1.a)

Token ring is an implementation of a point-to-point protocol where nodes are connected through point-to-point links [1]. A token ring network typically consists of stations physically connected in a ring or star topology, where all stations are connected sequentially [2]. Therefore, each station is connected to a total of two other stations, the previous and next station in the network.

A token is a special frame which indicates a station's current authority to transmit messages within the network [3]. The token is used to transmit data to stations in the network and is passed sequentially from one host to the next as it circulates around the ring. This process of passing the frame sequentially from one station to the next is called token passing. Frames are passed unidirectionally and a network will commonly have only one token circulating the network [2].

When a station receives an empty token frame, it can use the token to communicate with the network [4]. If this station would like to transmit, it alters the empty token frame, appending the data it wishes to transmit following a strict data frame structure [5]. This updated token will be passed from node to node around the network until it reaches the destination address. The intended receiver will copy the contents of the frame and alter the flag status of the data frame, indicating that it has successfully copied the sender's frame [6]. The token will again be passed around the network back to source node where it will see the acknowledgement in the flag status byte of the data frame. The source node will then convert the data frame back to an empty token frame and will pass it to the next node [3].

A noteworthy process of token passing occurs in the nodes between the sender and intended receiver of a data frame. First, they will investigate the frame for errors [7]. If an error is discovered, the node will make an amendment to frame indicating that an error has occurred [7]. After this process has been completed, it will pass the token either unchanged or including a change to the error detected flag which is a part of the end delimiter field.

2.a)

A token ring network uses a coding violation framing technique [7]. This technique involves the use of non-data symbols to differentiate the payload from delimiters and must implement strict clock synchronization and frame timing. Token ring uses Differential Manchester encoding to interpret data through the change of voltage within a specified period [5]. A 0 is represented by a change in voltage at the beginning of the period and a 1 is represented by no change of voltage at the beginning of the period [8]. Both data possibilities must also include a change in voltage during the middle of the period. Due to this rule of voltage change, there are two non-data possibilities. An invalid 0 and an invalid 1 [8]. These are called a J non-data symbol and K non-data symbol respectively. These are invalid as they do not have a voltage change during the middle of the period [7]. Using these non-data symbols, a frame's start and end delimiters can be easily distinguished from the payload as the payload will not use these symbols.

Using these non-data symbols, the Token Ring Start Frame Delimiter (SFD) is JK0JK000 and the End Delimiter (ED) is JK1JK1IE [9] where the I and E represent additional information about the frame and can either be a standard 1 or 0.

2.b)

Token Frame

Start Frame Delimiter (SFD) (1 Byte)	Access Control (AC) (1 Byte)	End Delimiter (ED) (1 Byte)

Data Frame

Start Frame Delimiter (SFD) (1 Byte)	Access Control (AC) (1 Byte)	Frame Control (FC) (1 Byte)	Destination Address (DA) (6 Bytes)	Source Address (SA) (6 Bytes)	Data (>= 0 Bytes)	Cyclic Redundancy Check (CRC) (4 Bytes)	End Delimiter (ED) (1 Byte)	Flag Status (FS) (1 Byte)

2.c)

The token frame is broken up into 3 fields and the data frame is broken up into 9 fields. All fields of the token frame are included in the data frame.

Start Frame Delimiter (SFD)

The SFD is a flag that occurs at the beginning of token and data frames and has two key functions. The first key feature of the SFD is to alert a station of the arrival of the token or data frame [10]. The second use of the SFD is to synchronize the signal clocks of the receiving station for the SFD's corresponding frame [10]. As discussed in question 2a, token ring networks use the coding violation framing technique. Strict clock synchronization and frame timing is required to implement this framing technique. Hence, the second key purpose of the SFD flag is to assist with signal synchronization.

Access Control (AC)

The AC is used to manage which stations in the network can access this token. This field is a byte in length and 8 bits are broken up to perform 4 functions.

The first 3 bits are used to indicate the level of priority set for the token [10]. A node can transmit using an available token that has a priority level equal to or below the node's transmission priority value [7]. For example, if a node wants to transmit a message with a priority level of 1, it must first see an available token with a priority level of 1 or less.

The 4^{th} bit is the token bit. This is used to identify if the frame is an empty token or a data frame [10]. When the bit is set to a 0, it indicates that this is a token frame. When the bit is set to 1, it indicates that this is a data frame in transit [7].

The 5^{th} bit is the monitor bit and is used to identify orphaned packets circulating the networking [9]. The monitor is a special machine used to change this bit's value and recalculate the CRC of the packet quickly and efficiently [10]. As a frame circulates the ring, the monitor will stamp the frame by changing the monitor bit from a 0 to a 1. If the frame comes around a second time and the monitor bit has already been set to a 1, the monitor will assume an error has occurred, remove the packet, and release a new token frame [7].

The final 3 bits are the reservation bits which are used by stations to attempt to reserve a token [9]. If a station wishes to transmit but does not meet the priority value of the available token, the station can set the reservation bits to their desired priority level [7]. However, a station can only alter the reservation bits if token's current reservation bits have either not been set or has a lower priority level value than that which this node would like to set [7]. Once the token has been utilised by another station that meets the priority requirement, when the station must reset the data frame to a token frame, the station will set priority bits to the reservation bits [7]. Using this method, stations with low priority transmission tasks will not be able to tokens reserved for high priority transmission tasks.

Frame Control (FC)

The FC field is a byte in length and is used to indicate if the field includes data or control information. If this frame is a control frame the FC will also include information about the type of control [10].

Destination Address (DA)

The DA field is 6 bytes in length and indicates the MAC address of the frame's destination node [10].

Source Address (SA)

Like the DA field, the SA field is also 6 bytes in length and indicates the MAC address of the frame's source node [10].

Data

The data field is used to transmit any information outside of the standard data frame fields. As an example, the data field could be used to house layer 3 IP Headers and Layer 4 TCP data. This field does not have a lower limit and can consist of 0 bytes [10].

IBM states that with a typical 4Mbps token ring network, the maximum amount of data that is allowed within a frame is 2044 bytes accounting for Logical Link Control overhead of 8 bytes [11]. Using this figure and considering the overhead of all other fields in the data frame, we can deduce that the data field has a maximum length of around 2000 bytes. Many other sources state that maximum length of the data field is around 4500 bytes [6]. Using these sources, we can determine that the data field maximum length depends on many different variables such as the network's Mbps.

Cyclic Redundancy Check (CRC)

The CRC is an error detection field and is created using a complex polynomial calculation of block bits in the frame. CRC is a sophisticated method of error detection and is used by most networking frameworks [12]. As this is a complex and expensive calculation, specialised hardware or circuitry is often used to calculate this value quickly and efficiently as to not slow down the network. This field is used to detect corruption of a frame [10]. If a frame is found to be corrupted using the CRC field, the frame will be discarded [10].

End Delimiter (ED)

The ED flag is used to serve 3 functions.

The first use of the ED flag is to identify the end of a frame [10].

The 7th and 8th bits of the ED flag byte represent the intermediate frame bit and the error detection bit respectively [7]. These 2 bits serve specific purposes and provide additional information about the frame.

The intermediate frame bit is used to manage multi-frame message messaging [7]. A value of 0 indicates this is the final frame and a value of 1 indicates that there are additional frames [7]. An example includes the transmission of a large amount of related data that must be split up among multiple frames. The intermediate bit is used to alert a station that there a related frames to follow [7].

The error detected bit is used to indicate if an error has been detected in the frame [7]. This value is initially set to 0 to indicate that there are no errors in the frame. As the token is passed from station to station, each host will check the frame, and, upon error detection, will change the E bit value to a 1, indicating an error has been identified in the frame [7].

Frame Status (FS)

The final field of the data frame is the FS byte which is used to terminate a data frame [10]. This field serves as an acknowledgement field and is used to tell the source station that the frame was successfully copied, and the information was received [13]. The token is the then sent back around the ring to communicate the acknowledgment to the sending station.

3.a)

Token ring networks implement a Local Area Networks (LAN) topology [2]. A LAN is a collection of devices connected to allow networking communication between each other. A key characteristic of a LAN is that the network exists in a single limited area [14]. Given that this type of network requires a ring or star like topology with regards to how stations are connected, a high level of control over these stations and the way that they are connected is required. A LAN topology best meets these needs as stations can be easily connected in a ring like format within the limited physical area. By using LAN, frames are very easily transmitted around the token ring network using token passing as stations are connected in sequence [4]. Finally, stations of a token ring network must use a token ring supported Network Interface Card (NIC) to use the network [15]. When creating a LAN network engineers have plenty of control over the connected an can therefore ensure that token ring enabled NICs are implemented.

3.b)

Token Ring networks utilise a strict ring or star topology where all stations of the network are connected to 2 other stations. Using the method of token passing, a token frame is passed sequentially around the network allowing for stations to transmit data between each other [2]. A high level of control around the way stations are connected to one another is required to be able to setup a network in a ring or star topology.

Let's use an example to contrast LAN. If we wanted to implement token ring into a Wide Area Network (WAN) such as the internet, we must ensure that all stations connected to the internet are connected sequentially and are only connected to 2 other stations. Data must be passed unidirectionally from one station to the next [2]. This is a near impossible task as we do not control all the machines and assets that make up the internet. Also, if data is being passed unidirectionally, we must pass our token to every node connected to the internet before coming back to the transmitter. This would cause an unreasonable amount of lag and a severe security issue as every node of the internet can see everyone else's traffic. For these reasons token ring networks are best suited for a LAN topology as we have more control over the way machines are connected and who has access to the traffic of the network.

To be able to use a token ring network, machines within the network must be fitted with a token ring NIC [13]. This is another key reason around why token ring networks are better suited to LAN topologies, as we need a high level of control of the machines in the network to ensure that that all have the appropriate NIC.

References

[1]J. Walrand and P. Varaiya, *High-Performance Communication Networks*, 2nd ed. Elsevier Inc, 2000, pp. 103-154.

[2]"Token-ring networks", *IBM*. [Online]. Available: https://www.ibm.com/docs/en/i/7.2?topic=standards-token-ring-networks. [Accessed: 22- Dec- 2021].

[3]N. Pidgeon, "Alternative Network Technologies: Token Ring", *HowStuffWorks*. [Online]. Available: https://computer.howstuffworks.com/ethernet17.htm. [Accessed: 22- Dec- 2021].

[4]A. Zola, K. Ferguson and J. Burke, "Token ring", *TechTarget - SearchNetworking*, 2021. [Online]. Available: https://www.techtarget.com/searchnetworking/definition/Token-Ring. [Accessed: 22- Dec- 2021].

[5]B. Glass, "Understanding Token Ring", *Byte Magazine*, no. 1, p. 363+, 1989.

[6]"What are the Token Ring Frame Formats in Computer Network?", *Tutorialspoint.com*, 2021. [Online]. Available: https://www.tutorialspoint.com/what-are-the-token-ring-frame-formats-in-computer-network. [Accessed: 22- Dec- 2021].

[7]G. Held, *Enhancing LAN Performance*, 4th ed. CRC Pres, 2004, p. 111.

[8]J. Haugdahl, *Network Analysis and Troubleshooting*, 1st ed. Addison-Wesley Professional, 2000, pp. 54-56.

[9]"IEEE 802.5 Token Ring", *Network Sorcery*. [Online]. Available: http://www.networksorcery.com/enp/protocol/IEEE8025.htm. [Accessed: 22- Dec- 2021].

[10]"Token Ring frame format", *GeeksForGeeks*, 2019. [Online]. Available: https://www.geeksforgeeks.org/token-ring-frame-format/. [Accessed: 22- Dec- 2021].

[11]"Token Ring IEEE 802.5", *IBM*. [Online]. Available: https://www.ibm.com/docs/en/zvm/7.2?topic=structure-token-ring-ieee-8025. [Accessed: 24- Dec- 2021].

[12]O. C. Ibe, *Fundamentals of Data Communication Networks*, 1st ed. Wiley, 2017.

[13]S. Ahuja, "IEEE 802.5 (Token Ring) LAN", School of Computing, University of North Florida.

[14]"What is a LAN? Local Area Network", *Cisco*, 2021. [Online]. Available: https://www.cisco.com/c/en_au/products/switches/what-is-a-lan-local-area-network.html. [Accessed: 29- Dec- 2021].

[15]D. Liu, B. Barber and L. DiGrande, *Cisco CCNA/CCENT Exam 640-802, 640-822, 640-816 Preparation Kit*. Syngress, 2009, pp. 1-46.