknologi komunikasi yang cekap dan tindakbalas dalam masa nyata untuk meningkatkan produktiviti dan menyediakan kos penyelesaian yang berkesan. Kajian ini mencadangkan sistem pemantauan pengeluaran otomatik dalam barisan pengeluaran menggunakan frekuensi radio (RFID) terbenam, di aplikasikan dalam Rangkaian Mesh Pengesan Tanpa Wayar (WMSN) dan sistem pemantau dan pemprosesan/pemusatan data melalui teknologi perisian berasaskan web. Peranti tertanam dalam barisan pengeluaran otomatik sistem pemantauan mampu bekerja sebagai unit individu atau bekerja bersama-sama dengan terminal rangkaian pelbagai seperti WMSN dan menyediakan penyelesaian komunikasi mesin ke mesin (M2M). Pengujian dan penilaian keseluruhan sistem telah dijalankan dalam syarikat industri yang terpilih. Keupayaan komunikasi membaca sistem yang dicadangkan itu mencapai jarak sehingga 123 m dengan kuasa tertinggi +3 dBm. Penilaian perlanggaran data dalam persekitaran WMSN menunjukkan peratusan purata data yang diterima mencapai hampir 100%. Melalui kaedah rangkaian pelbagai hop sistem yang dicadangkan memberi masa kutipan keseluruhan adalah kira-kira 37 % lebih rendah daripada RFID tag yang sedia ada. Perbandingan antara pangkalan data yang sedia ada, dalam spesifikasi yang sama menunjukkan keupayaan masa tindak balas server yang dibangunkan adalah lebih cepat sebanyak 30%. Ini bersesuaian

dengan sistem pemantauan pengeluaran kerana masukkan data terhadap sistem adalah secara berterusan berdasarkan ketetapan masa sesuatu produk. Cadangan infrastruktur tanpa wayar bersepadu dapat mengurangkan kira-kira 50 % kos berbanding dengan pembekal tempatan yang lain dengan penyelesaian berwayar. Paparan masa nyata dan laporan data juga boleh membantu kedua-dua kumpulan pekerja dan pengurusan untuk mengambil tindakan segera seterusnya menyumbang kepada peningkatan dalam mengurangkan kesilapan campur tangan manusia. Kemampuan sistem yang dibangunkan menyumbang kepada pengurangan 75 % masa berhenti operasi barisan pengeluaran. Manakala sumbangan data pemusatan dan sistem laporan secara otomatik dapat mengurangkan tiga jam hingga lima jam sehari masa bagi penyelia menyediakan laporan dan masukan data secara manual yang mana masa ini boleh diperuntukkan bagi tugas-tugas pemantauan pengeluaran. Syarikat industri pengeluaran yang menjalinkan kolaborasi dalam kajian ini juga melaporkan peningkatan kecekapan dan produktiviti selepas mengaplikasikan sistem pemantauan dengan RFID terbenam yang dinamakan Kawalan Pengurusan dan Sistem Perolehan Data (MCDAS).

AUTOMATED PRODUCTION LINE MONITORING SYSTEM USING EMBEDDED RFID

ABSTRACT

In industrial manufacturing, wireless network can be used in supply-chain, retail stock management, electronic security keys, and theft prevention. Manufacturers require an efficient communication and real time feedback to maximize uptime, improve productivity, and provide cost effective solution advancement. This research proposed automated production line monitoring system using embedded RFID through wireless mesh sensor network (WMSN) platform and smart data processing adopted through web-based monitoring system. Embedded devices in the automated production line monitoring system is capable to work as individual units or work together with multiple terminal links such as in WMSN and provide Machine-to-Machine (M2M) communication solution. The reading range capabilities of the proposed system have been tested in the WMSN platform in real world industrial environment. The results obtained shows that the reading range is able to achieve 123 m with the highest power of +3 dBm in Line-of-Sight (LOS). In data collision evaluation with WMSN platform, the average percentage of data received achieved merely 100%. In multi-hop network, the overall proposed system collection time is about 37% lower than the existing RFID tags. Response time within the same specifications shows that the developed server is faster by 30% compared to the existing database. Hence, this is compatible with the output monitoring system since the input is continuously fed based on the standard time of a certain product. The proposed integrated wireless infrastructures are able to minimize approximately 50% of cost compared to other local vendor with wired solutions. In addition, 75% reduction of downtime in the production line which causes the increase in productivity and yield is recorded due to the effective monitoring. On the other

hand, the contribution of automated data centralization and reporting system reduces three to five hours of supervision time per day. Therefore, the hours meant for report preparation and manual input can be assigned to monitor the production line. The collaborator factory also reported a higher efficiency and productivity after implementation of the proposed automated production line monitoring system with embedded RFID named Managerial Control and Data Acquisition System (MCDAS).

CHAPTER 1

INTRODUCTION

1.1 Overview of Embedded System

The first embedded system was introduced by the US Airforce's Minuteman ICBM in year 1961 to control the guidance and stability functions of missile. The development of this missile has proven that implementing embedded system can decrease the cost by several orders of magnitude (Mazidi and Mckinlay, 2006). The second embedded system introduced by the United States Navy's F14 Tomcat fighter in 1970, contained arguably the first microprocessor based embedded system which consists of 8 processors and 19 memory chips (Kia, 2005). Technologies have rapidly grown and now the spacious embedded system may simply be developed by a single chip known as a microcontroller. Microcontrollers are systems-on-a-chip which does not require any peripheral devices to function. Nowadays, consumer products are drivers of embedded systems technology such as iPhone, playstation and other sophisticated machines. Institute of Electrical Engineers (IEE) has described a general purpose embedded system as devices used to control, monitor or assist the operation of equipment machinery or plant. "Embedded" reflects the fact that they are an integral part of the system. In many cases, their "embeddedness" may be such that their presence is far from obvious to the casual observer (Mazidi and Mckinlay, 2006). The wider group of industries such as health care, defense, entertainment, plantations, industrial, until home automation have now gained many benefit of using embedded technology. However, there are deficiencies in optimizing the use of technologies due to time constraint, cost and others limitations.

Focusing in the industrial manufacturing applications, this research has taken up the challenges to propose a new architecture of embedded system.

1.2 Research Motivations

Report from EPU, Economic Planning Unit, WSN and RFID have many potential applications and also are the core enabler of Internet of Things (IoT). Beyond Asia, European framework also includes RFID technologies which will help shape our future. EPU concludes that ‘A global network infrastructure enables the linking of physical and virtual objects through the exploitation of data capture and communications capabilities (EPU, 2011). This infrastructure includes existing and evolving internet and network development. RFID will offer specific object identification, sensor and connection capability as the basis for the development of the independent federated services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability. Figure 1.1 illustrates the WSN market potential which shows the ability of Asia to grow beyond Europe in the near future.

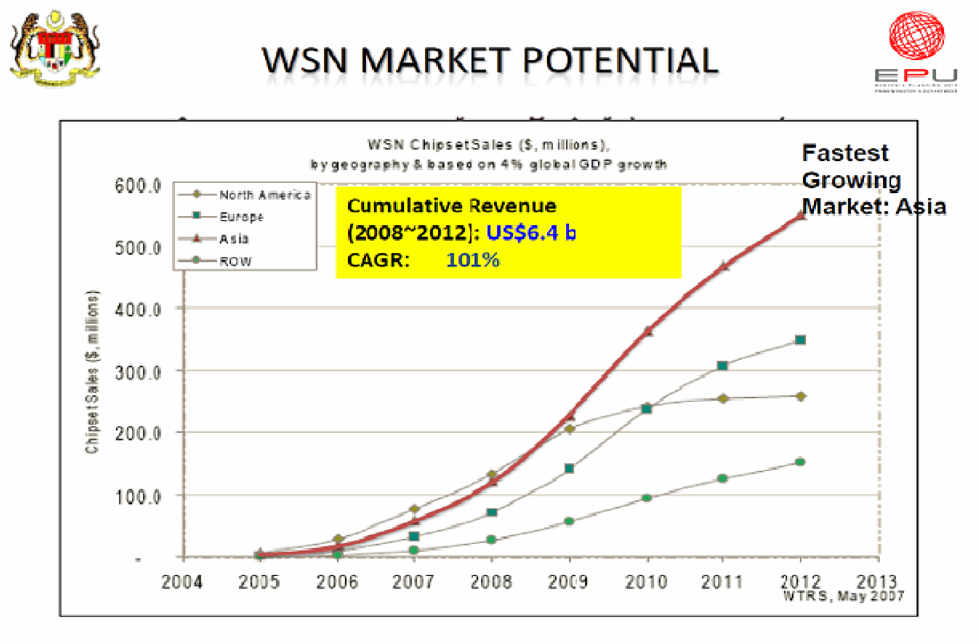

Figure 1.1: Trend for WSN market potential (EPU, 2011)

According to ICT National Roadmap for Malaysia study 2008, the key recommendations are inputs for the formulations of strategic policies, programs and plans to intensify Malaysia's transformation to a knowledge-based economy. There are three technology focus areas for Malaysia to pursue which are Wireless Sensor Networks, Predictive Analytics and Dimensional Internet. RFID technology possesses a high potential in solving many issues especially where innovation is applied. Figure 1.2 depicts the trend for RFID value creation analysis in Malaysia for the year 2011 to 2015.

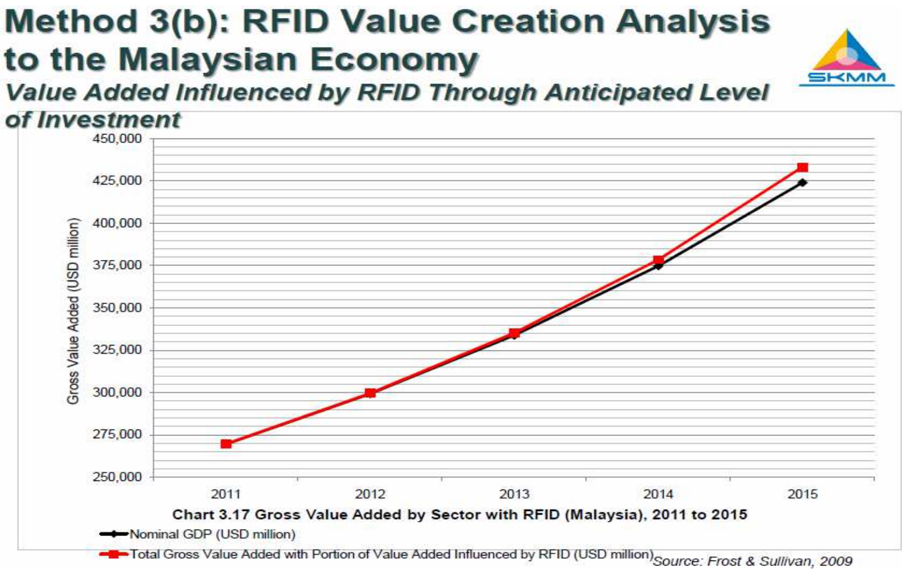

Figure 1.2: RFID value creation analysis (2011-2015)(EPU,2011)

Hence, in an industrial environment, the Industrial Management has wasted up to millions of dollars due to the delay of monitoring output achievement (Thomesse, 2005). This happened due to the weakness in using technologies, communication system and information delivery on production lines. A production line in a manufacturing industry is defined by a series of operation in sequence which has to undergo certain processes based on the specific organization needs involving machine or human. Each production line must be monitored to gain a higher productivity. To monitor the output achievement performance of the production line is not an easy task. It requires the use of technology to facilitate monitoring and real time feedback. To keep up with today's demanding workload, manufacturing plants may require long work shift in multiple areas and departments in one plant. In line with this, they require an efficient communication and real time feedback to maximize uptime and improve productivity.

By seeing the capabilities of WSN and RFID technologies, a decision to embed both has been made. The architecture of this system comprises of RFID tags and sensor nodes with the ability to read the content of active RFID tags, whereby a reader accepts information from the personal computer (PC) and sends signal to tag, and after that sends the received signal back to the PC. The PC is also known as the base station to monitor all the data received from the reader. Each sensor node will be fixed around the area where the objects will be tracked and monitored. RFID tags are mobile and there are three (3) parts of sensor node with RFID Reader which are sensing part, reading part which gathers data from RFID tags, and radio transceiver part which sends data to the sink node.

The studies show that these technologies have a good impact on the production output monitoring systems, owing to their flexibility, cost reduction and cabling minimization, and sharing important information among others. After conducting an investigation into several different options, in line with future market of new technologies deployment, the development and implementation of an Embedded Architecture System with active RFID on Wireless Mesh Sensor Network (WMSN) adopted through web-based system architecture in production area for output monitoring system has been proposed.

1.3 Research Objectives

The general aim of this research is to design and develop a new architecture of embedded system prototype components that comprise of the RFID technology, WMSN platform, counter system and web-based monitoring system. The particular objectives of the research work are outlined as follows:

1. To investigate and design the active RFID systems adopted through ZigBee technology that has the capability to function on WMSN platform, and can function to automate the production line output monitoring.

2. To design and implement a real time system for monitoring output production lines with consists of a embedded counter, RFID systems and web-base system capable of providing real time information in real world industrial manufacturing environment for proof of concept in accomplishing the machine-to-machine communication (M2M).

3. To analyze the performance and characterize the proposed solution of the complete package of embedded systems at a real-world environment for production line monitoring system output to prove it is able to automate its data collection and reporting, reducing downtime and hence improve company productivity.

These objectives are linked together in a continuous process to contribute to a more informed decision-making for the management of industry based on real time feedback and automated monitoring from the proposed system. Better decisions will lead to greater accountability and profit for the organization.

1.4 Technical Challenges and Requirements

In today's world there is a variety of sophisticated equipment, but to design an embedded system requires the understanding of the concept and in-depth technical knowledge for various related areas. In general, the technical challenges that have to be overcome to meet the embedded system specification are real time communication, complexity, and concurrency and legacy languages. Additionally this implementation involves industrial environment that needs the proper understanding of industrial requirements.

This research involves the designed and development of six main elements which comprise of:

- Hardware requirements including fabrication
- Software architecture and programming tasks
- Embedding and integration platforms and tools for hardware, software and firmware
- Server configuration and WSN tools and requirements
- Deployment and testing in real industrial environment
- Documentation

1.5 Thesis Outline

The thesis has been organized into six chapters as follows. The literature review is presented in Chapter 2 which describes the survey on the important and benefits of implementing the WSN in the industrial applications. This chapter also explains the scenario of the production line in the manufacturing environment and other impactful factors to achieve maximum profit in the industry. Highlighted in this chapter are also the existing technology and those such as ZigBee, WiFi, RFID, network topology, M2M communication as well as a description on the software platform. Specification and operation of the key components used in the research is discussed in Chapter 3. This particular chapter 3 also demonstrates the detailed aspects of design and development for hardware platform including the embedded mechanism between devices and WMSN platform. The methodology of hardware and network design and development is discussed in chapter 4. Chapter 4 also describes the software development and implementation for data acquisition system and proposed output monitoring system. Chapter 5 presents the results and discussion of the testing that have been conducted for the proof of concept (POC) in the selected real world industrial manufacturing environment located in Seberang Perai Pulau Pinang, Malaysia. Chapter 5 also demonstrates the actual contributions and advantages of the complete package of the proposed system for selected company that has been implemented for pilot testing. The last chapter provides the conclusion and future work that can be realized for this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The total revenues for wireless sensors and transmitters in industrial applications in 2009 reached $526.7 million. This market revenue is likely to reach $1.8 billion in the next four years. The size of the wireless pressure sensors and transmitters market alone is expected to reach $132.9 million in 2012 (Bekhet, 2012). Wired connections share one significant drawback with other wired industrial networking approaches: Cabling, distance and cost limitations associated with wired links surface quickly on sprawling factory floors and in large industrial settings, and running cable to new or relocated equipment can interrupt production. These hardwiring drawbacks have led many to seek a longer range and more flexible alternative in wireless sensor network.

WSN is no longer a new technology, but the use of WSN in the industry is still not very widely used especially in production areas of a plant. It is probably because the right technology and appropriate architecture of WSN is still not explored. Basically, users tend to consider WSN is a technology that can be developed by itself from its own components. But, a system architecture of WSN is designed in this research which is developed from enhancement and designing of other technology, namely active RFID technology. The proposed system architecture introduces embedding technology of WSN, active RFID, counter system and web-based monitoring system to be a smart architecture suitable for real time output monitoring achievement in industrial applications. A wireless sensor network

(WSN) is a wireless network that consists of spatially distributed sensor nodes comprising devices using sensors that monitor physical or environmental conditions, such as temperature, humidity, speed, pressure, motion or pollutants, at different locations. WSN is a network with low cost of sensing and processing compact devices that are connected among themselves by a wireless medium to perform distributed and cooperative sensing tasks. The system will be implementing one of WSN topology which is mesh network because it can be a good model for large-scale networks of wireless sensors that are distributed over a geographic region. The proposed system is focusing in building mesh network using XBee modules which are ZigBee-compliant chips manufactured by Digi International, Inc. In this proposed system, ZigBee platform 802.15.4 protocol is adopted for the indoor communication of 2.45 GHz active RFID.

This research observes the ability of these four approaches to address the unique requirements and challenges of industrial communications and provides an overview of integrated products designed specifically for industrial applications. Table 2.1 gives an idea about a breakdown of the main requirements for the levels which provide a relevant solution in communication for industrial applications. An initial approach in the proposed system architecture is to adopt the two main focuses from this table of requirements which is the amount of information and the response time needed that suit with the applications for the output achievement monitoring system.

Table 2.1: Communication requirements and constraints (Minan, 2007)

Level	**Requirement**	**Volume data to transmit**	**Response time**	**Distance**	**Netwo topolo**
Management	Data exchange, Real time monitoring, Computer security, Software packages	Files Mbits	1min	World	Bus, st
Production Floor	Synchronization of integrated microprocessor's in the same data exchange automation in client/server (supervision). Real time performance	Data Kbits	50-500 ms	2-500 m	Bus, st
Machine	Distributed architecture, Embedded functions and exchange. Transparency. Topology & connection costs	Data Kbits	5-100 ms (PLC cycle)	10 m to 1Km	Bus, st
Sensor	Simplification of distribution wiring for power supply to sensors and actuators. Optimized wiring costs.	Data Bits		1-100 m	No constra

Basically, this research involves four different big areas of technologies that are combined into high resourceful and dynamic solutions. In this proposed system, a ZigBee platform 802.15.4 protocol is adopted for the communication of 2.45 GHz active RFID. The implementation of ZigBee has the following advantages: low cost, range issues, low power consumption, real-time data collection, and fully automated monitoring system. The enhancement in RFID technologies resulting in a wireless mesh sensor network (WMSN) in industrial automation is a novelty for the industrial arena to achieve a higher gain with use of recent technological knowledge. In addition active RFID tags with electronic counter system has to be developed and embedded for device simplicity but are also capable of multiple functions. Furthermore, another additional smart integrated technology to reach a complete solution which is the development of the web-based monitoring systems with M2M functionalities. All this embedded technological convergence produces new system architecture named Managerial Control and Data Acquisition System (MCDAS).

2.2 Overview of Manufacturing

Manufacturing refers to the process in industrial production in which raw materials is transformed into finished goods and ready for sale based on the company requirements. Typically, manufacturing process is performed in the production lines.

2.2.1 The Production Line

A production line in a manufacturing industry is defined by a series of operation in sequence which has to undergo certain processes based on the specific organization needs involving machine or human. Production line in industries can be categorized into three main types which include the line being handled by robot or automated machine, semi automated machines (human and machines) and by human. Figure 2.1(a), (b) and (c) show the types of production lines respectively. In this research, all the data refers to human types of production line.

(a) (b) (c)

Figure 2.1: Types of production lines (a) automated machine
(b) human and machines (c) human

Regardless of the category, each production line must be monitored to gain a higher productivity. To monitor the output achievement performance of the production line is not an easy task. It requires the use of technology to facilitate monitoring and real time feedback. Normally, industries use human intervention in the form of supervisor to monitor and record monitoring data using paper or white board.

2.2.2 Factors Affecting Productivity of Production Line

The industry highlights that the main factors affecting production lines productivity can be classified into four as shown in Figure 2.2. Each element contributes in various consequences to production lines productivity (Siva *et.al.*, 2011).

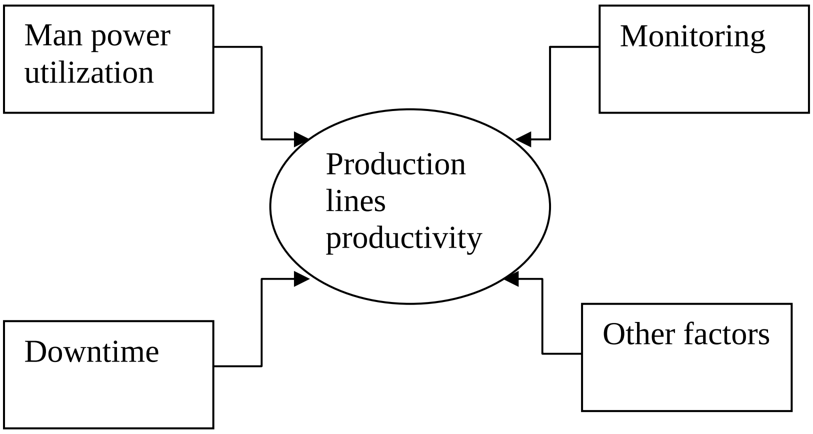

Figure 2.2: Factors affecting productivity of production lines

a) Manpower Utilization

Manpower is the most significant role in any organization in producing any output or in running the production line. Human performance is dependent on working environment, working hours and individual capability. It is a known fact that the performance of workers easily affects the productivity. When performance of the workers drops the production output is reduced and as such this will result in a lower profit. Figure 2.3 illustrates how the manpower performance would impact the companies' profit.

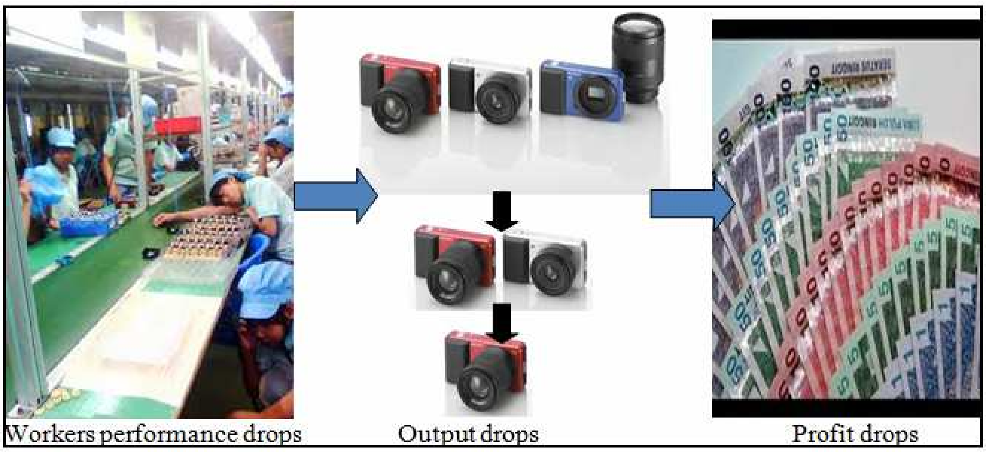

Figure 2.3: Illustration for relationship of workers, output and profit

The manpower utilization is precise from the length of actual working time. For manual process line by human, man power utilization is the ratio of actual production output to the target production output as in Equation 1 (Robert, 1999).

Man power utilization = Actual Production Output / Target Production Output *(1)*

b) Monitoring System

Monitoring system is divided into two different forms of monitoring which include human supervision and devices monitoring. Both are very much related to communication and real time feedback. However, when a manufacturing or production company has a wider range of production lines which would in turn require an enormous number of manpower, the output would be affected by the inefficient mode of communication. In fact, the use of technology can enhance the monitoring efficiency rather than merely relying on human intervention. For instance, the uses of internet, wireless connection as compared to cabling and manual recording of data are contributing factors to a more efficient communication (Ziemerink and Bodenstein, 1998).

As such, this research proposes that a new architecture of embedded RFID on WSN platform with a web-based monitoring system be implemented in minimizing human intervention and materializing M2M wireless communication. This would then ensure a better communication, provide a more effective and efficient faster response from management and data centralization instead of the current traditional method of human monitoring.

The processes of data entry and report preparation are very tedious and time-consuming and yet are very significant for the company's reference, observation and intervention. According to (Tom Pherson, 2006) a supervisor would have to spend an average of five hours in a shift to just key in the data and another 2.5 hours to prepare a production line report. As more time is spent on accomplishing these tasks, the supervisor would then spend less time monitoring the production line activity and this directly affects the productivity output. Figure 2.4(a) shows the traditional white board output monitoring system used in the industry and Figure 2.4(b) shows the output manual report that need to be prepared by a supervisor.

INPUT DAILY FINISHED PRODUCYS
#DON'T COUNT FINISHED RETURNS PRODUCTS

#1 RU = 0.06 SEC.

MASS PRODUCTION WORKING TIME EXPECTED (= S.T.(RU) X FINISHED PRODUCTS(pcs) / 60000(H))

MODEL	S.T.		ITEMS / DATE	Monday 10/01	Tuesday 11/01	Wednesday 12/01	Thursday 13/01	Friday 14/01	Saturday 15/01
		RU	FINISHED PRODUCTS	1500	1380	1560	1590	1380	
K288	5126		M.P.WORKING TIME EXPECTED	128.2	117.9	133.3	135.8	117.9	0.0
		RU	FINISHED PRODUCTS						
	0		M.P.WORKING TIME EXPECTED	0.0	0.0	0.0	0.0	0.0	0.0
		RU	FINISHED PRODUCTS						
	0		M.P.WORKING TIME EXPECTED	0.0	0.0	0.0	0.0	0.0	0.0
		RU	FINISHED PRODUCTS						
	0		M.P.WORKING TIME EXPECTED	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL MASS PRODUCTION WORKING TIME EXPECTED				128.2	117.9	133.3	135.8	117.9	0.0

(a) (b)

Figure 2.4: Current implementation (a) Output monitoring board (b) Manual report (CEM, 2011)

In relating to a better monitoring system, this also involves the top management and is not just limited to the production plant. Moreover it should not just be confined to certain place but should be made more accessible regardless of time and place. To exemplify, multinational companies such as SONY and CANON whose top management are based in Japan and yet have to monitor their branch factory output performance. Hence, the web-based system is a very useful technology in providing an efficient communication.

Strategic practices such as Kaizen, Lean Manufacturing and Total Quality Management are used by many organizations to help improved processes and drive productivity (Redlion Whitepaper, 2006). The visual management is used for KPI (Key Performance Indicator) monitoring such as large LED displays to powerful LCD displays. The large displays for visual management manage to displays real-time data and message to drive productivity. This type of monitoring is a innovative solution for industrial automation. Managing productivity and profitability is a key role of plant managers and engineers in world-class manufacturing operation. By estimating financial impact, output from production line or machine within a production facility could be increased up to 20%. Hence, the financial impact will be higher if downtime could be reduced by as much as 15% through visual monitoring (Redlion Whitepaper, 2006). Thus, the real-time displays shows that even the slightly improvement by visual monitoring can result in attractive returns. As such, this condition is suitable with the proposed application that is the production output monitoring system whereby the proposed integrated counter display enables management and workers to gain real time data visibility that drives productivity.

c) Downtime

Downtime refers to the period when a production line stops running. Downtime is divided into two types which are ‘Planned Downtime’ and ‘Unplanned Downtime’ (Siva *et al.,* 2007). The planned downtime doesn’t affect the target output achievement since it has been accounted for in the management output schedule. Planned downtime is a period of which the management halts the operation of a particular production line due to a few reasons such as the project betterment, line upgrading, low demand and others. On the other hand, unplanned downtime is a period of which the production line has to be put to a stop, due to the poor production line observation exemplified by the shortage of materials, the absence of workers and others. Unplanned downtime is a condition highly minimized by the industries since it only contributes to lower yield (Tom Pherson, 2006) and lower productivity efficiency.

Meanwhile, the yield of the manufacturing process refers to how many products can be manufactured and sold. Thus, the higher output an industry is able to produce its yield, it would then result in a higher amount of products which in turn gives more profit to the company. The product output yield is directly related to the actual operation time period. Total actual operation time is the period of runtime of production line after it is being deducted from the downtime period and other accompanying period like the workers' recess hours. As such, efficiency of productivity is calculated as in Equation 2 (Robert, 1999).

$$\textit{Productivity efficiency} = \frac{(\textit{run time of line}) \times (\textit{total good units produced})}{(\textit{total actual operation time}) \times (\textit{target})} \qquad (2)$$

Downtime of production line is a loss to a company. Supervisors are responsible in ensuring that downtime doesn't take place and minimizing it if it takes place. It can be seen that monitoring and an effective communication system can help minimize the downtime and eventually eliminate it. Communication time and feedback response are also time-wasters. A display of electronic board of output achievement, centralization of information and real time output data collection that are proposed in this research enable immediate feedback for the management, resulting in a better mechanism to control the downtime of production line.

d) Other Factors

In general, manpower capitalization involves most of the processes in the industries ranging from the management to the operators. In the industrial environment, workers from many departments have to work together to achieve the company's objectives. However, once the target isn't reached, they will start blaming one another. Hence the support department plays a very significant role in maintaining the work consistence on the industrial floor.

2.3 Review of RFID Applications

RFID technologies are used in many applications, such as in the military, education, government service, agriculture, home automation; health and automotive industry. Applications for each of these areas depend on each sector's requirements and specifications. For example, the health and welfare sector needs sensor compactness and wireless connectivity, while low cost is imperative for automotive and home automation sectors (Lionel and Yunhao, 2008). Industrial manufacturing, warehouse facilities, suppliers and government agencies use RFID technology to track, secure and manage items throughout the entire life of the product. In industries, barcodes are popular to be used in most applications. Compared to RFID technology, the barcodes or previous generation of auto ID technology has several weaknesses that include its requirement for human energy, space and the data stored in the barcode is smaller than RFID tag. What makes this proposed automated monitoring system different is that it will track the accumulated quantity production output achievement by each model running by individual line instead of tracking individual product or location. Furthermore, this embedded system is complete with data acquisition interfacing from wireless mesh network components and real time data processing over the web-based monitoring system. Table 2.2 presents a few famous RFID applications whereby most of the application involves the tracking of product absolutely difference requirements compared to proposed architecture which uses active RFID technology capabilities enhanced to WMSN implementation.

Table 2.2: Recent RFID applications (Fagui et al.,2009)

Organization/System	**Applications**	**RFID**	**WSN**
United Parcel Service of America (UPS)	Supply chain applications that provide RFID services for customers.	Passive	×
Wal-Mart	Its top 100 packaged-goods suppliers must attach RFID tags to cases and pallets	Passive and Active	×
U.S Department of Defense	Requires suppliers to put RFID tags on shipping pallets and cases	Passive and Active	×
Toyota (South Africa)	Toyota’s carrier tagged to improve manufacturing and vehicle tracking.	Passive	×

“×”: Does not implemented WSN

2.4 Review of WSN in Industrial Automation

Recently, the use of WSN in industrial automation has gained attention. This efficient technologies will raise especially in the following areas; industrial mobile robots, real time control and data acquisition system, periodic data collection, inventory and tracking, centralization information for management and process control and monitoring (Dermibas, 2005).

According to Low *et al.,* (2005), in industrial environments, the coverage area of WSN as well as the reliability of the data may suffer from noise, co-channel interferences, and other interferers. For example, the signal strength may be severely affected by the reflections from the walls (multi-path propagation) (Werb and Sexton, 2005), interferences from other devices using ISM bands (Low *et al.*, 2005), and by the noise generated from the equipment or heavy machinery. In these circumstances, it is important to sustain data integrity for operation-critical data. Every part of these issues set a special prominence on automation design and the fact that WSN is technically challenging systems, requiring expertise from several different disciplines. Additionally, requirements for industrial applications are often stricter than in other domains, since the failure may lead to loss of production or even loss of lives (Low *et al.,* 2005, Werb and Sexton, 2005). The system designed and implemented in this work is based on embedded architecture that design and develop the active RFID system becoming a WMSN and comprised of a plurality to form a self-healing communications network within indoor infrastructure in a manufacturing environment which also consider the above difficulties such as weak of signal strength.

The proposed work and research is closely related to the work of Young-Il *et al,* (2005). They also studied the application using RFID and integrated WSN technology. They design and implement the power facility management system with RFID tags and sensors in Korea Electric Power Corporation (KEPCO). Since, there are several other differences; a significant difference here is that they use the LAN protocol communication between the node to the access point using TCP / IP whilst the proposed application is upscaling an active RFID with wireless mesh sensor network infrastructure using ZigBee platform. Young-Il *et al.,* (2005), work, attached the RFID reader to the hand-held device and after inspections, the inspector needs to return to the office and connect the hand-held to the PC to run the output. Here, the significant difference is that the proposed system architecture introduces embedding technology of WSN, active RFID, counter system and web-based monitoring system to be a smart architecture suitable for real time output monitoring achievement in industrial applications. From the industrial perspective, based on an industrial analysis, wireless communications are divided into six classes of workgroup on inter-device wireless communication applications (ISA SP100.11, 2006) as shown in Figure 2.5.

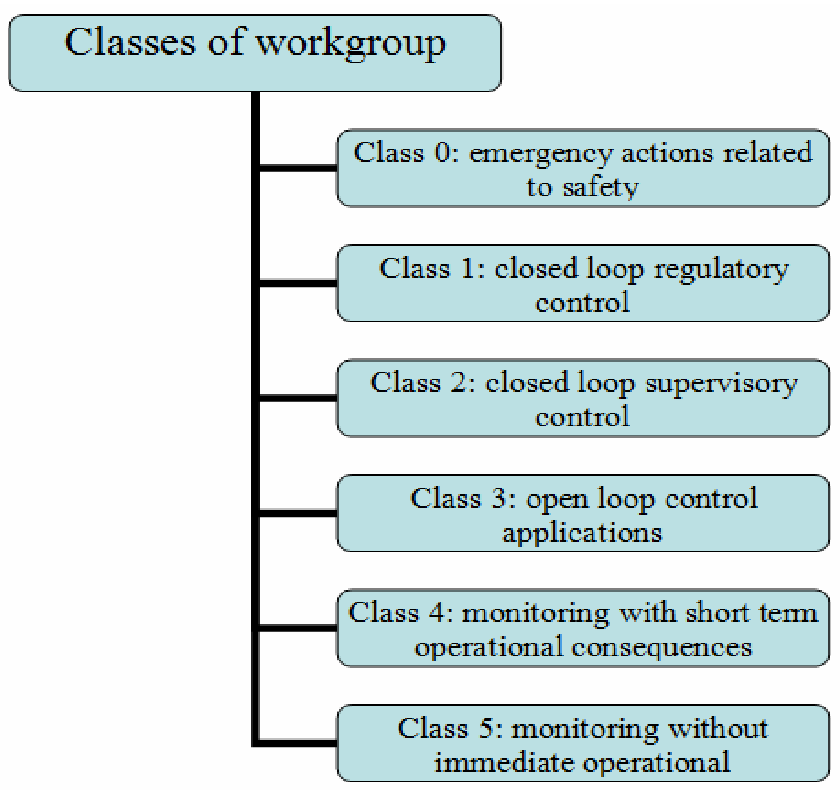

Figure 2.5: Classes of WSN in industrial applications

Class 0, categorized in emergency actions related to safety, which are critical to both personnel and plant. Class 1, closed loop regulatory control, includes motor and axis control. The timeliness of information in this class is repeatedly critical. Class 2, divide to close loop supervisory control and applications with long time constant and time scale measured in seconds and minutes. Class 3, defines which covers open loop control applications, in which an operator, rather than a controller. Class 4 is cover monitoring with short term operational consequences. This class needs involvement of a human for maintenance which includes alarm and other information. Class 5 is categorized in relation to monitoring without immediate operational consequences and less timeliness requirements. This class may need high reliability requirements (ISA SP100.11, 2006). Based on these six classes of WSN in industrial applications, the proposed system architecture may fall in the Class 2 which needs a long time constant and time scale measures due to deploying of WSN and other technologies as a monitoring system that provides continuous communications between system components in real time.

2.5 RFID Technology

RFID technology is available in two main types: passive RFID, where the tag is small, low cost, low range, and relies on the reader to provide the energy to power the tag; for an active RFID, the tag is larger and offers greater detection range and rich data capacities because it contains its own power source (i.e., battery, or any energy harvesting system). RFID consists of a transponder, a reader, and a software application. The RFID tag has a microchip with data storage, logical functions, and antenna, which receives radio frequency waves produced by the reader or transceiver to permit wireless transmission of data. The RFID reader consists of a radio frequency module, a control unit, and a coupling element to question the tags via radio frequency communication. The reader and the tag are the primary components of an RFID system. The host computer consists of API (Application Programming Interface) and application software utilizes the data obtained from the tags to perform useful tasks. Figure 2.6 shows typical RFID system components.

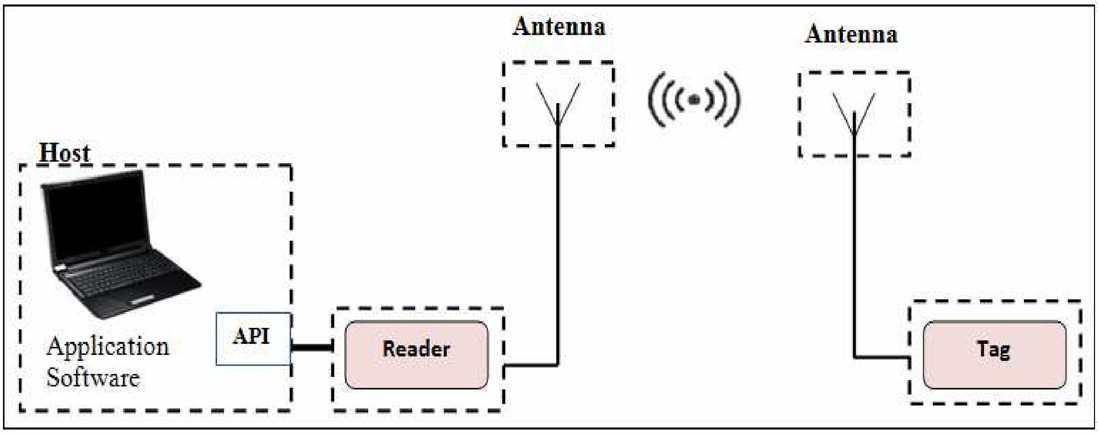

Figure 2.6: RFID system

Readers are usually connected through middleware to a back-end database. The RFID middleware refers to special software that is parked between the reader network and the application software to help on processing significant amount of data generated by the reader network. Middleware is responsible for cleaning the data, eliminating false reads apart from performing aggregation and filtering of data. By monitoring multiple readers, middleware can also detect the movement of RFID tags as they pass from the read range of one reader to another.

The application of RFID now is not only meant for person to machine or machine to person, but demands more for machine to machine communication. Thus, the trait is appropriate to be used in proposed system since it is applied for industrial automation environment which has prompted the communication market to adopt machine to machine communication via RFID. Real time monitoring system