OPTIMIZATION OF SUPPLY CHAIN MANAGEMENT BY SIMULATION BASED RFID WITH XBEE NETWORK

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I would like to dedicate this thesis to

Almighty "ALLAH (SWT)"

(Who gave me great strength, best knowledge, powerful patience and wisdom)

My "Parents"

(Their great pure love, attentiveness, cares, help and always pray for me to achieve this target)

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(Her real love, care, commitment and sincerity motivate me to finish this invaluable work)

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ABSTRACT

The aim of every Supply Chain Management (SCM) is to reduce the operational cost and maximize the benefits. These necessitate the use of advance technology to optimize the operational activities. Among the widely used technology in recent years is Radio Frequency Identification (RFID). It is an advanced Auto-ID wireless network based configuration system used for identification and tracking of items movement data. Technically, basic requirements for deploying RFID network are to identify the number of readers needed, location of the readers and the efficient parameter setting for each reader. Among the problems associated with RFID technology are the multi-objective optimizations, which include tags coverage, economic efficiency, interference and load balance. In order to solve this problem, a simulation based "Multi-Colony Global Particle Swarm Optimization (MC-GPSO)" algorithm was developed. This algorithm computes the optimal results of objective functions in a scientific manner. However, RFID reader is an expensive and has limited data transmission range. It alone cannot transmit data to the main server. Thus, its communication range was enhanced by the integration of RFID with XBee (ZigBee) wireless mesh network devices. Furthermore, the identification data need to be monitored and transmitted to the business organizations, which are connected through the network. This has been achieved by the integration of RFID-XBee network with database connectivity through Internet of Things (IoT). This integrated system provides the visibility of items at real time identification and tracking activity at single control platform. This system also provides data sharing activity with business enterprises using IoT. The benefits of this system include reduction of shrinkage and data transfer time in global network. This system also increases the accuracy, productivity and improves delivery of service in supply chain to the optimum level. This would contribute towards a more sustainable and green supply chain management.

ABSTRAK

Matlamat setiap Pengurusan Rantaian Bekalan (SCM) adalah untuk mengurangkan kos operasi dan memaksimumkan keuntungan. Ia memerlukan teknologi canggih, yang memudahkan untuk melaksanakan dari segi aktiviti operasi dan mengoptimumkan manfaatnya. *Radio Frequency Identification (RFID)* adalah satu teknologi tanpa wayar Auto-ID digunakan untuk pengenalan dan pengesanan data pergerakan barangan dalam pengurusan rantaian bekalan. RFID adalah sistem konfigurasi berasaskan rangkaian yang banyak digunakan dalam SCM. Secara teknikal, keperluan asas untuk menggunakan rangkaian RFID termasuklah mengetahui bilangan pembaca yang diperlukan, lokasi pembaca dan penggunaan kuasa yang efisien oleh setiap pembaca. Antara masalah yang berkaitan dilaporkan bahawa teknologi RFID ialah pengoptimuman pelbagai objektif termasuk liputan tag, kecekapan ekonomi dan gangguan. Bagi mengatasi masalah ini, satu algorithma simulasi "*Multi-Colony Global Particle Swarm Optimization (MC-GPSO)*" mendapatkan keputusan optimum bagi setiap fungsi objektif secara saintifik. Walau bagaimanapun, pembaca RFID adalah mahal dan mempunyai penghantaran data yang terhad. Ia tidak boleh menghantar data kepada pelayan utama secara bersedirian. Oleh itu, komunikasi telah dipertingkatkan dengan integrasi antara RFID dengan XBee (ZigBee) peranti rangkaian mesh tanpa wayar. Tambahan pula, data pengenalan perlu dipantau dan dihantar kepada organisasi perniagaan, yang dihubungkan dengan rangkaian. Ia telah dicapai melalui integrasi rangkaian RFID-XBee dengan sambungan pangkalan data mengunakan “Internet of Things” (IoT). Sistem bersepadu menyediakan pengenalan keterlihatan item pada masa sebenar dan pengesanan aktiviti di platform kawalan tunggal. Sistem ini juga menyediakan aktiviti perkongsian data kepada perusahaan perniagaan menggunakan IoT. Antara kebaikan sistem ini termasuklah ia dapat mengurangkan ketirisan dan masa pemindahan data dalam rangkaian global. Sistem ini meningkatkan ketepatan, produktiviti dan penyampaian

perkhidmatan dalam rantaian bekalan pada peringkat optimum. Ini mampu menyumbang kepada pengurusan rantaian bekalan yang lebih mampan dan mesra alam.

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LIST OF ABBREVIATIONS

ABC	Ant Bee Colony
ACO	Ant Colony Optimization
ADO	Active X Data Object
AIDC	Auto Identification and Data Capture
BFO	Bacterial Foraging Optimization
COM	Component Object Model
DBMS	Data Base Management System
DSN	Data Source Name
EA	Evolutionary Algorithm
EPC	Electronic Product Code
GPS	Global Positioning System
GSCM	Green Supply Chain Management
GUI	Graphical User Interface
HF	High Frequency
IZ	Interrogation Zone
JIT	Just-In-Time
LabVIEW	Laboratory Virtual Instruments Engineering Workbench
LF	Low Frequency
MAC	Medium Access Control
MATLAB	Matrix Laboratory
NPV	Net Present Value
OCR	Optical Character Recognition
ODBC	Open Data Base Connectivity
OLEDB	Object Linking and Embedded Data Base
ONS	Object Naming Service
PAN	Personal Area Network

POS	Point Of Sale
PSO	Particle Swarm Optimization
RCS	Radar Cross Section
RFID	Radio Frequency Identifications
RNP	Radio Frequency Identifications Network Planning
ROI	Return On Investment
RTLS	Real Time Locating System
SCM	Supply Chain Management
SI	Swarm Intelligence
SMI	Small and Medium Scale Industry
UART	Universal Asynchronous Receiver Transmitter
UDL	Universal Data Link
UHF	Ultra High Frequency
UPC	Universal Product Code
WPAN	Wireless Personal Area Network
WSN	Wireless Sensor Network

LIST OF PUBLICATIONS

Journal Articles

1 **Integration of Value Stream Mapping with RFID, WSN and ZigBee Network**
Aftab Ahmed, Khalid Hasnan, Badrul Aisham, Qadir Bakhsh
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3 **Optimization of RFID network planning using ZigBee and WSN *(In Press)***
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5 **International Conference on Mathematics, Engineering & Industrial Applications 2014 (ICoMEIA 2014)**
Organised by: Institute of Engineering Mathematics, Universiti Malaysia Perlis Universiti Malaysia Perlis (UniMap) at The Gurney Resort Hotel & Residences, Penang, Malaysia on 28th ~ 30th May, 2014

6 **12th Global Conference on Sustainable Manufacturing**
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7 **5th International Conference on Mechanical and Manufacturing Engineering (ICME 2014)**
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8 **International conference on Green Computing and Engineering Technology 2015 (ICGCET'15)**
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CHAPTER 1

INTRODUCTION

Radio Frequency Identification (RFID) is an Automatic Identification and Data Capture (AIDC) wireless technology is used for real time identification and data collection of entities. It has been used since more than half century. Currently the RFID technology is most commonly used in toll collection, logistics, asset tracking and supply chain management. It has great potential to use in various applications.

Currently the enterprises are going towards advance RFID technology in place of barcode system. However, RFID is an enabling and promising technology, even though it has challenging issues of the optimal deployment of RFID network are tags coverage, interference, economic efficiency and load balance (Chen *et al.*, 2011b). RFID network has multi-objective optimization functions, which can be solved by optimization algorithm. However, the RFID reader has limited communication range and high cost. It has been found that the RFID reader can easily integrate with XBee (ZigBee) wireless mesh network to increase communication range. RNP-XBee network can integrate with database connectivity and Internet of Things (IoT) to enhance business benefits by data sharing among enterprises.

1.1 Research Background

Radio frequency identification (RFID) wireless technology has been used for automatic identification and data capture of entities at real time locating system through electromagnetic waves (Turcu, 2010). It has also been used in a library management system and various other applications. This technology has been used by thousands of

companies for a decade or more. It quickly gained attention because of its ability to track moving objects. As technology is refined, RFID tags are used in different works tends to spreading throughout.

RFID and barcode technologies are used for the same purpose, but the principle of operation is different and has various advantages. The advantages of RFID over barcode are that it can track through human body and non-metallic materials. It does not require direct orientation to scan. Moreover it can detect large number of items at the same time and is able to read in harsh and dirty environment. RFID tags have longer read range and large storage data as compared to the barcode tag and it can be writable to update the data at any time (Lehpamer, 2008).

The implementation of RFID system based upon network configuration. The RFID network planning (RNP) has some challenging issues that includes coverage, interference, economic efficiency and load balance. Before deploying RFID readers consider the basic requirement for achieving the optimized network such as minimum number of readers deployed at strategic placement and best suitable parameter setting for each reader (Chen *et al.*, 2011b, Gong *et al*., 2012).

In this research particle swarm optimization algorithm was used innovatively for solving RNP issues by using multi-colony global particle swarm optimization (MC-GPSO) algorithm.

However, RFID reader has limited communication range and high cost. It has been found that the RFID can easily be integrated with XBee (ZigBee) wireless mesh network devices for increasing the node placement and wider the range of communication (Bolic *et al*., 2008). XBee (ZigBee) is low cost and low power consumption network device in RFID system. RFID-XBee integrated system can increase the overall function and efficiency to get real time information of supply chain effectively resulting to cut the product loss (shrinkage) and bullwhip effect (Sumi *et al*., 2009, Elshayeb *et al*., 2009). RFID has been widely used in supply chain cycle (Soon & Gutiérrez, 2008, Kok *et al*., 2008). Aim of every supply chain is to maximize the overall benefits which depend on several decisions relating to the real time flow of information, product, and funds for successful supply chain management (Darla *et al*., 2012).

This research focuses on novel approach to solve RFID network planning (RNP) and to integrate with XBee (ZigBee) wireless network devices, database connectivity and IoT. It enhances the efficiency of supply chain management.

The benefit of integrated system is to increase the range of communication of RFID system by low cost XBee (ZigBee) network. It can provide accurate real time visible picture of items flow status at single platform and update the database during running operation. This information can share among networked organizations and it is useful to forecast the business benefits at each level of supply chain. It could control product loss or shrinkage. The system also has ability to significantly reduce the wastage in terms cost, expenditure, time and services which makes the organizations in supply chain green and sustainable.

1.2 Problem Statement

Mostly organizations use optical barcode technology for items scanning process, because barcode system can easy to implement, less expensive/economic and it takes few minutes to train the operator for scanning items. However, the barcode scanning system has some drawbacks e.g. It needs proper orientation for scanning by human intervention. Each item scan individually takes longer time and might be human error happened by missing of an item during scanning activity. Currently business enterprises are going towards advance RFID auto-ID technology for collecting the object movement data, which can cut labor cost significantly (Kao & Lee, 2011). There are various advantages of RFID over barcode technology in terms of accuracy, speed, quality and flexibility of operational strategy and it can scan multiple items at longer distance (Ferrer *et al*., 2010).

The implementation of RFID system based upon network configuration. It is difficult to implementation in any specific area. The basic issues of RNP include coverage, economic efficiency, interference and load balance (Irfan *et al*., 2012, Tsai & Lin, 2013, Nawawi *et al*., 2014). Before deploying the optimal reader network following queries are raised.

i. How many minimum readers are required to cover all tags?

ii. Where to deploy these minimum readers?

iii. What parameters are to be set for each reader?

The RFID network planning (RNP) is a multi-objective optimization problem (Lee, 2010), need to solve innovatively using optimization techniques to achieve the goal of optimum RFID network planning for sustainable competitive business benefits of enterprise operations focus on green supply chain management.

Due the limited communication range and high cost of RFID reader, it has been found that the RFID reader can easily integrate with XBee (ZigBee) wireless mesh network devices. This can increase the number of node placement and enhance the communication range of RFID reader (Sumi *et al*., 2009, Bolic *et al*., 2008).

The RNP-XBee integrated system is used to identify and data collection of items at longer distance. The collected data can be monitored and updated on real time basis at single control platform of LabVIEW database connectivity program (Elshayeb *et al*., 2009). This data can be shared among other organizations, which are connected in to the global network by using IoT to enhance the optimal business benefits.

1.3 Aim and objectives of research

The aim of this research was to develop an optimal RFID network and to integrate with XBee (ZigBee) wireless network devices, database connectivity and IoT module, to achieve the competitive business benefits of green supply chain management by real time data exchange into the network organization. The specific objectives of this research are included:

i. To develop and implement multi-colony global particle swarm optimization algorithm for RNP issues.
ii. To integrate RNP with XBee wireless network devices.
iii. To integrate RFID-XBee network with database connectivity and Internet of Things (IoT) module for data exchange into the network connected organizations.

1.4 Scope of the research

The scope of this research is wide aimed at enhancing business profits by improved supply chain cycle through updated data on commodities on trade and in transit. However solution of integrated RFID and XBee network will help:

i. Developing and implementing multi-colony global particle swarm optimization (MC-GPSO) algorithm for the solution of RNP issues.
ii. Developing the physical RFID-XBee wireless communication module for data collection of items and to communicate at longer distance.
iii. Developing a database connectivity module for RFID-XBee applications to monitor the data collection of items at single control platform.
iv. Develop an Internet of Things (IoT) module, which is used for data exchange to the business related organizations connected into the network to enhance business benefits.

1.5 Summary

The outline of this research begins with the introduction of RFID and its application. The background study is focused on supply chain management. On the basis of background study the problem statement has to be identified and establish the aims and objectives of research. Finally followed by scope of research is outlined to achieve the target of research outcomes.

The literature review is explained in Chapter 2, which describe the Auto-ID technology, shrinkage, the basics of RFID wireless communication system and its type (near field & far field), link budget and read range, path loss propagation model, optimization of RFID network planning by PSO, XBee (ZigBee) wireless mesh network and its application are introduced. At the end the research gap is defined.

On the basis of research gap the research framework is explained in Chapter 3, which describes the RFID network parameter and their objective functions (coverage, interference and number of readers). The parameters and topology of search space was set, and then represent coding of tags, reader and objective function. Followed by the

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