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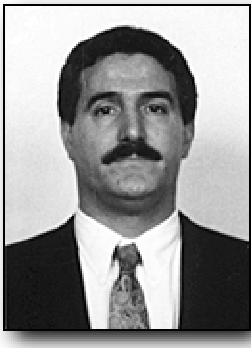
# Local Area Network (LAN) in Manufacturing

**By Dr. Massoud Maxwell Rabiee**



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## Abstract

Since the late sixties, Programmable Logic Controllers (PLCs) have been an invaluable control device for the manufacturing and material handling industries. The use of PLCs has allowed companies to respond in a more timely manner to issues regarding product design and distribution of goods. PLCs equipped with sophisticated instruction sets, larger memories, and Input/Output ports can perform several tasks. Among these are the control of robots, conveyors, and electrical, hydraulic, or pneumatic machines. PLCs also perform communication tasks with Personal Computers (PCs), mini computers, or main frame computers. Effective communication between machines and other equipment is highly essential in order to coordinate the function of an efficient Computer Integrated System (CIM).

A Local Area Network (LAN) is a communication network that connects several devices and provides a means for information exchange among those devices. This paper focuses on the Local Area Network (LAN) communication method used by PLCs in automated plants. It discusses and demonstrates the use of the Allen-Bradley brand of Local Area Network (LAN) system.


## Introduction

When considering a network system, one must discuss the three main elements involved; Network Connection Topology, Transmission Medium, and Network Access Control Scheme. There are different methods used to physically connect PLCs, and computers in a Local Area Network (LAN). The way a network is connected is referred to as, "Network Connection Topology". The transmission medium or wiring type used to connect each network's nodes is critical in setting the actual distance, number of nodes (LAN stations), and frequencies of transmitted signals in the network system. Another important aspect of the LAN considers the way equipment in the network communicates. This is referred to as the network access control scheme.

A brief explanation of the machines and components mentioned above, and the specific method employed by the Allen-Bradley programmable logic controller network follows. However, prior to discussing the three aforementioned network topics, we will explain the communication channeling methods.

## Network Communication Channeling

The Data Terminal Equipment (DTE) which can be a computer or a master PLC initiates communication by sending messages (Hall, 1992). The Data Communication Equipment (DCE) which can be a modem or slave PLC(s) responds to the messages transmitted by the DTE(s). Therefore, in a network there is at least one, or possibly more initiators (DTEs), and several responders (DCEs). Figure 1 displays three channeling forms referred to as Simplex, Half Duplex, and Full Duplex channeling.

Simplex channeling occurs when the DTE transmits data to, or receives data from the DCE, but not both. In a simplex communication system data flows only in one direction. Therefore, flow of data is unidirectional, either from the DTE to the DCE or vice versa. In half duplex communication systems, the DTE transmits data to, and receives data from the DCE. Transmission and reception of data do not occur simultaneously. In a full-duplex communication system, the DTE transmits data to, and receives data from the DCE through two separate transmission lines. Therefore, data flow to and from DTE / DCE is simultaneous. The equipment in the local area network presented in this paper has access to full-duplex communication channels.

## Transmission Media

Three categories of transmission media are available. Twisted Pair (TP) Wires, Coaxial Cables, and Fiber Optic Cables are used for connecting equipment in a network (Stallings, 1997). Due to ease of installation, maintenance, and lower cost, the Shielded and Unshielded Twisted Pair (STP / UTP) Wires are the most preferred method of connection.

The Electronic Industry Association (EIA) has set and defined standards for twisted pair wires in the EIA-586 Standard (EIA, 1991). Shielded Twisted Pair (STP) wires will provide more immunity against electromagnetic / electrical noise interference than the Unshielded Twisted Pair (UTP) wires. Each two twisted wires is used for one communication channel. Usually, in PLC networks the shielded twisted pair

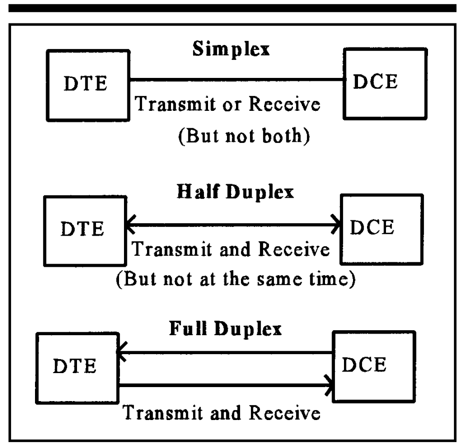


***Figure 1. Communication Channeling Systems***

cables are preferred, since PLCs are placed in manufacturing plants where the presence of electrical noise is common.

Two of the most often used twisted pair wires as specified by their transmission speed are the sixteen Mega bits per second (16Mbs) TP, and the one hundred Mega bits per second (100Mbs) TP. The 16Mbs twisted pair typically has three or four twists per foot and carries data at lower speeds over shorter distances. While, the 100Mbs twisted pair typically has three or four twists per inch and carries data at faster speeds over longer distances.

The Coaxial cable is more expensive but offers much better noise immunity than the twisted pair (TP) medium. Three types of coaxial cable used in communications are defined according to the type of signals they transmit. The coaxial cables are categorized as Baseband, Broadband, and Carrier Band coaxial cables.

The Baseband coaxial cable uses a special 50-ohm cable rather than the typical 75-ohm CATV cable. Baseband coaxial cable carries digital signals only. Note that, Twisted Pair (TP) wires carry digital signals also. The baseband coaxial is usually referred to as Ethernet cable, because it was originally used in the Ethernet Networks.

The broadband, and carrier band cables transmit analog signals, therefore a modem converts the digital signal to analog signal prior to transmission of the data. A modem at the receiving end of the medium will convert the analog signal to a digital signal. The analog signal that carries digital data can travel longer distances and is more immune to electrical noise interferences, and signal degradation damage. The broad band coaxial cable carries multiple analog frequencies. Note that, the cable TV industry uses broadband coaxial cable to transmit signals to its customers. The carrier band cable that is sometimes called single channel broadband, covers only one analog frequency signal spectrum. Therefore, carrier band coaxial cables are less expensive than broadband coaxial cables, and the modems used in carrier band systems are less expensive than the modems used in broadband systems.

Fiber Optic cables can carry data at the rate of 2 Giga bits per second (2 Gbs) or more, for up to one hundred miles. Fiber optic cables offer the best electrical noise immunity, since data is transmitted as optical light signals. An optical fiber strand can transmit several frequency signals. Installation, maintenance, and material costs of Fiber Optic cables are much greater than the Twisted Pair wires or Coaxial cables.

Due to the cost, the twisted pair wires are often used for the PLC local area network connections. In this network, the Belden #9842 Shielded Twisted Pair (STP) wires are used to connect the PLCs, and the computer.

## *Network Connection Topologies*

The physical layout of the LAN is called Network Topology. Common LAN topologies are Ring, Bus, Tree, and Star (Stallings, 1997). Figure 2 shows these LAN topologies. In a ring topology, a transmitted signal will circle through the closed loop and is then copied by the intended destination network node. The signal is then absorbed by the original station that transmitted the signal. The transmitted signal in a Bus Topology is copied by the target station, and the signal is absorbed by the terminating point resistors. The Bus Topology, and the Tree Topologies are similar in their transmission logic. The Tree Topology connection is more complicated, since it has branches that are identical to Bus Topologies. The transmission of data by any station in the network is controlled by the Central Hub in a Star Topology. Bus Topology is used to connect the equipment in the PLC local area network presented in this paper. In a Bus Topology network, all PLC stations are attached through appropriate hardware interface cards called “Isolated Link Couplers”. There are no switches or repeaters. Therefore, fewer hardware components are required for Bus Topology local area networks.

## *Network Access Control Schemes*

Three commonly used network access control schemes in programmable logic controller LANs are; Master-Slave, Token Ring, and Carrier Sense Multiple Access with Collision Detection (CSMA/CD) (Jones, 1996). In the Master-Slave network scheme, the initiator station which is called the Master PLC will “poll” the responder

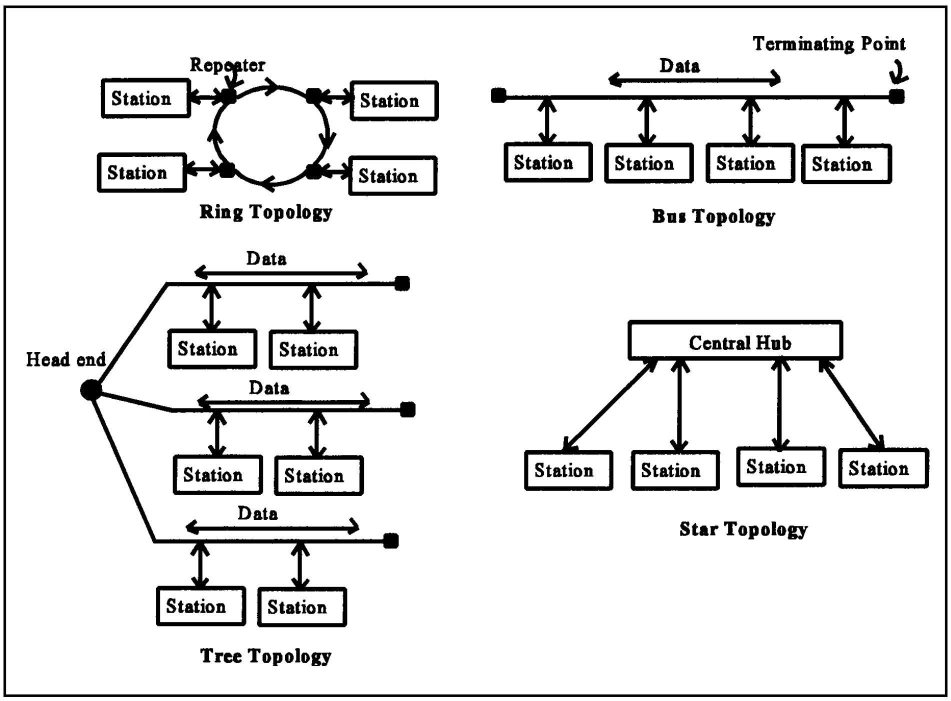


*Figure 2. Local Area Network Topologies*

stations called Slave PLCs. This "polling" action is used to see which station in the "polling list" is trying to gain access to the network highway. In the Token Passing network a signal package called "Token" is passed around from one station to the other. The "token" consists of the present station address, the predecessor station address, and the successor station address. The station that needs to have access to the network for receiving and transmitting data will hold on to the token for a pre-determined amount of time. Otherwise, the token is passed to the next station.

In the CSMA/CD network scheme, every station is "listening" to the line. If the transmission line is available, the station that needs to get access to the medium will try to send or receive data. Also, the stations keep "listening" to make sure there was not a data collision in the case that two or more stations were simultaneously transmitting data. In case of a data collision, the transmitting stations would remedy the situation by "re-transmitting" their data.

The PLC network presented in this paper uses Master-Slave PLCs with a Token Passing access control scheme. This means that the master PLC or master PLCs have control of passing the token to their associated slave PLCs.

## *The Programmable Logic Controller Network Hardware*

Figure 3 displays an Allen-Bradley programmable logic controller local area network. Three LAN stations or LAN nodes are in this network. The LAN stations are; a Personal Computer (PC), a Master PLC, and a Slave PLC. The personal computer is used for downloading the ladder logic programs into the PLCs, and monitoring the data flow during the program executions.

## *The Programmable Logic Controller Network Software*

Initially we load and run the Rockwell International's Advance Programming Software (APS, 1995). Next we activate the "Who Active" function by pressing the F5 key. Then, we activate the Master PLC and download its ladder logic program. Finally, we must "cycle power" to the processor in order for changes to take place. Turning the processor off, and then on is called "cycling power" to the processor. Repeat the aforementioned steps for all the PLCs in order to download the ladder logic programs for all the PLCs connected in the LAN.

The Master PLC program has three rungs. A listing of the program is in Appendix A. When the first rung is activated, the "Write-Message" function will send six delay time numbers from the Master PLC register addresses N7:14 through N7:19 to the Slave PLC register addresses N7:0 through N7:5. Note that fourteen addresses N7:0 through N7:13 in the master PLC are used as control registers for the "Write-Message" function. Therefore, they could not be used to hold delay time numbers.

When the second rung is activated, the output device control bit registers in the Slave PLC (B3:0 through B3:5) are read by the "Read-Message". The content of these bit registers will be copied into the Master PLC registers N7:35 through N7:40. Registers N7:20 through N7:33 in the master PLC are used to control the "Read-Message". Therefore, they could not be used to hold the output pattern data bits.

The third rung contains a "Network Service" rung. In the Allen-Bradley PLC network, there are two communication channels. We are only using channel number one. Channel number one is available through the DH-1485 line of the Allen-Bradley SLC-503 master PLC. Channel number zero uses the RS-232C line of the Allen-Bradley SLC-503 master PLC. Do not disable a communication channel on the PLC local area network (LAN) unless you do not intend to use it, or the LAN system has access to the second channel (AB Reference Manual, 1996).

A sequencer program will be loaded into the Slave PLC. A listing of the program is in Appendix B. This program contains two Sequencer functions, and one Retentive Timer function (AB Reference Manual, 1996). The program is used to control output devices on a programmable logic controller lab station (Rabiee, 1997). The Retentive Timer Done (T4:0/DN) Contact is used to forward the sequencers to the next step. Each sequencer has six steps. The "Event-Control" sequencer steps are used for turning ON/OFF output devices, while the "Timer-Control" sequencer will regulate the delay times between the steps.

## *Conclusion*

The programmable logic controller network program discussed in this paper demonstrates the power and versatility of utilizing a local area network in a manufacturing plant. We can download programs into several

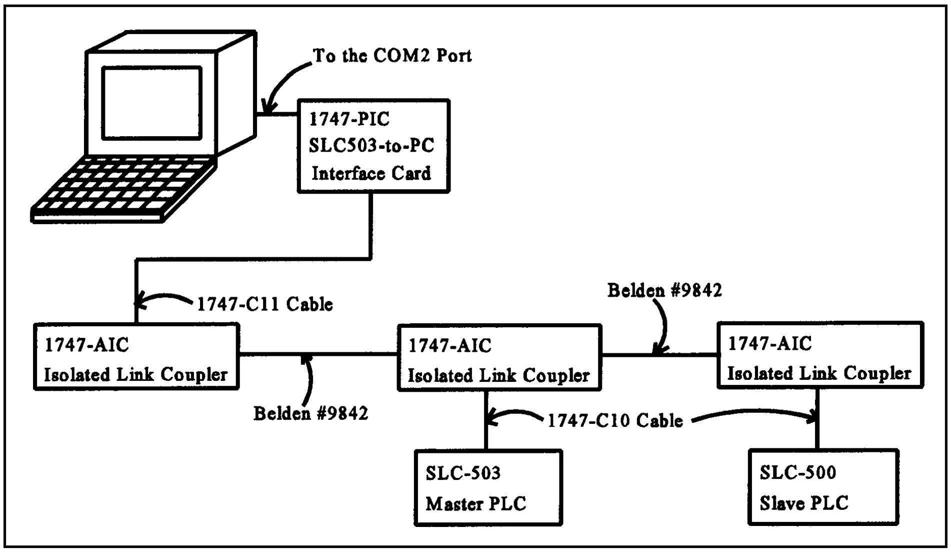


*Figure 3. Local Area Network Topologies.*

PLCs from one PC station connected to the network. Then, use the computer terminal on the PC station to monitor programs in several PLC stations. Also, we may use the Master PLC stations to vary data and program settings in their associated slave PLC stations. The above-mentioned network benefits are an essential part of modern automated manufacturing, and industrial / process control plants.

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```
Rung 2:0                                                              Green-LT
| I:1                                                                    O:2       |
|--] [---------------------------------------------+-------------------------------------------( )---------|
|   0                                              |                                             3         |
| Black-SW                                         +MSG----------------------------------+                 |
|                                                  +READ/WRITE MESSAGE            +(EN)-----               |
|                           Message Function       |Type        PEER-TO-PEER      +(DN)                    |
|                           to Write Timing        |Read/Write       WRITE        +(ER)                    |
|                           Values to SQO:0.       |Target Device    500CPU       |                        |
|                           SQO:0 is the           |Local/Remote       LOCAL      |                        |
|                           "Time-Control"         |Control Block      N7:0       |                        |
|                           Sequencer.             |Control Block Length 14       |                        |
|                                                  +-----------------------------------------+             |
|                                                                                                          |
Rung 2:1                                                                                                  |
| I:1                                                                                                     |
|--] [---------------------------------------------|-+MSG--------------------------------+                |
|   3                                              | +READ/WRITE MESSAGE          +(EN)-----              |
| Thermostat                                       | Type        PEER-TO-PEER     +(DN)                   |
|                                                  | Read/Write        READ       +(ER)                   |
|                           Message Function       | Target Device    500CPU      |                       |
|                           to Read the Status     | Local/Remote       LOCAL     |                       |
|                           of Outputs From        | Control Block      N7:20     |                       |
|                           the SQO:1.             | Control Block Length 14      |                       |
|                           SQO:1 is the           +-----------------------------------------+             |
|                           "Event-Control"        |                                                       |
|                           Sequencer.             |                          White-LT                     |
|                                                  |                             O:2                       |
|                                                  +-------------------------------------------( )---------|
|                                                                                2                         |
Rung 2:2                                                                                                  |
| I:1                                                                                                     |
|--] [---------------------------------------------|-+SVC--------------------------------------+--------- |
|   1                       Service Routine        | +SERVICE COMMUNICATIONS        |                     |
| Green-PB                  To Check Ch#1          |Channel 0 (232)     NO          |                     |
|                                                  |Channel 1 (485)     YES         |                     |
|                                                  +--------------------------------------------+          |
|----------------------------------------------+END+-------------------------------------------------------|
```

*Appendix A. The Master PLC (SLC503) Program Listing.*

```
Rung 2:0
| I:0  Red-PB                                                        B3        |
|--] [---------------------------------------------------------------(L)-------|
|    2                                                                 0       |
Rung 2:1                                                                       |
| I:0  Thermostat       R6:0                                         B3        |
|--]/[------------------] [------------------------------------------(U)-------|
|    3                  DN                                             0       |
Rung 2:2                                                                       |
| I:0  Black-SW         B3                                                     |
|--] [------------------] [------------------|-+RTO-------------------+        |
|   0                   0                    | +RETENTIVE TIMER ON    +(EN)----|
|                                            |Timer       T4:0        +(DN)    |
|                                            |Time Base   0.01        |        |
|                                            |Preset      500         |        |
|                                            |Accum         0         |        |
Rung 2:3                                     +------------------------+        |
| I:0  Black-SW         T4:0                                                   |
|--] [------------------] [------------------|+SQO--------------------+        |
|    0                  DN                   |+SEQUENCER OUTPUT       +(EN)----|
|                         "Time-Control"     |File       #N7:0        +(DN)    |
|                         Sequencer for      |Mask       FFFF         |        |
|                         Input to Register  |Dest       T4:0.PRE     |        |
|                         T4:0.pre.          |Control    R6:0         |        |
|                                            |Length       6          |        |
|                                            |Position     6          |        |
|                                            +------------------------+        |
Rung2:4                                                                        |
| I:0  Black-SW         T4:0                                                   |
|--] [------------------] [------------------|+SQO--------------------+        |
|    0                  DN                   |+SEQUENCER OUTPUT       +(EN)----|
|                         "Event-Control"    |File       #B3:0        +(DN)    |
|                         Sequencer          |Mask       FFFF         |        |
|                         to Control         |Dest       O:0.0        |        |
|                         Output Ports.      |Control    R6:1         |        |
|                                            |Length       6          |        |
|                                            |Position     6          |        |
Rung 2:5                                     +------------------------+        |
| T4:0                                                            T4:0         |
|--] [--------------------------------------------------------------(RES)------|
|   DN                                                         Timer Reset     |
|----------------------------------+END+---------------------------------------|
```

*Appendix B. The Slave PLC (SLC500) Program Listing.*