Industrial Data Communications – Local Area Network Topologies and Access Control

Tutorial 3

This tutorial on industrial data communications is broken down into the following sections:

- Local Area Networks
- Topologies
- Access Control
- CSMA/CD
- Token Passing

Local Area Networks

Local Area Networks are about sharing information and resources. To enable all the nodes on the network to share information, they must be connected by some transmission medium. The method of connection is known as the network topology.
The nodes need to share this transmission medium in such a way as to allow nodes access to the medium and minimise disruption of an established sender. The main methods of this media access control, as it is called, will be discussed as well as their effects on system performance.

Network Topologies

The way the nodes are connected to form a network is known as its topology. A physical topology defines the wiring layout for a network. This specifies how the elements in the network are connected to each other electrically. This arrangement will determine what happens if a node on the network fails. Physical topologies fall into three main categories... bus, star, and ring topology. Combinations of these can be used to form hybrid topologies to overcome weaknesses or restrictions in one or other of these three component topologies.
A bus describes a network in which each node is connected to a common single communication channel or “bus”. This bus is sometimes called a backbone, as it provides the spine for the network. Every node can hear each message packet as it goes past. Each node checks the destination address that is included in the message packet to determine whether that packet is intended for the specific node. When the signal reaches the end of the bus, an electrical terminator absorbs the packet energy to keep it from reflecting back again along the bus cable, possibly interfering with other messages already on the bus. Each end of a bus cable must be terminated, so that signals are removed from the bus when they reach the end.

In a bus topology, nodes should be far enough apart so that they do not interfere with each other. However, if the backbone bus cable is too long, it may be necessary to boost the signal strength using some form of amplification, or repeater. The maximum length of the bus is limited by the size of the time interval that constitutes “simultaneous” packet reception. Figure 1 illustrates the bus topology.

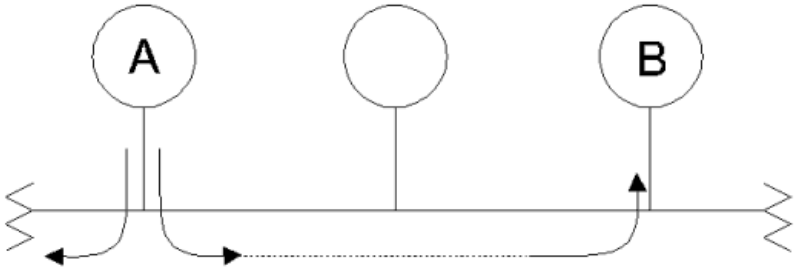

Figure 1 Bus Topology

Bus topologies offer the following advantages:

- A bus uses relatively little cable compared to other topologies, and arguably has the simplest wiring arrangement.
- Since nodes are connected by high impedance tappings across a backbone cable, it’s easy to add or remove nodes from a bus. This makes it easy to extend a bus topology.
- Architectures based on this topology are simple and flexible.
- The broadcasting of messages is advantageous for one-to-many data transmissions.

Bus topologies have the following disadvantages:

- There can be a security problem, since every node may see every message, even those that are not destined for it.
- Diagnosis/troubleshooting (fault-isolation) can be difficult, since the fault can be anywhere along the bus.
- There is no automatic acknowledgement of messages, since messages get absorbed at the end of the bus and do not return to the sender.
- The bus cable can be a bottleneck when network traffic gets heavy. This is because nodes can spend much of their time trying to access the network.

A star topology is a physical topology in which multiple nodes are connected to a central component, generally known as a hub. The hub of a star usually is just a wiring centre; that is, a common termination point for the nodes, with a single connection continuing from the hub. In some cases, the hub may actually be a file server (a central computer that contains a centralised file and control system), with all its nodes attached directly to the server. As a wiring centre, a hub may, in turn, be connected to the file server or to another hub.

All signals, instructions, and data going to and from each node must pass through the hub to which the node is connected. The telephone system is doubtless the best known example of a star topology, with lines to individual customers coming from a central telephone exchange location. There are not many LAN implementations that use a logical star topology. The low impedance ARCnet networks are probably the best examples. However, you will see that the physical layout of many other LANs look like a star topology even though they are considered to be something else. An examples of a star topology is shown in Figure 2.

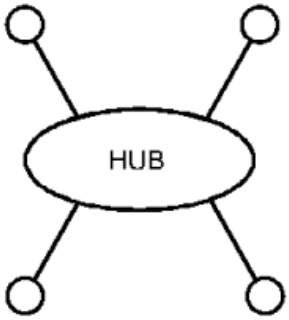

Figure 2 Star Topology

The advantages of the Star Topology are:

- Troubleshooting and fault isolation is easy.
- It is easy to add or remove nodes, and to modify the cable layout.
- Failure of a single node does not isolate any other node.
- The inclusion of a central hub allows easier monitoring of traffic for management purposes.

The disadvantages of the star topology are:

- If the hub fails, the entire network fails. Sometimes a backup central machine is included, to make it possible to deal with such a failure.
- A star topology requires a lot of cable.

A ring topology is both a logical and a physical topology. As a logical topology, a ring is distinguished by the fact that message packets are transmitted sequentially from node to node, in a predefined order, and as such it is an example of a point-to-point system. Nodes are arranged in a closed loop, so that the initiating node is the last one to receive a packet. As a physical topology, a ring describes a network in which each node is connected to exactly two other nodes.

Information traverses a one-way path, so that a node receives packets from exactly one node and transmits them to exactly one other node. A message packet travels around the ring until it returns to the node that originally sent it. In a ring topology, each node can acts as a repeater, boosting the signal before sending it on. Each node checks whether the message packet's destination node matches its address. When the packet reaches its destination, the destination node accepts the message, then sends it back to the sender, to acknowledge receipt.

Since ring topologies use token passing to control access to the network, the token is returned to sender with the acknowledgement. The sender then releases the token to the next node on the network. If this node has nothing to say, the node passes the token on to the next node, and so on. When the token reaches a node with a packet to send, that node sends its packet. Physical ring networks are rare, because this topology has considerable disadvantages compared to a more practical star-wired ring hybrid, which is described later.

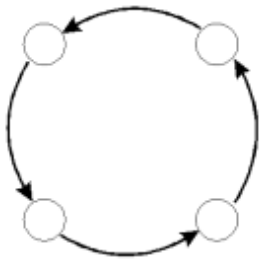

Figure 3 Ring Topology.

Ring Topology Advantages are:

- A physical ring topology has minimal cable requirements.
- No wiring centre or closet is needed.
- The message can be automatically acknowledged.
- Each node can regenerate the signal.

Disadvantages of the Ring Topology are:

- If any node goes down, the entire ring goes down.
- Diagnosis/troubleshooting (fault isolation) is difficult because communication is only one-way.
- Adding or removing nodes disrupts the network.
- There will be a limit on the distance between nodes.

As well as these three main topologies, some of the more important variations will now be considered. Once again, you should be clear that these are just variations, and should not be considered as topologies in their own right.

Media Access Methods

A common and important method of differentiating between different LAN types is to consider their media access methods. Since there must be some method of determining which node can send a message, this is a critical area that determines the efficiency of the LAN. There are a number of methods which can be considered, of which the two most common in current LANs are the contention or CSMA/CD method and the token passing method.

CSMA/CD (or Contention Systems)

The basis for a first-come-first-served media accesses method. This operates in a similar manner to polite human communication. We listen before we speak, deferring to anyone who already is speaking. If two of us start to speak at the same time, we recognise that fact and both stop, before starting our messages again a little later. In a contention-based access method, the first node to seek access when the network is idle will be able to transmit. Contention is at the heart of the Carrier Sense; Multiple Access; Collision Detection (CSMA/CD) access method used in the IEEE 802.3 and the original Ethernet networks, described in greater detail in a later tutorial.

Let us now discuss this access method in more detail. The Carrier Sense component involves a node wishing to transmit a message listening to the transmission media to ensure there is no “carrier“ present. In fact, the signalling method used on Ethernet type systems that make use of this method do not use a carrier in its true sense, and the name relates back to the original Aloha project in Hawaii that used radio links for transmission. The length of the channel and the finite propagation delay means that there is still a distinct probability that more than one transmitter will attempt to transmit at the same time, as they both will have heard “no carrier”. The collision detection logic ensures that more than one message on the channel simultaneously will be detected and transmission, from both ends, eventually stopped. The system is a probabilistic system, since access to the channel cannot be ascertained in advance.

Token Passing

Token passing is a deterministic media-access method in which a token is passed from node to node, according to a predefined sequence. A token is a special packet, or frame, consisting of a signal sequence that cannot be mistaken for a message. At any given time, the token can be available or in use. When an available token reaches a node, that node can access the network for a maximum predetermined time, before passing the token on. This deterministic access method guarantees that every node will get access to the network within a given length of time, usually in the order of a few milliseconds.

This is in contrast to a probabilistic access method (such as CSMA/CD), in which nodes check for network activity when they want to access the network, and the first node to claim the idle network gets access to it. Because each node gets its turn within a fixed period, deterministic access methods are more efficient on networks that have heavy traffic. With such networks, nodes using probabilistic access methods spend much of their time competing to gain access and relatively little time actually transmitting data over the network. Network architectures that support the token passing access method include Token Bus, ARCnet, FDDI, and Token Ring.

To transmit, the node first marks the token as “in use”, and then transmits a data packet, with the token attached. In a ring topology network, the packet is passed from node to node, until the packet reaches its destination. The recipient acknowledges the packet by sending the message back to the sender, who then sends the token on to the next node in the network.

In a bus topology network, the next recipient of a token is not necessarily the node that is nearest to the current token passing node. Rather, the next node is determined by some predefined rule. The actual message is broadcast on to the bus for all nodes to “hear”. For example, in an ARCnet or token bus network, the token is passed from a node to the node with the next lower network address. Networks that use token passing generally have some provision for setting the priority with which a node gets the token. Higher level protocols can specify that a message is important and should receive higher priority.

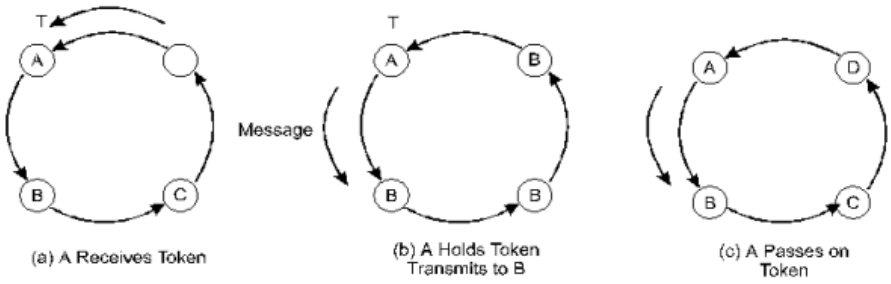

Figure 4 Token Passing

Now click here to go to the short quiz based on this tutorial.