



Introduction to Control Networks in an Industrial Setting

An Online Continuing Education Course for Engineers

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1.0 Introduction

Communication networks in the industrial arena have, in the past decade, revolutionized the way facilities are controlled. They have made centralized control centers possible, with a wider range of features and more flexibility than ever before. High data transfer rates have allowed for more efficient data storage, trending, alarming, and analysis. The drawbacks that plagued the early generations of networks have been solved, for the most part, making them reliable enough to be used in the most critical of applications.

We take communication for granted, and while we practice it on a routine basis, it can be complex to achieve on an artificial level. We'll start with an example of two people wanting to communicate: person one has an idea he wants to share with his friend, person two. He must first formulate his idea into a coherent thought. He must then organize that thought into an expression that makes sense. He must structure that expression into a sentence that will effectively convey his idea. At this point he has a message that he must transmit to the other person. At the appropriate time, he begins vibrating air with exhaled breath across his vocal cords, and modulates those vibrations with his mouth. The message is transmitted, and person two must receive the message. Person two must recognize that person one is about to transmit a message, and prepare to receive it. He must perceive the vibrations in the air with his eardrum, and convert the vibrations into electrical stimuli to his brain, where it is transformed into a sentence in his conscious mind. He must then decode the sentence to determine its literal translation, do error checking, and then extract the real, intended meaning from it.

This sounds cumbersome, but think in more everyday terms: you're at work, and getting hungry. You notice it is nearly your normal lunch time. You walk over to your friend's desk. When he notices you walking toward him, he looks up. You say "Are you ready for lunch?" He nods, gets up from his desk, and proceeds to the door. You did all of the previously mentioned tasks with hardly a thought.

The definition of a network is two or more devices connected by some means so they can share information. The "means" is what we will address here. Additionally, even though the most general interpretation of the definition could include many manifestations (including our two friends going to lunch), we will focus on data communication between devices commonly found in industry. If the problem is broken into manageable parts, we can deal with each one effectively.

1.1 Communication Nomenclature

There are several techniques used to transmit information. Nearly all data network systems in use today, use binary digits (bits), a series of 1s and 0s, to send information, but there also must be methods of carrying the bits across the network.

Baseband involves the use of the entire bandwidth of a channel to transmit a single signal, using one carrier frequency. **Broadband** divides multiple analog signals into different frequencies and transmits them simultaneously (multi-mode fiber optic signals are one example of this).

Baseband hardware and associated cable are typically less expensive. Broadband requires high quality coaxial cable, which has the disadvantage of being expensive, as well as heavy, stiff, and difficult to work with. **Bandwidth** is the range of frequencies that a given carrier is able to effectively transmit. The rate at which data can be sent depends on the bandwidth of the cable, and is expressed in “baud”. **Baud** is actually the rate of signaling events (changes in frequency, amplitude, etc.) **Bits per second** is not necessarily the same as the baud rate and should not be confused, even though the terms are routinely used interchangeably. For instance, if the modulation allows for four distinct states rather than the traditional two (1 & 0), two bits could be conveyed with every state. This would mean that the rate of bits-per-second would be twice as fast as the baud rate. The baud rate is the same as the bits-per-second rate if and only if each signal element is equal to one bit exactly.

Messages are assembled into packets with formatting and addressing information, along with the data. The general form of a message packet or frame is a leading **header** (sometimes called the *preamble*), the **data** area (called the *payload*), and the **trailer**. The header contains addressing and error checking information, the data area contains the actual data being transmitted, and the trailer contains more error checking and message management information (e.g. parity and stop bits). **Parity**, a simple error checking method, uses the number of 1s in a byte (odd or even) to determine if the byte was received correctly.

Simplex transmissions are only in one direction, all of the time. **Half-duplex** is bidirectional communication allowed in one direction at any given time, and **full-duplex** is bidirectional transmission in both directions simultaneously. In addition to this, **synchronous** (clocked) transmissions are timed so that both devices know exactly when a transmission will begin and end, whereas **asynchronous** (un-clocked) transmissions must mark the beginning and end of messages. Synchronous transmission is usually faster than asynchronous, but the timing issue between two remote machines can introduce problems causing asynchronous transmission to be simpler and less expensive, and therefore more widely used. Asynchronous transmission does, however, introduce extra control bits into a message, which slows the rate that actual data can be transferred.

1.2 The OSI Seven-Layer Model

The OSI (Open System Interconnection) Reference Model (developed by the International Standards Organization, or ISO, so don't get confused) has been developed to define the communication process. It contains seven layers, and is independent of technology:

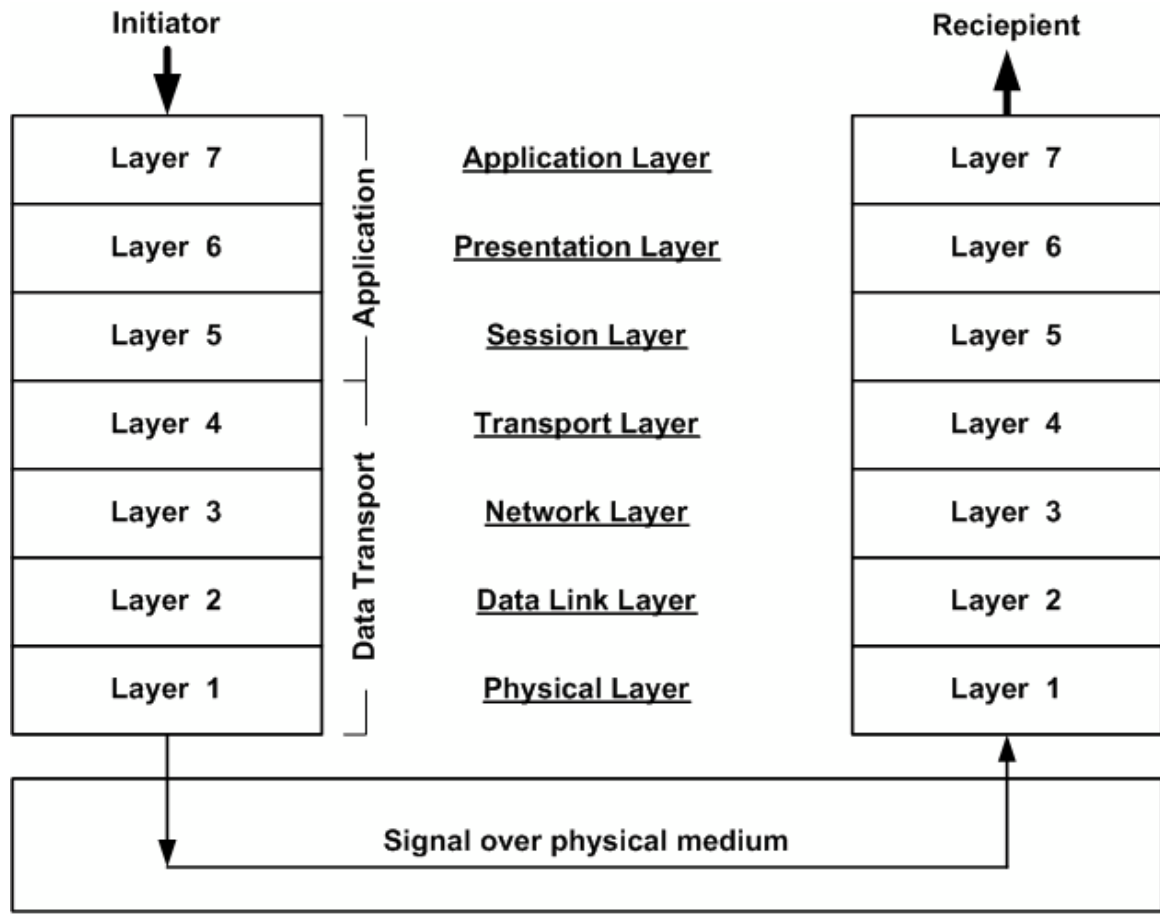


Figure 1 – The Seven Layer OSI Model

- Layer 1 - **Physical** - Defines the media characteristics (e.g. cable, connector, voltage levels, modulation techniques, etc.) necessary to originate, maintain, and terminate the link between physical devices.
- Layer 2 - **Data link** - Provides the physical addressing, network topology, data packets assembly, managing links between nodes, as well as error detection and correction at the bit level.
- Layer 3 - **Network** - Establishes connectivity and path selection between two end systems with logical addressing. It is the layer at which routing across sub-nets occurs.
- Layer 4 - **Transport** - Responsible for reliable network communication between end nodes, mid-level control of message delivery, including handshaking, message-level error detection and retransmission.

Layer 5 - **Session** - Establishes, manages, and terminates sessions between applications and manages data exchange between presentation layer entities, the higher level addressing of messages, as well as system control that controls communication sequencing and timing.

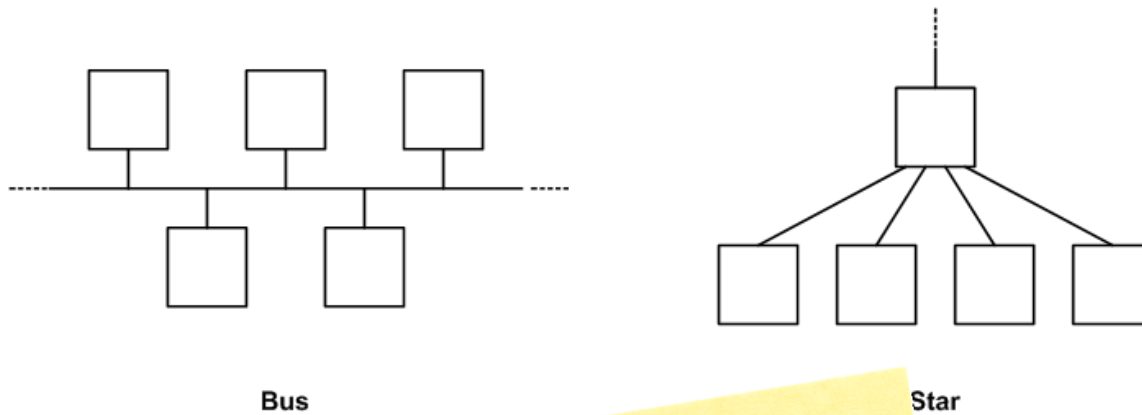
Layer 6 - **Presentation** - Ensures that information sent by the application layer of one system will be readable by the application layer of another by translating the message into the proper format. It is concerned with the data structures used by programs.

Layer 7 - **Application** - Provides services to application processes, the user programs that make a transmission request (such as e-mail, file transfer, and terminal emulation) that are outside of the OSI model. The application layer identifies and establishes the availability of intended communication partners (and the resources required to connect with them), synchronizes cooperating applications, and establishes agreement on procedures for error recovery and control of data integrity.

This discussion will primarily include the transport portion of the model (Layers 1 through 4). Those layers include most of what people mean when they speak of communication networks. The upper layers, referred to as the application portion, have more to do with the programs that manipulate data.

2.0 Network Topology

The arrangement of the devices on a network (sometimes called nodes), is called the topology. There are several that are commonly used, including the following:



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Combinations of the basic network topologies are used depending on the application.

It is important to remember that the model is “technology independent”, and is not limited to wire or even a physical connection.

3.0 Physical Media

There are several types of media used in industry: coax, twisted pair, and optical fiber are common examples.

Coaxial Cable (Coax) - A type of cable with a single solid conductor surrounded by a tubular shield, or outer conductor, separated by insulation and oriented about a common axis (hence the name). The shield reduces electrical interference (EMI : Electro-Magnetic Interference & RFI : Radio Frequency Interference). The shield also acts as the signal reference conductor.