Data Transfer Rate, Central Processing Unit Usage and Read Access Memory Usage in Networked Control System via Industrial Ethernet

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***Abstract*— Data transfer rate is the amount of data that can be transferred at a time. Network Control System (NCS) based communication system Industrial Ethernet (IE) is becoming very popular for automation system. The Fast Ethernet system with data rate transfer 100Mb/s is used in this project. Star topology with the hub connected to a computer and two Programmable Logic Controller (PLC) are analysis for the data transfer rate performance. Real-time communication for the system is very good without no disconnected between the computer and PLCs. Data transfer rate, packets speed (#/s), packets volume, sum volume (KByte), Central Processing Unit (CPU) usage in percentage, percentage available Read Access Memory (RAM), available memory RAM(MByte) are analysed. It is shown that the data flow for traffic out (speed) is greater than traffic in (speed) for the data transfer rate between the computer and PLCs.**

***Keywords*—Data Transfer Rate, Networked Control System (NCS), Industrial Ethernet and Programmable Logic Controller (PLC).**

I. INTRODUCTION

Advanced of the network technology and convergence of communications, control and computer enabled the Networked Control System (NCS) can be achieved [1]. All signal in the NCS is transmitted through shared communication channels used with the other users. Industrial Ethernet (IE) is the applications of IEEE 802.3 standards with requirements of factory equipment and network protocols [2]. The Programmable Logic Controller (PLC) is a microprocessor based control system that can be programmed to sense, activate and control an industrial equipment which has been made possible with the incorporation of a number of input/output (I/O) terminals for interfacing to an industrial process. A control routine stored in the PLC memory determines the communication between the input and output of the PLC [3].

Real-time are usually reactive systems that are in continual interaction with their environments. Control systems for real-time applications are characterized by their ability to support strong time constraints. Since the processing element (controller) is close to the devices, real-time constraints can significantly be improved by appropriately configuring the devices. Besides the room for accommodating control code at the local level, nodes has memory space (buffers) to store temporary real-time data for subsequent use. Storage facility at the local level, in this context, is highly desirable to meet the need for improving real-time performance [4].

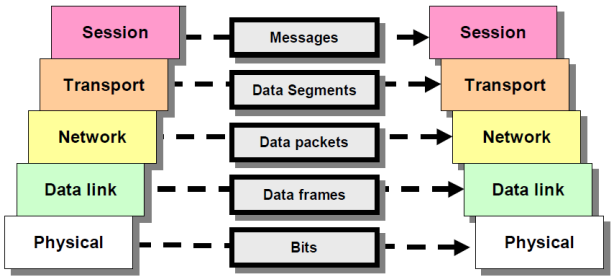

Fig. 1. Bits, frames, packets and segments [5].

Fig. 1 shows the data passes from layer to layer that is called Protocol Data Units (PDU). At the physical layer these are the bits, at the data link layer these are the frames, at the network layer these are the packets and at the transport layer these are the segments.

The amount of the data can transfer at time is normally defined either in bits per second (b/s) or bytes per second (B/s). Typically, serial busses are defined in b/s and parallel busses in B/s. The more the bits that can be transferred and the faster of transfer will be.

Data rate transfer is defined [5]:

$$data\ rate\ transfer(b/s) = \frac{Number\ of\ bits\ transmitted\ per\ operation\ (bits)}{transfer\ time\ per\ operation\ (s)}$$

$$f = \frac{1}{T}$$

f is clock frequency (Hz)
T is clock period (s)

data rate transfer (b/s)
= number of bits transmitted per operation (bits) X clocking rate,f (Hz)

II. EXPERIMENTAL SETUP

The specifications of the computer used for this project are:

* Processor: Dual CPU 2.00 GHz.
* Read Access Memory (RAM): 3.00 GB
* Fast Ethernet 100Mb/s local area network (LAN) card.

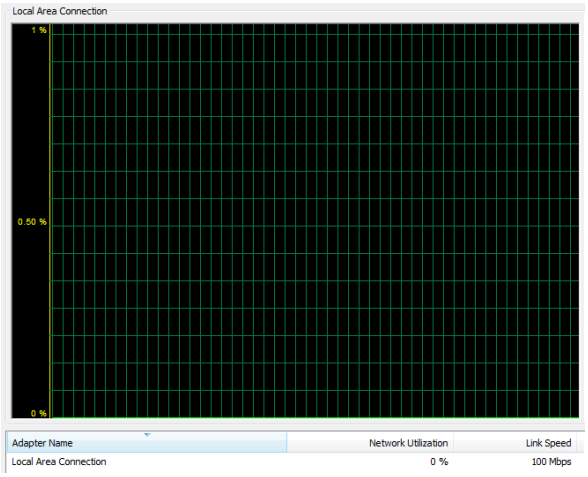

Fig. 2. Local Area Network of Fast Ethernet with maximum Link Speed to 1 Mbps.

There are three type of the connection done for the real-time communication between computer and PLC as shown in Fig. 3, Fig. 4 and Fig. 5. Star topology used for each connections and hub are centered for the networking between computer and PLC.

The types of the PLC used for this project are OMRON SYSMAC CS1D-CPU65P with Fast Ethernet. RJ45 (RJ stands for registered jack) Unshielded Twisted-Pair (UTP) cable used to connect between the computer, PLC and hub. IP address are set unique for each computer, PLC 1 and PLC 2 to avoid data conflict and this is as shown in the TABLE I.

Hub is the simplest method of redistributing data on Ethernet. The hub has several ports and an incoming signal is rebuild and then transmitted on all the remaining ports [6]. The hub also does not make any decisions about the Ethernet frame or its contents.

Ladder diagram for the PLC 1 have 7 rungs and PLC 2 have 32 rungs. The software interface between computer and PLC is CX-Programmer version 6.11 2005 from OMRON.

TABLE I
IP ADDRESS (CLASS C)

node	IP Adresss
Computer	192.168.0.10
PLC 1	192.168.0.2
PLC 2	192.168.0.5

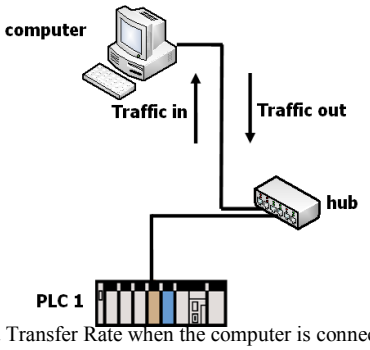

Fig. 3. Data Transfer Rate when the computer is connected to PLC 1.

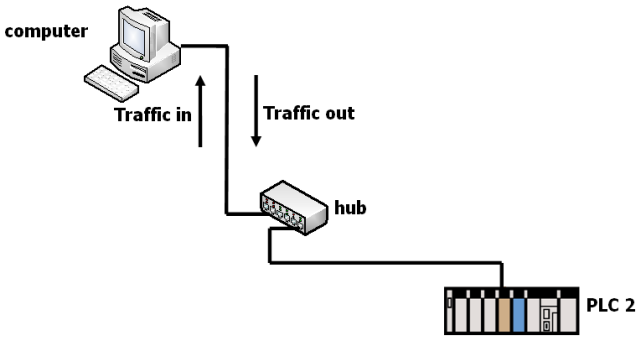

Fig. 4. Data Transfer Rate when the computer is connected to PLC 2.

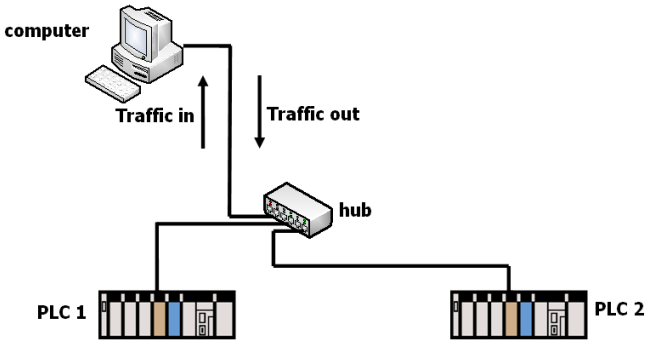

Fig. 5. Data Transfer Rate when the computer is connected to PLC 1 & 2.

III. RESULT & DISCUSSION

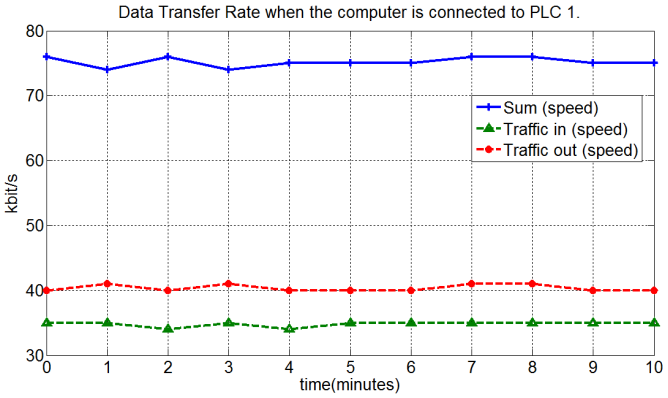

Fig. 6. Data Transfer Rate when the computer is connected to PLC 1.

TABLE II
DATA STATISTICS FOR FIG. 6.

kbit/s	Sum (speed)	Traffic in (speed)	Traffic out (speed)
min	74	34	40
max	76	35	41
mean	75.18	34.82	40.36
median	75	35	40
mode	75	35	40
std	0.7508	0.4045	0.5045
range	2	1	1

The processor of computer usage must be fewer than 50% for the system to work well without errors and when the system is ON and idle. The results from the project had shown in the Fig. 6, 7, 8, 9, 10, 11, 12, 13 and 14. Data from the project are getting using PRTG Network Monitor software. Time interval from the results shown is 1 minutes.

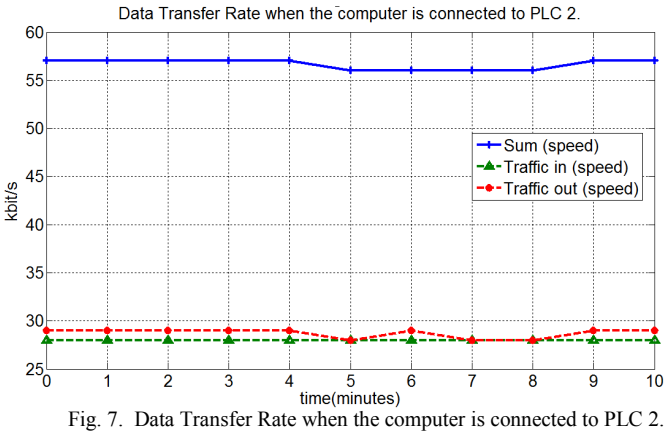

Fig. 7. Data Transfer Rate when the computer is connected to PLC 2.

TABLE III
DATA STATISTICS FOR FIG. 7.

kbit/s	Sum (speed)	Traffic in (speed)	Traffic out (speed)
Min	56	28	28
max	57	28	29
mean	56.64	28	28.73
median	57	28	29
mode	57	28	29
std	0.5045	0	0.4671
range	1	0	1

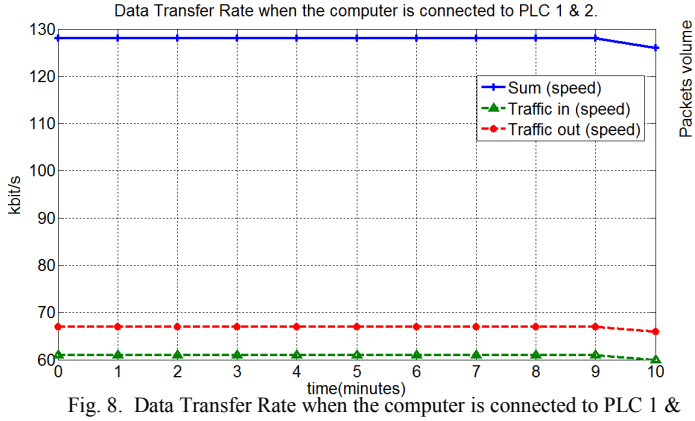

Fig. 8. Data Transfer Rate when the computer is connected to PLC 1 & 2.

TABLE IV
DATA STATISTICS FOR FIG. 8.

kbit/s	Sum (speed)	Traffic in (speed)	Traffic out (speed)
Min	126	60	66
max	128	61	67
mean	127.8	60.91	66.91
median	128	61	67
mode	128	61	67
std	0.603	0.3015	0.3015
range	2	1	1

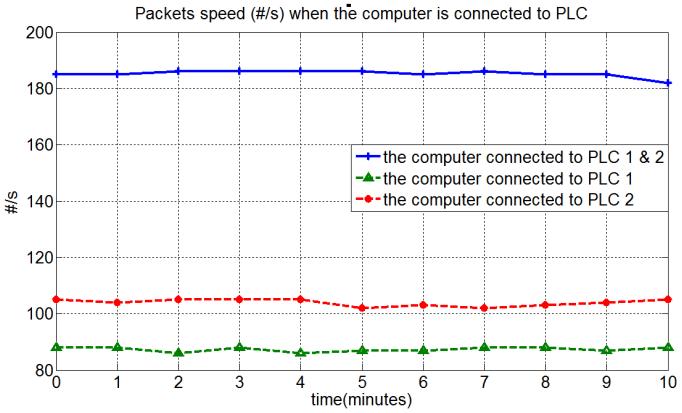

Fig. 9. Packets speed (#/s) when the computer is connected to PLC.

TABLE V
DATA STATISTICS FOR FIG. 9.

Packets speed (#/s)	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	182	86	102
max	186	88	105
mean	185.2	87.36	103.9
median	185	88	104
mode	185	88	105
std	1.168	0.809	1.221
range	4	2	3

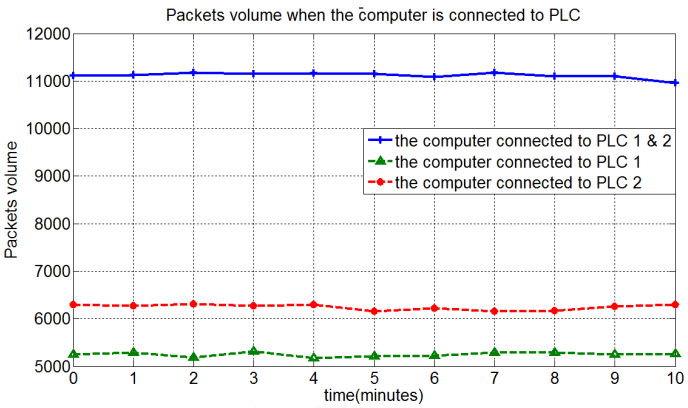

Fig. 10. Packets volume when the computer is connected to PLC.

TABLE VI
DATA STATISTICS FOR FIG. 10.

Packets volume	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	10960	5170	6153
max	11180	5307	6304
mean	11120	5247	6244
median	11120	5249	6266
mode	10960	5170	6153
std	61.23	44.43	59.63
range	217	137	151

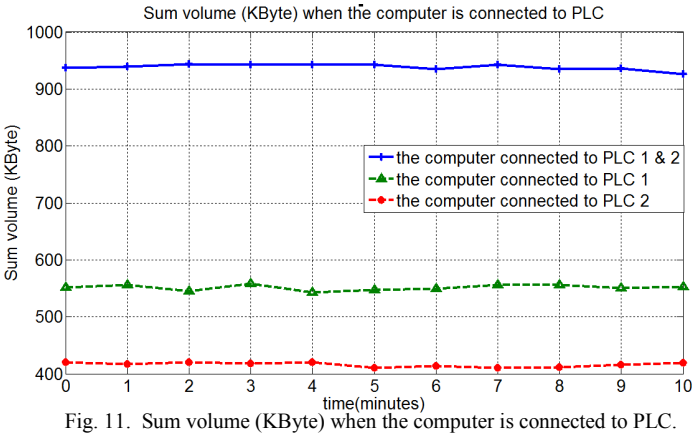

Fig. 11. Sum volume (KByte) when the computer is connected to PLC.

TABLE VII
DATA STATISTICS FOR FIG. 11.

Sum volume (KByte)	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	926	543	410
max	944	558	420
mean	938.3	551.5	415.9
median	939	552	417
mode	942	556	420
std	5.255	4.967	4.036
range	18	15	10

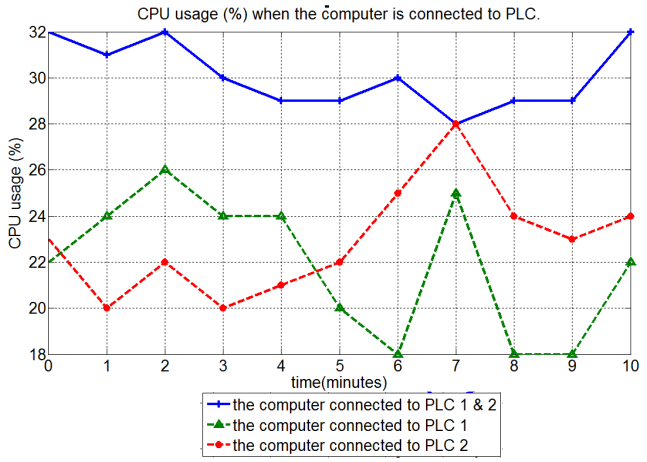

Fig. 12. CPU usage (%) when the computer is connected to PLC.

TABLE VIII
DATA STATISTICS FOR FIG. 12.

CPU usage (%)	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	28	18	20
max	32	26	28
mean	30.09	21.91	22.91
median	30	22	23
mode	29	18	20
std	1.446	2.982	2.343
range	4	8	8

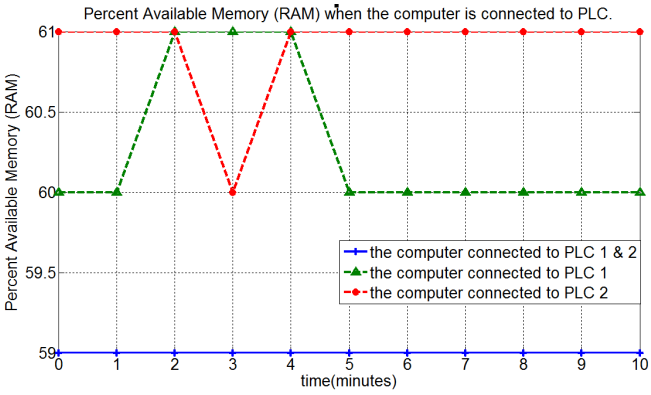

Fig. 13. Percent Available Memory (RAM) when the computer is connected to PLC.

TABLE IX
DATA STATISTICS FOR FIG. 13.

Percent Available Memory (RAM)	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	59	60	60
max	59	61	61
mean	59	60.27	60.91
median	59	60	61
mode	59	60	61
std	0	0.4671	0.3015
range	0	1	1

From the Fig. 6, 7 and 8 speed of traffic out is higher than speed of traffic in. Its show that quantity of data packets flow out from computer is greater than data packets came inside computer. This results means that computer communicated with the PLC with data packets came out from computer is greater than data packets came in when the system in stage of on and idle.

Traffic out (speed) > Traffic in (speed) (1)

From the Fig. 6, 7 and 8 also,

Sum Data Transfer Rate when the computer is connected to PLC 1 & 2
≈ Sum Data Transfer Rate when the computer is connected to PLC 1 + Sum Data Transfer Rate when the computer is connected to PLC 2 (2)

Sum Data Transfer Rate $_{PLC2}$ *< Data Transfer Rate* $_{PLC1}$ *< Data Transfer Rate* $_{PLC1\ \&\ 2}$ (3)

From the results for Packets speed (#/s),
Packets speed (#/s) when the computer is connected to

PLC 1 & 2
≈ Packets speed (#/s) when the computer is connected to PLC 1 + Packets speed (#/s) when the computer is connected to PLC 2 (4)

Packets speed (#/s)$_{PLC1}$ < Packets speed (#/s)$_{PLC2}$ < Packets speed (#/s)$_{PLC1\ \&\ 2}$ (5)

About Packets volume,
Packets volume when the computer is connected to PLC 1 & 2
≈ Packets volume when the computer is connected to PLC 1 + Packets volume when the computer is connected to PLC 2 (6)

Packets volume$_{PLC1}$ < Packets volume $_{PLC2}$ < Packets volume $_{PLC1\ \&\ 2}$ (7)

For Sum volume (KByte),
Sum volume (KByte) when the computer is connected to PLC 1 & 2
≈ Sum volume (KByte) when the computer is connected to PLC 1 + Sum volume (KByte) when the computer is connected to PLC 2 (8)

Sum volume (KByte)$_{PLC2}$ < Sum volume (KByte) $_{PLC1}$ < Sum volume (KByte) $_{PLC1\ \&\ 2}$ (9)

But for CPU usage (%),
CPU usage (%) when the computer is connected to PLC 1 & 2
≠ CPU usage (%) when the computer is connected to PLC 1 + CPU usage (%) when the computer is connected to PLC 2 (10)

CPU usage (%)$_{PLC1}$ < CPU usage (%) $_{PLC2}$ < CPU usage (%) $_{PLC1\ \&\ 2}$ (11)

and Available Memory RAM(MByte),
Available Memory RAM(MByte) when the computer is connected to PLC 1 & 2
≠ Available Memory RAM(MByte) when the computer is connected to PLC 1 + Available Memory RAM(MByte)when the computer is connected to PLC 2 (12)

Available Memory RAM(MByte)$_{PLC1\ \&\ 2}$ < Available Memory RAM(MByte) $_{PLC1}$ < Available Memory RAM(MByte) $_{PLC2}$ (13)

Percent Available Memory (RAM)$_{PLC1\ \&\ 2}$ < Percent Available Memory (RAM) $_{PLC1}$ < Percent Available Memory (RAM) $_{PLC2}$ (14)

The CPU usage is not approximately sum because of the duo core technology processor with high performance are during these experiments. The Read Access Memory (RAM) is used for this experimental is Double Data Rate Memory (DDR) with high performance.

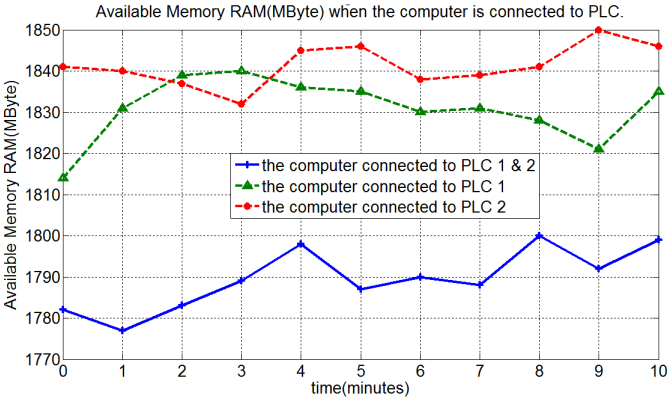

Fig. 14. Available Memory RAM(MByte) when the computer is connected to PLC.

TABLE X
DATA STATISTICS FOR FIG. 14.

Available Memory RAM(MByte)	the computer connected to PLC 1 & 2	the computer connected to PLC 1	the computer connected to PLC 2
Min	1777	1814	1832
max	1800	1840	1850
mean	1790	1831	1841
median	1789	1831	1841
mode	1777	1831	1841
std	7.367	7.752	5.065
range	23	26	18

TABLE XI

	* <	< *	< *
Sum Data Transfer Rate	PLC2	PLC1	PLC1& 2
Packets speed (#/s)	PLC1	PLC2	PLC1& 2
Packets volume	PLC1	PLC2	PLC1& 2
Sum volume (KByte)	PLC2	PLC1	PLC1& 2

From the TABLE XI, if the Sum Data Transfer Rate is higher, the consequence is that the Sum volume (KByte) also would become higher. From TABLE XI also, the packet size operating in PLC 1 is larger as compared to PLC 2.

IV. CONCLUSION

From the project, equations (2), (4), (6), (8), (10) and (12) are obtained by the experimental setup already done. The characteristics of data transfer rate, central processing unit usage and read access memory usage of NCS via Industrial Ethernet are investigated to get the optimum results.

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