

A STUDY ON INDUSTRIAL COMMUNICATION NETWORKING:
ETHERNET BASED IMPLEMENTATION

HAIRULAZWAN BIN HASHIM

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

PERPUSTAKAAN UTHM



3000001883557

009000

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

PENGESAHAN STATUS LAPORAN PROJEK SARJANA

A STUDY ON INDUSTRIAL COMMUNICATION NETWORKING:
ETHERNET BASED IMPLEMENTATION

SESI PENGAJIAN : 2006/2007

Saya **HAIRULAZWAN BIN HASHIM** mengaku membenarkan Laporan Projek Sarjana ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan Projek Sarjana adalah hakmilik Kolej Universiti Teknologi Tun Hussein Onn.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. ** Sila tandakan (✓)

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh


(TANDATANGAN PENULIS)


(TANDATANGAN PENYELIA)

Alamat Tetap:

NO. 15 BLOK 1,
FELDA SEMENCHU,
81900 KOTA TINGGI,
JOHOR DARUL TAKZIM.

PM DR. ZAINAL ALAM BIN HARON
Nama Penyelia

Tarikh: 30 NOVEMBER 2006

Tarikh: 30/11/06

CATATAN:

** Jika Laporan Projek Sarjana ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu di kelaskan sebagai SULIT atau TERHAD.

**A STUDY ON INDUSTRIAL COMMUNICATION NETWORKING:
ETHERNET BASED IMPLEMENTATION**


HAIRULAZWAN BIN HASHIM

A project report is submitted as partial fulfillment of the requirements for
the award of the degree of
Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Kolej Universiti Teknologi Tun Hussein Onn

NOVEMBER, 2006

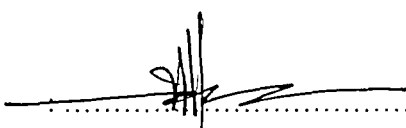
"I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged."

Student : 

HAIRULAZWAN BIN HASHIM

Date : 30 NOVEMBER 2006

Supervised by

Supervisor : 

ASSOC. PROF. DR. ZAINAL ALAM BIN HARON

*For my beloved wife,
Norasiah binti Md Aspan*

*My father and mother,
Hashim bin Mohd Said and Uminah binti Kaseran@Hj. Yusof*

*My family,
Zainita, Mohd Rizal, Mohd Nazree, Norzela, Mohd Haizam, Md Syfulnizam,
Noorzalila, Siti Norida, Mohd Salehudin, Siti Nordinah and Mohd Syafiq*

for their encouragement, support, caring and blessing...

ACKNOWLEDGEMENT

Alhamdulillah, I am grateful to ALLAH S.W.T on His blessing in completing this project.

I am deeply grateful for the help that I received from my supervisor, Associate Professor Dr. Zainal Alam bin Haron during this development of this project. His willingness to help and ideas has kept me on my toes from the beginning stage of this project until the completion of this thesis.

I could not have done this project without the unconditional support, active encouragement, complete cooperation, and honest sacrifice by my wife, Norasiah binti Md Aspan and family. To appreciate their immense contribution, this thesis is lovingly dedicated to them.

I am also indebted to Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO) and Jabatan Perkhidmatan Awam (JPA) for supporting me in the form of a scholarship and study leave.

I would also like to extend my gratitude to all lecturers and technician that has given me all the basic needed for completing this project, and also to my classmates, friend, colleagues and who helped me directly or indirectly for their encouragement and help. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

ABSTRACT

Recent enhancement of an industrial communication and networking technology has made it possible to apply Ethernet networks at all levels of industrial automation, especially at controller level where the data exchange in real-time communication is mandatory. This thesis presents a study on the development of industrial communication network based on the Ethernet and its implementation on a Computer Integrated Manufacturing (CIM-70A) system which located at Robotic Laboratory in KUiTTHO. The Ethernet module was installed on supervisory OMRON PLC to integrate the various stations in the CIM-70A system. The workability of this communication technique was analyzed and compared with the conventional serial communication which is widely used in automation networking systems. Through this approach, the communication and integration of CIM systems can be accessed easily and hence available to be upgraded to the management and enterprise levels of automation.

ABSTRAK

Penambahan penggunaan komunikasi dan rangkaian industri sejak akhir-akhir ini telah menjadikan rangkaian Ethernet boleh diaplikasikan di semua peringkat automasi perindustrian, terutamanya di tahap pengawal di mana penukaran data dalam masa nyata adalah mandatori. Tesis ini membentangkan satu kajian pembangunan perindustrian rangkaian komunikasi berdasarkan Ethernet dan seterusnya akan diaplikasikan kepada sistem pembuatan komputer bersepadu (CIM-70A) yang terletak di Makmal Robotik, KUiTTHO. Modul Ethernet telah dipasang kepada pengawal logik boleh aturcara (PLC) jenama OMRON (siri CJ1M) untuk menyepadukan pelbagai stesen pengeluaran di dalam sistem CIM-70A. Keboleherjaan teknik komunikasi ini telah dianalisis dan dibandingkan dengan sistem konvensional yang begitu meluas digunakan di dalam rangkaian sistem automasi iaitu komunikasi bersiri. Menerusi pendekatan ini, komunikasi dan integrasi sistem CIM lebih mudah dicapai dan seterusnya boleh dipertingkatkan ke peringkat pengurusan dan perusahaan di dalam sistem automasi.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xiv
	LIST OF APPENDICES	xvii
I	INTRODUCTION	1
	1.1 Project Overview	1
	1.2 Problem Statement	2
	1.3 Objective	3
	1.4 Scope of Work	3
	1.5 Thesis Layout	4

CHAPTER	TITLE	PAGE
II	LITERATURE REVIEW	5
2.1	Introduction of Industrial Communication	5
2.2	Fieldbuses Standard	7
2.3	Real-time Communication Evolution	9
2.4	Industrial Ethernet	10
III	INDUSTRIAL ETHERNET COMMUNICATION AND NETWORKING	16
3.1	Ethernet Background	16
3.1.1	Ethernet and the OSI Model	16
3.1.2	Ethernet Frame Format	17
3.2	Ethernet System Configuration and Devices	18
3.2.1	Ethernet Station Interface	19
3.2.2	Twisted-pair Cables	19
3.2.3	Switched Ethernet	20
3.3	OMRON Communication and Networking	21
3.4	OMRON PLC and OSI Model	23
3.4.1	Application Layer	25
3.4.2	Transport Layer	26
3.4.2.1	FINS/UDP Method	26
3.4.2.2	FINS/TCP Method	28
3.4.3	Network Layer	30
3.4.3.1	IP Address Configuration	30
3.4.3.2	Subnet Masks Configuration	31
3.4.4	Physical Layer	32
3.4.5	FINS Communications	33
3.5	OMRON Network Instructions	34

CHAPTER	TITLE	PAGE
IV	HARDWARE INSTALLATION AND SOFTWARE DEVELOPMENT	36
4.1	Introduction	36
4.2	CIM-70A System	37
4.2.1	Introduction of CIM-70A System	37
4.2.2	Communication Networking of CIM-70A System	38
4.2.3	Real-Time Monitoring of CIM-70A System	39
	4.2.3.1 OMRON CX-Programmer	40
	4.2.3.2 Citect SCADA	40
	4.2.3.3 ASRS HMI	41
4.3	Hardware Installation	42
4.3.1	Ethernet Module Installation	43
4.3.2	Communications Test	45
4.4	Software and Programming Development	47
4.4.1	Introduction	47
4.4.2	Programming Development	47
V	RESULTS AND ANALYSIS	52
5.1	Introduction	52
5.2	System Setup and Memory Allocations	52
5.3	Communication Test	54
5.4	Real-time Monitoring	55

CHAPTER	TITLE	PAGE
VI	CONCLUSIONS AND RECOMMENDATIONS	59
6.1	Conclusion	59
6.2	Recommendations for Future Development	60
	REFERENCES	61
	APPENDICES	65

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Characteristic of some standard fieldbuses	8
2.2	Some of the Ethernet network types	11
3.1	OMRON PLC communication network comparison	21
3.2	Subnet Mask classification	32
3.3	Ethernet version 2.0 and IEEE 802.3 standard	33
3.4	OMRON network instructions; SEND(090) and RECV(098)	34
3.5	Control words format	35
4.1	CIO memory area of CIM-70A system	39
4.2	Ethernet module setup for CIM-70E system	44
4.3	Control data for ASRS Station in Conveyor System Station PLC program	49
4.4	Control data created in Conveyor System Station PLC program	50
4.5	Control data created in CIM-70E station PLC program	51
5.1	IP and MAC addresses for CIM-70E system	53
5.2	CIO memory area comparison	54
5.3	Communication test results	55

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Pyramid of industrial automation system	2
3.1	OSI model comparison	17
3.2	Standard Ethernet frame format	17
3.3	Ethernet basic configuration	18
3.4	Ethernet module, ETN-21	19
3.5	Ethernet network method using hub/switch	20
3.6	Ethernet OSI model	23
3.7	FINS command architecture	25
3.8	FINS command and response	25
3.9	FINS/UDP method	27
3.10	FINS/TCP method	28
3.11	IP address classification	30
3.12	Subnet Mask example	32
3.13	Ethernet version 2.0 and IEEE 802.3 configuration	33
3.14	FINS communication architecture	34
4.1	Overall CIM-70A system layout	37
4.2	CIM-70A system networking	38
4.3	Complete Link method of CIM-70A system	39
4.4	Rack status of ASRS HMI	41
4.5	CIM-70E system networking	42
4.6	Overview of Ethernet module installation procedure	43
4.7	PING command	45
4.8	Example of PING command	46

FIGURE NO.	TITLE	PAGE
4.9	A main parts of ladder program for Conveyor System Station	48
5.1	IP and MAC addresses scanning	53
5.2	PING command results	54
5.3	Online monitoring through CX-Programmer window	57

LIST OF ABBREVIATIONS

ACK	-	acknowledgement
ARP	-	address resolution protocol
ASRS	-	automatic storage and retrieval system
AUI	-	attachment unit interface
BACNet	-	building automation and control network
CAN	-	controller area network
CD	-	compact disc
CIM	-	computer integrated manufacturing
CiN	-	CAN in automation
CIO	-	common input/output
COM	-	component object model
CPU	-	central processing unit
CSMA/CD	-	carrier sense multiple access with collision detection
DCOM	-	distributed component object model
DEC	-	Digital Electronic Corporation
DIX	-	DEC, Intel, and Xerox
DM	-	digital memory
DNS	-	domain name system
EHS	-	European Home System
ERP	-	entrepreneurs resources planning
FA	-	field assembly
FF	-	Foundation Fieldbus
FINS	-	factory interface network service
FINS/TCP	-	factory interface network service/transmission control protocol
FINS/UDP	-	factory interface network service/user datagram protocol

FIP	-	factory instrumentation protocol
FKEE	-	Faculty of Electrical and Electronic Engineering
FTP	-	file transfer protocol
HART	-	Highway Addressable Remote Transducer
HMI	-	human machine interface
ICMP	-	internet control message protocol
ID	-	identity device
IDA	-	interface for distributed automation
IEEE	-	Institute of Electrical and Electronic Engineer
IEC	-	International Electrotechnical Commission
IP	-	internet protocol
ISA	-	Instrument Society of America
ISP	-	interoperable system project
KUiTTHO	-	Kolej Universiti Teknologi Tun Hussein Onn
LAN	-	local area network
LLC	-	logical link control
LonWorks	-	local operating networks
MAC	-	medium access control
MAU	-	multi-station access unit or medium attachment unit
MES	-	manufacturing execution system
MRP	-	material requirement planning
MRP-II	-	manufacturing resources planning
NIC	-	network interface card
OSI	-	open system interconnection
PC	-	personal computer
PID	-	proportional, integral and derivative
PING	-	packet internet groper
PLC	-	programmable logic controllers
POP3	-	post office protocol version 3.0
Profibus	-	Process Fieldbus
P-Net	-	Process Network
SCADA	-	supervisory control and data acquisition
ScTP	-	screened twisted-pair cable
SDS	-	smart distributed system

SMTP	-	simple mail transfer protocol
SNTP	-	simple network time protocol
STP	-	shielded twisted-pair cable
TCP	-	transmission control protocol
TCP/IP	-	transmission control protocol/internet protocol
UDP	-	user datagram protocol
UTP	-	unshielded twisted-pair cable

LIST OF APPENDICES

APPENDIX NO.	TITLE	PAGE
A	OMRON CJ Series Manuals	65
B	CIM-70A System Operation	67
B.1	System Operation	67
B.2	Master: Conveyor System Station	68
B.3	Station 1: Robot Arm	69
B.4	Station 2: Pick & Place	70
B.5	Station 3: Vision Inspection Station	71
B.6	Automatic Storage and Retrieval System (ASRS) Station	72
C	Ethernet Module Installation	75
C.1	Switch Settings	75
	C.1.1 Setting the Unit Number	76
	C.1.2 Setting the Node Address	76
C.2	Mounting Ethernet Module to a PLC	77
C.3	Creating an Input/Output (I/O) Tables	78
C.4	Ethernet Module Setup Procedure	79
	C.4.1 Using CX-Programmer	79
	C.4.2 Using the Web Browser Setting Function	83
C.5	Creating Routing Tables	86
	C.5.1 Routing Tables Overview	87
	C.5.2 Creating Routing Tables Procedure	88

APPENDIX NO.	TITLE	PAGE
D	OMRON PLC Program	93
D.1	Conveyor System Station Program	93
D.2	ASRS Station Program	97
D.3	Station 1: Robot Arm Program	98
D.4	Station 2: Pick & Place Program	99
E	Attachment CD	100

CHAPTER I

INTRODUCTION

1.1 Project Overview

Data communication and networking may be the fastest growing technology in our culture today (Forouzan, 2001). It is extensively used in an industrial network to integrate both office and manufacturing equipment. During the last two decades, the industrial communication system have evolved at a rapid pace and passed from the traditional serial communication to the fieldbuses. The term fieldbus applies to a large family of two-way digital communication protocols that were specially developed to overcome the physical and performance limitations of low level digital and analogue standard (Sterling and Wissler, 2003). A full fieldbus protocol can handle byte size data for complex transmitters and valves as well as diagnostics or control information. Any control device requiring extensive communication for configuration requires a full fieldbus.

Ethernet, the well-known Local Area Network (LAN) standardized by IEEE has been largely utilized in industrial communication. The Ethernet network have gained the capability of communicating in real-time thus opening an attractive scenario, implementation of Ethernet at all level of an industrial automation system (Figure 1.1).

1.2 Problem Statement

Real-time communication has become some major issue in automated manufacturing system. Some problems such as data and status monitoring, transmission data size and speed, online program editing, and accessibility of controller are encountered in conventional serial communication networking such as in Computer Integrated Manufacturing (CIM) system. Furthermore, the integration into higher level of automation system; Manufacturing Resources Planning (MRP-II), Manufacturing Execution System (MES) and Entrepreneurs Resources Planning (ERP) has difficulty to implement (Figure 1.1).

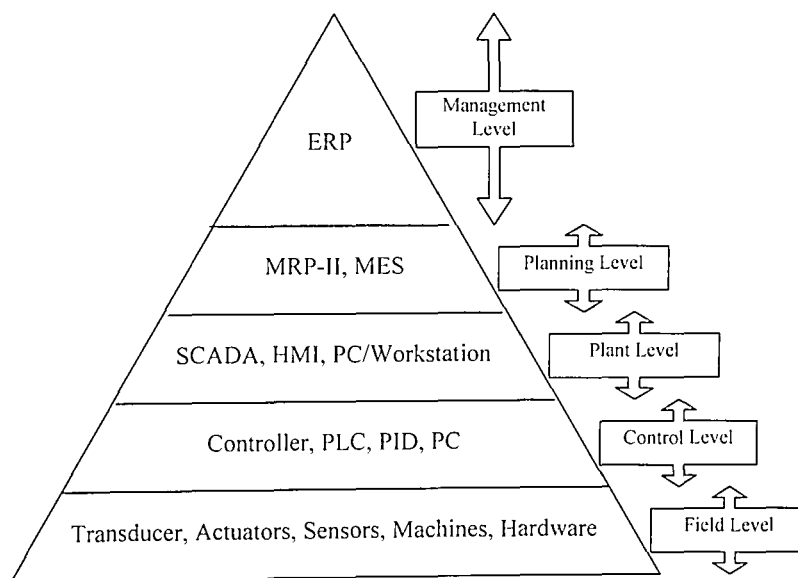


Figure 1.1: Pyramid of industrial automation system

1.3 Objective

The objectives of this project are:

- i) To develop a hardware infrastructure of CIM system communication network based on Ethernet protocol.
- ii) To familiarize and thus overcome real-time monitoring issues so that allows easier integration between the different units of the CIM systems via Ethernet module on OMRON PLC CJ-series.
- iii) To verify and validate the functionality, feasibility and workability of the project.

1.4 Scope of Work

This project is concentrating to develop a CIM system communication network based on the Ethernet protocol. The work will involve using OMRON PLC controller (CJ Series) attached with Ethernet module to integrate the various production units in the CIM system including supervisory workstation. The environment of this implementation is established CIM-70A systems developed in the Robotics Laboratory, Faculty of Electrical and Electronic Engineering (FKEE), Kolej Universiti Teknologi Tun Hussein Onn (KUiTTTHO).