Module 5

Broadcast Communication Networks

Lesson 4

IEEE Ring LANs

Specific Instructional Objectives

At the end of this lesson, the students will become familiar with the following concepts:

- Explain the operation of IEEE 802 LANs
    - 802.4 – Token bus-based
    - 802.5 – Token ring-based
- Compare performance of the three LANs

5.4.1 Introduction

In the preceding lesson we have mentioned that for the fulfillment of different goals, the IEEE 802 committee came up with a bunch of LAN standards collectively known as LANs as shown in Fig. 5.4.1. We have already discussed CSMA/CD-based LAN proposed by the IEEE 802.3 subcommittee, commonly known as Ethernet. In this lesson we shall discuss Token bus, Token Ring based LANs proposed by the IEEE 802.4 and IEEE 8.2.5 subcommittees.

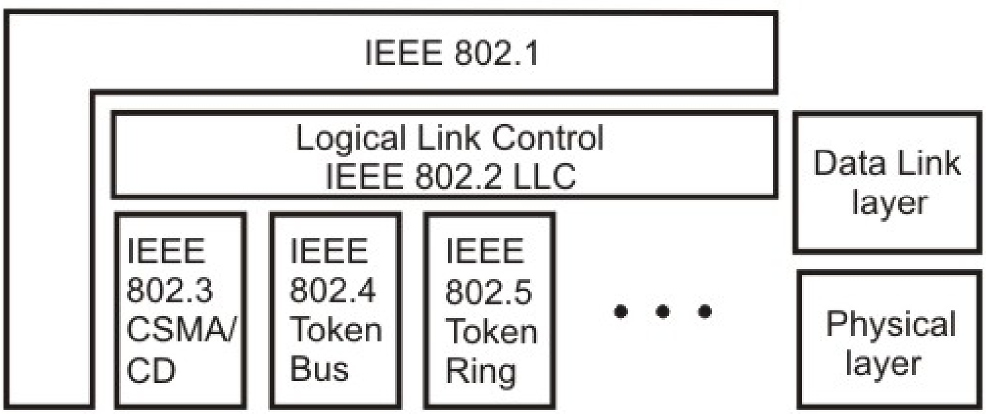

Figure 5.4.1 IEEE 802 Legacy LANs

5.4.2 Token Ring (IEEE 802.5)

5.4.2.1 Token Ring: A Brief History

Originally, IBM developed Token Ring network in the 1970s. It is still IBM's primary local-area network (LAN) technology. The related IEEE 802.5 specification is almost identical to and completely compatible with IBM's Token Ring network. In fact, the IEEE 802.5 specification was modeled after IBM Token Ring, and on the same lines. The term *Token Ring* is generally used to refer to both IBM's Token Ring network and IEEE 802.5 networks.

5.4.2.2 Introduction

Before going into the details of the Token Ring protocol, let's first discuss the motivation behind it. As already discussed, the medium access mechanism used by Ethernet (CSMA/CD) may results in collision. Nodes attempt to a number of times before they can actually transmit, and even when they start transmitting there are chances to encounter collisions and entire transmission need to be repeated. And all this become worse one the traffic is heavy i.e. all nodes have some data to transmit. Apart from this there is no way to predict either the occurrence of collision or delays produced by multiple stations attempting to capture the link at the same time. So all these problems with the Ethernet gives way to an alternate LAN technology, Token Ring.

Token Ring and IEEE802.5 are based on token passing MAC protocol with ring topology. They resolve the uncertainty by giving each station a turn on by one. Each node takes turns sending the data; each station may transmit data during its turn. The technique that coordinates this turn mechanism is called Token passing; as a Token is passed in the network and the station that gets the token can only transmit. As one node transmits at a time, there is no chance of collision. We shall discuss the detailed operation in next section.

Stations are connected by point-to-point links using repeaters. Mainly these links are of shielded twisted-pair cables. The repeaters function in two basic modes: Listen mode, Transmit mode. A disadvantage of this topology is that it is vulnerable to link or station failure. But a few measures can be taken to take care of it.

Differences between Token Ring and IEEE 802.5

Both of these networks are basically compatible, although the specifications differ in some ways.

- IEEE 802.5 does not specify a topology, although virtually all IEEE 802.5 implementations are based on the star topology. While IBM's Token Ring network explicitly specifies a star, with all end stations attached to a device called a Multi-Station Access Unit (MSAU).
- IEEE 802.5 does not specify a media type, although IBM Token Ring networks use twisted-pair wire.
- There are few differences in routing information field size of the two.

5.4.2.3 Token Ring Operation

Token-passing networks move a small frame, called a *token*, around the network. Possession of the token grants the right to transmit. If a node receiving the token has no information to send, it passes the token to the next end station. Each station can hold the token for a maximum period of time.

If a station possessing the token does have information to transmit, it seizes the token, alters 1 bit of the token (which turns the token into a start-of-frame sequence), appends the information that it wants to transmit, and sends this information to the next station on the ring. While the information frame is circling the ring, no token is on the network (unless the ring supports early token release), which means that other stations wanting to transmit must wait. Therefore, *collisions cannot occur in Token Ring networks*. If *early token release* is supported, a new token can be released immediately after a frame transmission is complete.

The information frame circulates around the ring until it reaches the intended destination station, which copies the information for further processing. The information frame makes a round trip and is finally removed when it reaches the sending station. The sending station can check the returning frame to see whether the frame was seen and subsequently copied by the destination station in error-free form. Then the sending station inserts a new free token on the ring, if it has finished transmission of its packets.

Unlike CSMA/CD networks (such as Ethernet), token-passing networks are *deterministic*, which means that it is possible to calculate the maximum time that will pass before any end station will be capable of transmitting. Token Ring networks are ideal for applications in which delay must be predictable and robust network operation is important.

5.4.2.4 Priority System

Token Ring networks use a sophisticated priority system that permits certain user-designated, high-priority stations to use the network more frequently. Token Ring frames have two fields that control priority: *the priority field* and the *reservation field.*

Only stations with a priority equal to or higher than the priority value contained in a token can seize that token. After the token is seized and changed to an information frame, only stations with a priority value higher than that of the transmitting station can reserve the token for the next pass around the network. When the next token is generated, it includes the higher priority of the reserving station. Stations that raise a token's priority level must reinstate the previous priority after their transmission is complete.

5.4.2.5 Ring Maintenance

There are two error conditions that could cause the token ring to break down. One is the *lost token* in which case there is no token the ring, the other is the *busy token* that circulates endlessly. To overcome these problems, the IEEE 802 standard specifies that one of the stations be designated as ‘active monitor’. The monitor detects the lost condition using a timer by *time-out* mechanism and recovers by using a new free token. To detect a circulating busy token, the monitor sets a ‘monitor bit’ to one on any passing busy token. If it detects a busy token with the monitor bit already set, it implies that the sending station has failed to remove its packet and recovers by changing the busy token to a free token. Other stations on the ring have the role of passive monitor. The primary job of these stations is to detect failure of the active monitor and assume the role of active monitor. A contention-resolution is used to determine which station to take over.

5.4.2.6 Physical Layer

The Token Ring uses shielded twisted pair of wire to establish point-point links between the adjacent stations. The baseband signaling uses differential Manchester encoding. To overcome the problem of cable break or network failure, which brings the entire network down, one suggested technique, is to use *wiring concentrator* as shown in Fig. 5.4.2.

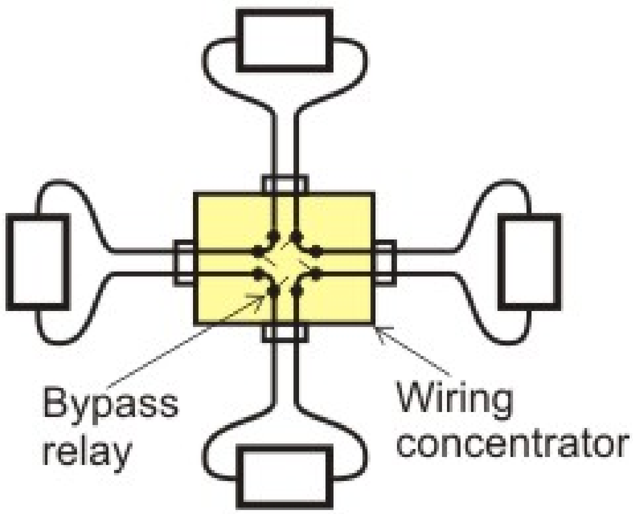

Figure 5.4.2 Star Connected Ring topology

It imposes the reliability in an elegant manner. Although logically the network remains as a ring, physically each station is connected to the *wire center* with two twisted pairs for 2-way communication. Inside the wire center, *bypass relays* are used to isolate a broken wire or a faulty station. This Topology is known as *Star-Connected Ring*.

5.4.2.7 Frame Format

Token Ring and IEEE 802.5 support two basic frame types: tokens and data/command frames. Tokens are 3 bytes in length and consist of a start delimiter, an access control byte, and an end delimiter. Data/command frames vary in size, depending on the size of the Information field. Data frames carry information for upper-layer protocols, while command frames contain control information and have no data for upper-layer protocols.

Token Frame Fields

Start Delimiter	**Access Control**	**Ending delimiter**

Token Frame contains three fields, each of which is 1 byte in length:

- **Start delimiter (1 byte)**: Alerts each station of the arrival of a token (or data/command frame). This field includes signals that distinguish the byte from the rest of the frame by violating the encoding scheme used elsewhere in the frame.
- **Access-control (1 byte)**: Contains the Priority field (the most significant 3 bits) and the Reservation field (the least significant 3 bits), as well as a token bit (used to differentiate a token from a data/command frame) and a monitor bit (used by the active monitor to determine whether a frame is circling the ring endlessly).
- **End delimiter (1 byte)**: Signals the end of the token or data/command frame. This field also contains bits to indicate a damaged frame and identify the frame that is the last in a logical sequence.

Data/Command Frame Fields

Start Delimiter	Access Control	Frame Control	Destination address	Source address	Data	Frame check sequence	End Delimiter	Frame Status

Data/command frames have the same three fields as Token Frames, plus several others. The Data/command frame fields are described below:

- **Frame-control byte (1 byte)—**Indicates whether the frame contains data or control information. In control frames, this byte specifies the type of control information.
- **Destination and source addresses (2-6 bytes)—**Consists of two 6-byte address fields that identify the destination and source station addresses.
- **Data (up to 4500 bytes)—**Indicates that the length of field is limited by the ring token holding time, which defines the maximum time a station can hold the token.
- **Frame-check sequence (FCS- 4 byte)—**Is filed by the source station with a calculated value dependent on the frame contents. The destination station recalculates the value to determine whether the frame was damaged in transit. If so, the frame is discarded.
- **Frame Status (1 byte)—**This is the terminating field of a command/data frame. The Frame Status field includes the address-recognized indicator and frame-copied indicator.

5.4.3 Token Bus (IEEE 802.4)

5.4.3.1 Token BUS: A Brief History

Although Ethernet was widely used in the offices, but people interested in factory automation did not like it because of the probabilistic MAC layer protocol. They wanted a protocol which can support priorities and has predictable delay. These people liked the conceptual idea of Token Ring network but did not like its physical implementation as a break in the ring cable could bring the whole network down and ring is a poor fit to their linear assembly lines. Thus a new standard, known as Token bus, was developed, having the robustness of the Bus topology, but the known worst-case behavior of a ring. Here stations are logically connected as a ring but physically on a Bus and follows the collision-free token passing medium access control protocol. So the motivation behind token bus protocol can be summarized as:

- The probabilistic nature of CSMA/ CD leads to uncertainty about the delivery time; which created the need for a different protocol
- The token ring, on the hand, is very vulnerable to failure.
- Token bus provides deterministic delivery time, which is necessary for real time traffic.
- Token bus is also less vulnerable compared to token ring.

5.4.3.2 Functions of a Token Bus

It is the technique in which the station on bus or tree forms a logical ring, that is the stations are assigned positions in an ordered sequence, with the last number of the sequence followed by the first one as shown in Fig. 5.4.3. Each station knows the identity of the station following it and preceding it.

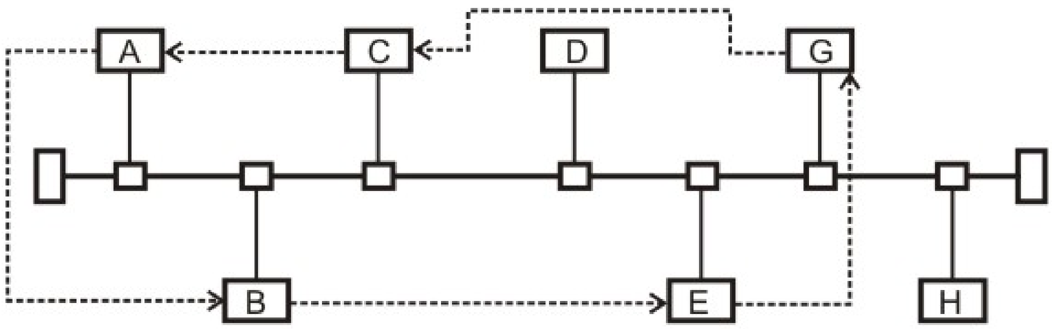

Figure 5.4.3 Token Bus topology

A control packet known as a *Token* regulates the right to access. When a station receives the token, it is granted control to the media for a specified time, during which it may transmit one or more packets and may poll stations and receive responses when the station is done, or if its time has expired then it passes token to next station in logical sequence. Hence, steady phase consists of alternate phases of token passing and data transfer.

The MAC sublayer consists of four major functions: the interface machine (IFM), the access control machine (ACM), the receiver machine (RxM) and the transmit machine (TxM).

IFM interfaces with the LLC sublayer. The LLC sublayer frames are passed on to the ACM by the IFM and if the received frame is also an LLC type, it is passed from RxM component to the LLC sublayer. IFM also provides quality of service.

The **ACM** is the heart of the system. It determines when to place a frame on the bus, and responsible for the maintenance of the logical ring including the *error detection* and *fault recovery*. It also cooperates with other stations ACM's to control the access to the shared bus, controls the admission of new stations and attempts recovery from faults and failures.

The responsibility of a **TxM** is to transmit frame to physical layer. It accepts the frame from the ACM and builds a MAC protocol data unit (PDU) as per the format.

The **RxM** accepts data from the physical layer and identifies a full frame by detecting the SD and ED (start and end delimiter). It also checks the FCS field to validate an error-free transmission.

5.4.3.3 Frame Form

The frame format of the Token Bus is shown in Fig. 5.4.4. Most of the fields are same as Token Ring. So, we shall just look at the Frame Control Field in Table 5.4.1

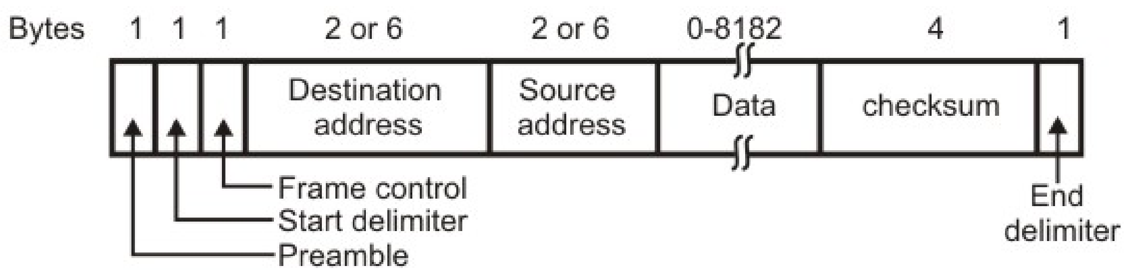

Figure 5.4.4 Token Bus frame format

Table 5.4.1 The Frame Control Field

Frame Control	Name	Use
0000 0000	Claim-Token	Ring Initialization
0000 0001	Solicit-successor -1	Addition to the Ring
0000 0010	Solicit-successor -2	Addition to the Ring
0000 0011	Who-follows	Recovery from lost token
0000 0100	Resolve Contention	Multiple station to join the Ring
0000 1000	Token	Pass the Token
0000 1100	Set-Successor	Deletion from the ring

5.4.3.4 Logical ring maintenance

The MAC performs the following functions as part of its maintenance role of the ring.

Addition to the Ring: Non-participating stations must periodically be granted the opportunity to insert themselves into the ring. Each node in the ring periodically grants an opportunity for new nodes to enter the ring while holding the token. The node issues a solicit–successor–1 packet, inviting nodes with an address between itself and the next node in logical sequence to request entrance. The transmitting node then waits for a period of time equal to one response window or slot time (twice the end-to-end propagation delay of the medium). If there is no request, the token holder sets its successor node to be the requesting node and transmits the token to it; the requester sets the linkages accordingly and proceeds.

If more than one node requests, to enter the ring, the token holder will detect a garbled transmission. The conflict is resolved by *addressed based contention scheme;* the token holder transmits a resolved contention packet and waits for four response windows. Each requester can transmit in one of these windows, based on the first two bits of its address. If requester hears anything before its windows comes up, it refrains from requesting entrance. If a token holder receives a valid response, then it can proceed, otherwise it tries again and only those nodes that request the first time are allowed to request this time, based on the second pair of bits in their address. This process continues until a valid request is received or no request is received, or a maximum retry count is reached. In latter cases, the token holder passes the token to logical successor in the ring.

Deletion from Ring: A station can voluntarily remove itself from the ring by splicing together its predecessor and successor. The node which wants to be deleted from the ring waits until token comes to it, then it sends a set successor packet to its predecessor, instructing it to splice to its successor.

Fault Management: Errors like duplicate address or broken ring can occur. A suitable management scheme should be implemented for smooth functioning. It is done by the token-holder first, while holding the token, node may hear a packet, indicating that another node has the token. In this case, it immediately drops the token by reverting to listener mode, and the number of token holders drops immediately from one to zero. Upon completion of its turn, it immediately issues a data or token packet. The sequence of steps are as follows:

i. After sending the token, the token issuer will listen for one slot time to make sure that its predecessor is active.
ii. If the issuer does not hear a valid packet, it reissues the token to the same successor one more time.
iii. After two failures, the issuer assumes that its successor has failed and issues a “who-follows” packet, asking for the identity of the node that follows the failed node. The issuer should get back a set successor packet from the second node down the time. If so, the issuer adjusts its linkage and issues a token (back to step i).
iv. If the issuing node gets a response to its “who-follows” packet, it tries again.
v. If the “who-follows” tactic fails, the node issues a solicit-successor-2 packet with full address range (i.e. every node is invited to respond). If this packet works then the ring is established and procedure continues.
vi. If two attempts in step (v) fail, it assumes that a catastrophe has happened; perhaps the node receiver has failed. In any case, the node ceases the activity and listen the bus.

Ring Initialization: Ring is to be initialized by starting the token passing. This is necessary when the network is being setup or when ring is broken down. Some decentralized algorithms should take care of, who starts first, who starts second, etc. it occurs when one or more stations detects a lack of bus activity lasting longer than a specific time. The token may get lost. This can occur on a number of occasions. For example, when network has been just powered up, or a token holding station fails. Once its time out expires, a node will issue a claim token packet. Contending clients are removed in a similar fashion to the response window process.

5.4.3.4 Relative comparison of the three standards

A comparison of the three standards for different functions is shown in Table 5.4.2 and results of the analysis of the performance of the three standards are summarized below:

- The CSMA/CD protocol shows strong dependence on the parameter 'a', which is the ratio of the propagation time to the transmission time. It offers shortest delay under light load and it is most sensitive under heavy load conditions.
- Token ring is least sensitive to different load conditions and different packet sizes.
- Token bus is highly efficient under light load conditions.

Table 5.4.2 Comparison of the three standards

Function	**CSMA/CD**	**Token bus**	**Token ring**
Access determination	Contention	Token	Token
Packet length restriction	64 bytes (Greater than 2.Tprop)	None	None
Priority	Not supported	Supported	Supported
Sensitivity to work load	Most sensitive	Sensitive	Least sensitive
Principle advantage	Simplicity, wide installed base	Regulated/fair access	Regulated/fair access
Principle disadvantage	Nondeterministic delay	Complexity	Complexity

Fill In The Blanks

1. Originally, _______________ developed Token Ring network in the _________.
2. A disadvantage of this topology is that it is vulnerable to __________ or _____ failure.
3. Unlike CSMA/CD networks (such as Ethernet), token-passing networks are _________________, which means that it is possible to calculate the maximum time that will pass before any end station will be capable of transmitting.
4. Token Ring frames have two fields that control priority: ____________ and the ____________*field.*

5. In Token Ring inside the wire center, _____________ are used to isolate a broken wire or a faulty station.
6. The Mac sublayer in Token BUS consists of four major functions: ____________, the access control machine (ACM), ______________________and _____________.
7. ___________ determines when to place a frame on the bus, and responsible for the maintenance of the logical ring including the *error detection* and *fault recovery*.

Answers:

1. IBM, 1970
2. link**,** station
3. deterministic
4. the priority field, reservation
5. *bypass relays*
6. the interface machine (IFM), the receiver machine (RxM), the transmit machine (TxM).
7. Access control machine (ACM)

Short question Answers:

Q-1. What is the advantage of token passing protocol over CSMA/CD protocol?
Ans. Advantage of token passing protocol over CSMA/CD protocol:

The CSMA/CD is not a deterministic protocol. A packet may be delivered after many (up to 15) collisions leading to long variable delay. An unfortunate packet may not get delivered at all. This feature makes CSMA/CD protocol unsuitable for real-time applications. On the other hand, token passing protocol is a deterministic approach, which allows a packet to be delivered within a known time frame. It also allows priority to be assigned to packets. These are the two key advantages of token passing protocol over CSMA/CD protocol.

Q-2. What are the drawbacks of token ring topology?
Ans. Token ring protocol cannot work if a link or a station fails. So, it is vulnerable to link and station failure.

Q-3. How the reliability of token ring topology can be improved?
Ans. Reliability of the ring network can be improved by implementing the ring topology using a wiring concentrator. This allows not only to detect fault, but also to isolate the faulty link/station with the help of a bypass relay.

Q-4. What role the active token monitor performs?
Ans. Token ring is maintained with the help of active token monitor. Any one of the stations has the capability to act as active token monitor, but at a particular instant only

one acts as active token monitor. It monitors various error situations such as multiple token, orphan packet, etc, and takes appropriate action to come out of the error situation.