18EID41

Hall Ticket Number:

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

November,2022 — **Electronics & Instrumentation Engineering**

Seventh Semester — **Data Communications**

Time: Three Hours — **Maximum: 5**0 Marks

Answer Question No. 1 Compulsorily. (10X1 = 10 Marks)

*Answer **ANY ONE** question from each Unit.* (4X10=40 Marks)

1.	a)	What are the data link layer protocols?	CO1(BL1)	
	b)	What is the difference between the OSI Model and TCP/IP Model?	CO1(BL1)	
	c)	What is the need of bridge?	CO2(BL1)	
	d)	What is the difference betweena Bridge and a router?	CO2(BL1)	
	e)	What is MODBUS?	CO3(BL1)	
	f)	What is a Fieldbus?	CO3(BL1)	
	g)	What is the need of MODEM?	CO4(BL1)	
	h)	What are the different types of Ethernet standards?	CO4(BL1)	
	i)	What is an OPC?	CO4(BL1)	
	j)	What is the purpose of the jam signal in CSMA/CD?	CO1(BL1)	
		Unit - I		
2.	a)	Draw and explain functionalities of different layers of TCP/IP.	CO1(BL2)	**10M**
		(OR)		
3.	a)	Describe in detail the CSMS/CD procedure with a neat block diagram.	CO1(BL2)	**8M**
	b)	What is token passing?	CO1(BL1)	**2M**
		Unit - II		
4.	a)	Discuss the functionality of bridges,Routers and gate ways.	CO2(BL2)	**5M**
	b)	Describe the RS-485 serial communication concepts.	CO2(BL2)	**5M**
		(OR)		
5.	a)	Compare and contrastRS-232 and RS-485.	CO2(BL2)	**4M**
	b)	Discuss the functionality of anyone Routing protocol.	CO2(BL3)	**6M**
		Unit - III		
6.	a)	What are the two types of frame formats in HART Protocol? Discuss	CO3(BL2)	**6M**
	b)	What are the benefits of Fieldbus?	CO3(BL2)	**4M**
		(OR)		
7.	a)	How MODBUS works? Explain in detail.	CO3(BL2)	**5M**
	b)	Explain in detail HART communication protocol.	CO3(BL2)	**5M**
		Unit - IV		
8.	a)	What is an Ethernet in the computer network?	CO4(BL2)	**2M**
	b)	Explain the concepts of 10 Mbps and 100 Mbps Ethernet standards.	CO4(BL3)	**8M**
		(OR)		
9.	a)	Explain different components of Radio link.	CO4(BL2)	**6M**
	b)	Briefly introduce radio MODEMs.	CO4(BL2)	**4M**

SCHEME AND SOLUTION

1. a) What are the data link layer protocols? CO1 (BL1)

A: Examples of data link protocols are **Ethernet, Point-to-Point Protocol (PPP), HDLC**

b) What is the difference between the OSI Model and TCP/IP Model? CO1 (BL1)

A:

OSI is a generic, protocol independent standard. It is acting as an interaction gateway between the network and the final-user.	TCP/IP model depends on standard protocols about which the computer network has created. It is a connection protocol that assigns the network of hosts over the internet.

c) What is the need of bridge? CO2 (BL1)

A: It **provides interconnection with other computer networks that use the same protocol**.

d) What is the difference between a Bridge and a router? CO2 (BL1)

A: Bridge is a network device, which works in data link layer. Through bridge, data or information is not stored and sent in the form of packets. Whereas Router is also a network device which works in network layer. Through router, data or information is stored and sent in the form of packets.

e) What is MODBUS? CO3 (BL1)

A: Modbus is a serial communication protocol developed by Modicon published by Modicon® in 1979 for use with its programmable logic controllers (PLCs).

f) What is a Fieldbus? CO3 (BL1)

A: Fieldbus is simply a means of communicating with **input devices** (sensors, switches, etc.) and output devices (valves, drives, indication lamps etc.) without the need to connect each individual device back to the controller (PLC, Industrial PC etc.).

g) What is the need of MODEM? CO4 (BL1)

A: A modem is a very important piece of network hardware that allows a computer to send and receive data through a telephone line or cable connection.

h) What are the different types of Ethernet standards? CO4 (BL1)

A: Token Ring, Fast Ethernet, Gigabit Ethernet, 10 Gigabit Ethernet

i) What is an OPC? CO4 (BL1)

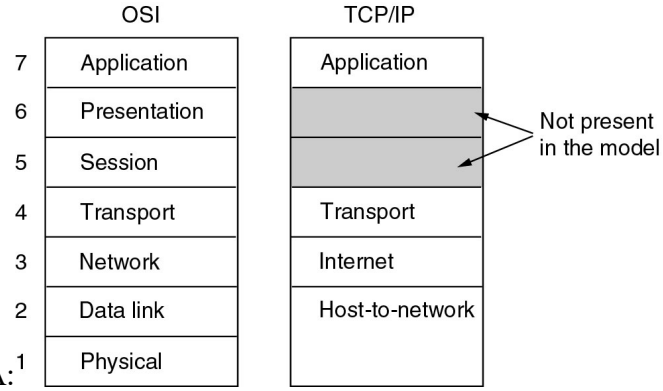
A: OPC is **the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries**.

j) What is the purpose of the jam signal in CSMA/CD? CO1 (BL1)

A: When a CSMA/CD station senses that a collision has occurred, it immediately stops transmitting its packets and sends a brief jamming signal to notify all stations of this collision.

2. a) Draw and explain functionalities of different layers of TCP/IP. CO1 (BL2) 10M

A:1



The layers are

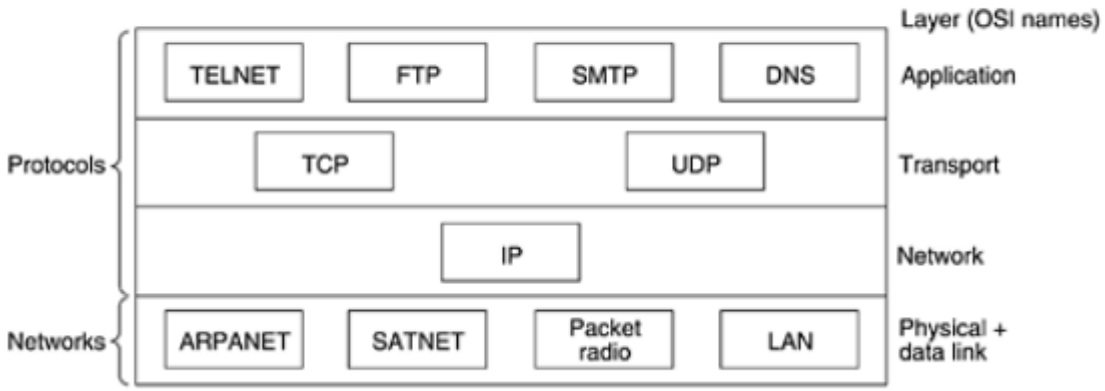
- Host to Network Layer
- Internet Layer
- Transport Layer
- Application Layer

The Host-to-Network Layer:The TCP/IP reference model does not really say much about what happens here, except to point out that the host has to connect to the network using some protocol so it can send IP packets to it. This protocolis not defined and varies from host to host and network to network.

The Internet Layer:The internet layer defines an official packet format and protocol called IP (Internet Protocol). The job of the internet layer is to deliver IP packets where they are supposed to go. Packet routing is clearly the major issue here, as is avoiding congestion. For these reasons, it is reasonable to say that the TCP/IP internet layer is similar in functionality to the OSI network layer. Figure 2.a shows this correspondence.

The TCP/IP reference model. –

Protocols and networks in the TCP/IP model initially.



The Transport Layer:

The layer above the internet layer in the TCP/IP model is called the transport layer. It is designed to allow peer entities on the source and destination hosts to carry on a conversation, just as in the OSI transport layer. Two end-to-end transport protocols have been defined here.

The first one, TCP (Transmission Control Protocol), is a reliable connection-oriented protocol that allows a byte stream originating on one machine to be delivered without error on any other machine in the internet. It fragments the incoming byte stream into discrete messages and passes each one on to the internet layer.

At the destination, the receiving TCP process reassembles the received messages into the output stream. TCP also handles flow control to make sure a fast sender cannot swamp a slow receiver with more messages than it can handle.

The second protocol in this layer, UDP (User Datagram Protocol), is an unreliable, connectionless protocol for applications that do not want TCP's sequencing or flow control and wish to provide their own. It is also widely used for one-shot, client-server-type request-reply queries and applications in which prompt delivery is more important than accurate delivery, such as transmitting speech or video.

The Application Layer:

On top of the transport layer is the application layer. It contains all the higher-level protocols. The early ones included virtual terminal (TELNET), file transfer (FTP), and electronic mail (SMTP).The virtual terminal protocol allows a user on one machine to log onto a distant machine and work there. The file transfer protocol provides a way to move data efficiently from one machine to another. Electronic mail was originally just a kind of file transfer, but later a specialized protocol (SMTP) was developed for it. Many other protocols have been added to these over the years: the Domain Name System (DNS) for mapping host names onto their network addresses, NNTP, the protocol for moving USENET news articles around, and HTTP, the protocol for fetching pages on the World Wide Web, and many others.

(OR)

3. a) Describe in detail the CSMS/CD procedure with a neat block diagram. CO1 (BL2) 8M

A: CSMA/CD

In CSMA scheme, when two packets collide the channel remains unutilized for the entire duration of transmission time of both the packets.

If the propagation time is small (which is usually the case) compared to the packet transmission time, wasted channel capacity can be considerable.

This wastage of channel capacity can be reduced if the nodes continue to monitor the channel while transmitting a packet and immediately cease transmission when collision is detected.

This refined scheme is known as Carrier Sensed Multiple Access with Collision Detection (CSMA/CD).

On top of the CSMA, the following rules are added to convert it into CSMA/CD:

(i)If a collision is detected during transmission of a packet, the node immediately ceases transmission and it transmits jamming signal for a brief duration to ensure that all stations know that collision has occurred.

(ii) After transmitting the jamming signal, the node waits for a random amount of time and then transmission is resumed.

The random delay ensures that the nodes, which were involved in the collision are not likely to have a collision at the time of retransmissions. To achieve stability in the back off scheme, a technique known as binary exponential back off is used. A node will attempt to transmit repeatedly in the face of repeated collisions, but after each collision, the mean value of the random delay is doubled. After 15 retries (excluding the original try), the unlucky packet is discarded and the node reports an error. A flowchart representing the binary exponential back off algorithm is given in Fig.

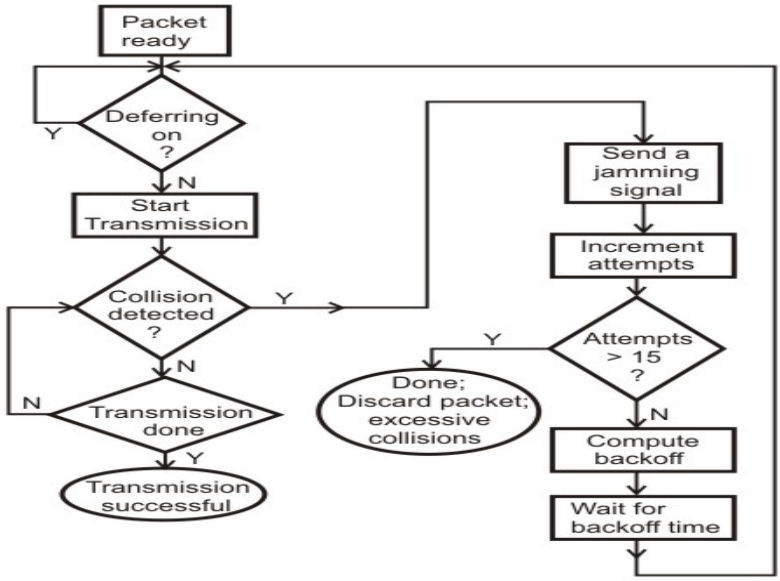


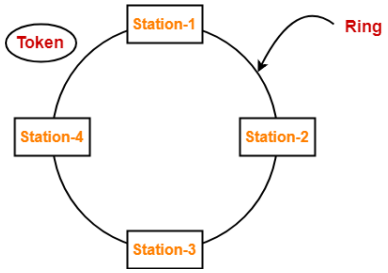
Figure .Binary exponential back off algorithm used in CSMA/CD

b) What is token passing? CO1 (BL1) 2M

A: Token Passing-

In this access control method,

- All the stations are logically connected to each other in the form of a ring.
- The access of stations to the transmission link is governed by a token.
- A station is allowed to transmit a data packet if and only if it possess the token otherwise not.
- Each station passes the token to its neighboring station either clockwise or anti-clockwise.



Assumptions-

Token passing method assumes-

- Each station in the ring has the data to send.
- Each station sends exactly one data packet after acquiring the token.

4. a) Discuss the functionality of bridges,Routers and gate ways.CO2 (BL2) 5M

A:

Bridges:A bridge connects two or more LANs, as shown in Fig. 4.b. When a frame arrives, software in the bridge extracts the destination address from the frame header and looks it up in a table to see where to send the frame. For Ethernet, this address is the 48- bit destination address .Like a hub, a modern bridge has line cards, usually for four or eight input lines of a certain type. A line card for Ethernet cannot handle, say, token ring frames, because it does not know where to find the destination address in the frame header. However, a bridge may have line cards for different network types and different speeds. With a bridge, each line is its own collision domain, in contrast to a hub.

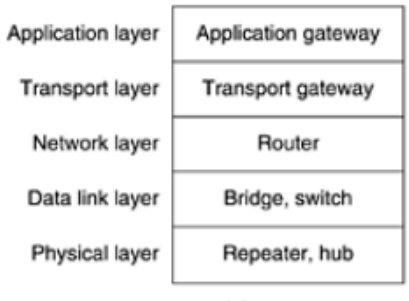


Fig a.

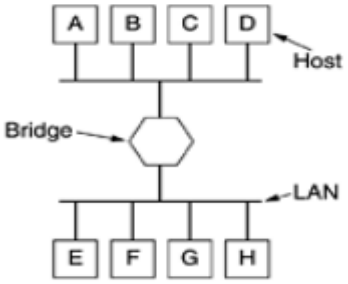


Fig b.

Routers: When a packet comes into a router, the frame header and trailer are stripped off and the packet located in the frame's payload field (shaded in Fig. 4-46) is passed to the routing software. This software uses the packet header to choose an output line. For an IP packet, the packet header will contain a 32-bit (IPv4) or 128-bit (IPv6) address, but not a 48-bit 802 address. The routing software does not see the frame addresses and does not even know whether the packet came in on a LAN or a point-to-point line.

Transport gateways:These connect two computers that use different connection-oriented transport protocols. For example, suppose a computer using the connection-oriented TCP/IP protocol needs to talk to a computer using the connection-oriented ATM transport protocol. The transport gateway can copy the packets from one connection to the other, reformatting them as need be.

Application gateways understand the format and contents of the data and translate messages from one format to another. An e-mail gateway could translate Internet messages into SMS messages for mobile phones, for example.

b) Describe the RS-485 serial communication concepts. CO2 (BL2) 5M

A: RS485 was able to provide high speed data communications. Although many other formats have taken over, it was widely used and was able to meet the needs for a number of applications where data needed to be transmitted at high speeds for the time. RS485 proved to be a robust standard and able to provide reliable data communications over extended distances

The EIA-485A standard is one of the most versatile of the EIA interface standards. It is an extension of EIA-422 and allows the same distance and data speed but increases the number of transmitters and receivers permitted on the line. EIA-485 permits a ‘multidrop’ network connection on 2 wires and allows reliable serial data communication for:

• Distances of up to 1200 m (4000 feet, same as EIA-422)

• Data rates of up to 10 Mbps (same as EIA-422)
• Up to 32 line drivers on the same line
• Up to 32 line receivers on the same line.

The maximum bit rate and maximum length can, however, not be achieved at the same time.

For 24 AWG twisted pair cable the maximum data rate at 4000 ft (1200 m) is approximately 90 kbps.

The maximum cable length at 10 Mbps is less than 20 ft (6 m).

Better performance will require a higher-grade cable and possibly the use of active (solid state) terminators in the place of the 120-ohm resistors.

According to the EIA-485 standard, there can be 32 ‘standard’ transceivers on the network If more transceivers are required, repeaters have to be used to extend the network.

The two conductors making up the bus are referred to as A in B in the specification.

The A conductor is alternatively known as A–, TxA and Tx+. The B conductor, in similar fashion, is called B+, TxB and Tx–.

. In the MARK or OFF state (i.e. when the EIA-232 TxD pin is LOW (e.g. minus 8 V), the voltage on the A wire is more negative than that on the B wire.

The differential voltages on the A and B outputs of the driver (transmitter) are similar (although not identical) to those for EIA-422, namely:

• –1.5 V to –6 V on the A terminal with respect to the B terminal for a binary 1 (MARK or OFF) state, and
• +1.5 V to +6 V on the A terminal with respect to the B terminal for a binary 0 (SPACE or ON state).

As with EIA-422, the line driver for the EIA-485 interface produces a ±5 V differential voltage on two wires.

The major enhancement of EIA-485 is that a line driver can operate in three states called tri-state operation:

• Logic 1
• Logic 0
• High-impedance

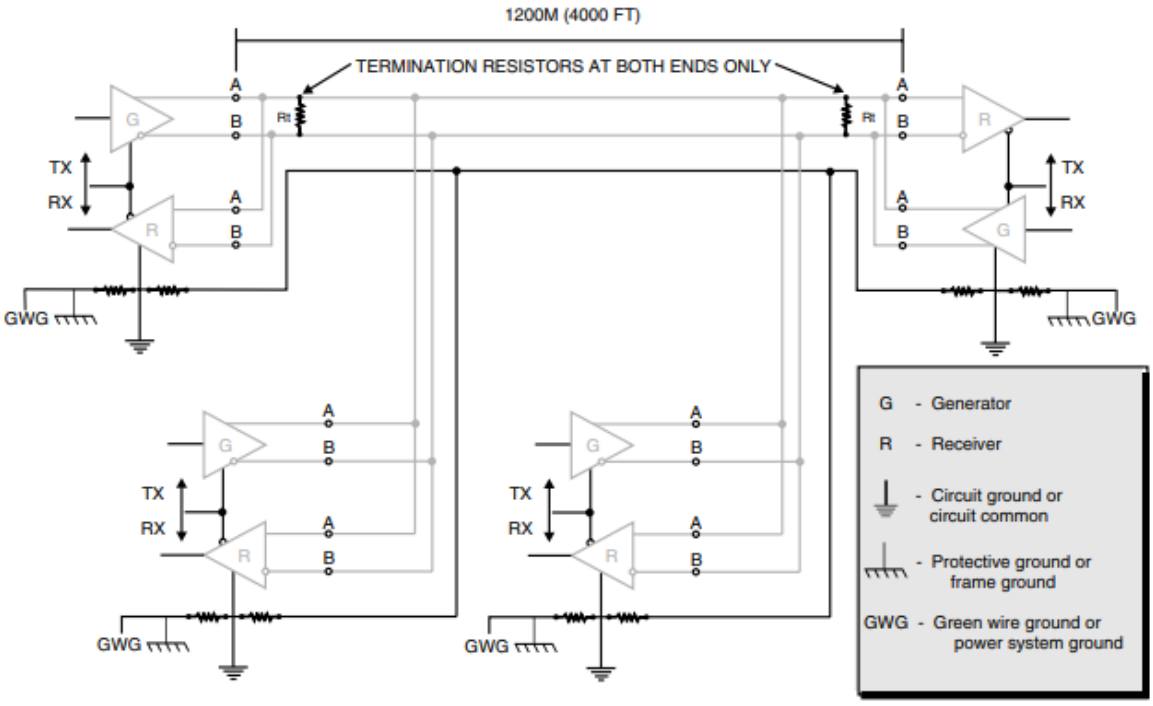
In the high-impedance state, the line driver draws virtually no current and appears not to be present on the line. This is known as the ‘disabled’ state and can be initiated by a signal on a control pin on the line driver integrated circuit. Tri-state operation allows a multidrop network connection and up to 32 transmitters can be connected on the same line, although only one can be active at any one time. Each terminal in a multidrop system must be allocated a unique address to avoid conflicting with other devices on the system. EIA-485 includes current limiting in cases where contention occurs.

The EIA-485 interface standard is very useful for systems where several instruments or controllers may be connected on the same line. Special care must be taken with the software to coordinate which devices on the network can become active. In most cases, a master terminal, such as a PC or computer, controls which transmitter/receiver will be active at a given time.

The two-wire data transmission line does not require special termination if the signal transmission time from one end of the line to the other end (at approximately 200 meters per microsecond) is significantly smaller than one quarter of the signal’s rise time. This is typical with short lines or low bit rates. At high bit rates or

in the case of long lines, proper termination becomes critical. The value of the terminating resistors (one at each end) should be equal to the characteristic impedance of the cable. This is typically 120 ohms for twisted pair wire.

Figure 4.1 shows a typical two-wire multidropnetwork.The transmission line is terminated on both ends of the line but not at drop points in the middle of the line.



Typical two-wire multidrop network

(OR)

5. a) Compare and contrast RS-232 and RS-485. CO2 (BL2) 4M

A: Any four points.

	RS-232	RS-485
Signalling Technique	Single-ended(Unbalanced)	Differential (Balanced)
Drivers and Receivers on Bus	1 Driver 1 Receiver	1 Driver 32 Receivers
Maximum Cable length	50feet	4000 feet
Original Standard Maximum Data Rate	20kbps	10Mbps down to 100kbps
Minimum Loaded Driver Output Voltage levels	+/- 5.0v	+/- 1.5v
Driver Load Impedance	3-7k	54k
Receiver Input Impedance	3-7k	=>12k

b) Discuss the functionality of anyone Routing protocol. CO2 (BL3) 6M

a: Shortest Path Routing: To choose a route between a givenpair of routers, the algorithm just finds the shortest path between them on the graph.

One way of measuring path length is the number of hops. Using this metric, the paths ABC and ABE in Fig. 5-b are equally long. Another metric is the geographic distance in kilometers, in which case ABC is clearly much longer than ABE (assuming the figure is drawn to scale). from A to D. The arrows indicate the working node.

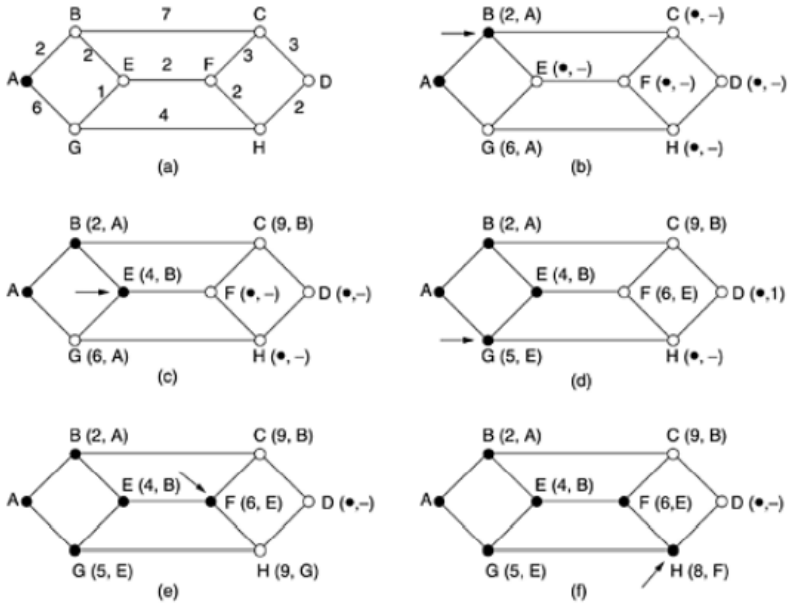


Figure 5-b. The first five steps used in computing the shortest path

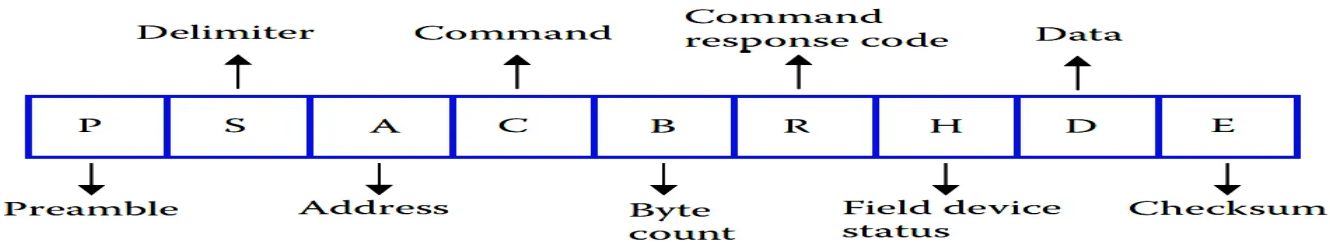
Unit - III

6. a) What are the two types of frame formats in HART Protocol? Discuss CO3 (BL2) 6M

A: The HART message frame format, often called a HART telegram, is shown in Below Figure. It consists of nine fields.

A:Preamble is the first field in the message that is sent first, and it wakes up and synchronizes all the receivers of the connected devices in the network. The delimiter, a single-byte field, signifies the end of the preamble. The delimiter is a start field and its content denotes if the frame is a request from a master, a response from a slave, or a request from a slave in the burst mode. It also indicates whether the address used

is a polling address or a unique ID.



The address field that follows may be a single byte (short-frame format) for polling address or 5 bytes (long-frame format) for a unique ID address.

The fourth field is the command field and is of single byte. It represents the HART command associated with the message. The data link layer does not interpret the same but passes (accepts) the same to (from) the application layer. The byte count is of single byte length and indicates how many more bytes are still left for

the message to be completed, excluding the checksum. The receiver can thus check for the end of the message from the information provided by this field.

The response code is also single byte and is included only in response messages. This response field from the slave would indicate the type of error that occurred in the received message, if it was received erroneously. Correct message reception would also be indicated by this field. The field device status, a single-byte field, is included in response messages to indicate the health of the device.

The data field may contain from 0 to 24 bytes. Data is not interpreted in the data link layer and is merely passed to the application layer. The checksum is of single byte and of longitudinal cyclic redundancy check type. If the data is received correctly, the transmitting end checksum value would be identical to the receiving end checksum.

b) What are the benefits of Fieldbus? CO3 (BL2) 4M

A:any four

a. Simultaneous analog and digital communications
b. Allows other analog devices on the highway
c. Allows multiple masters to control same smart instrument
d. Multiple smart devices on the same highway
e. Long distance communications over telephone lines
f. Two alternative transmission modes
g. Flexible messaging structure for new features
h. Up to 256 process variables in any smart field device

(OR)

7. a) How MODBUS works? Explain in detail. CO3 (BL2) 5M

Modbus is a simple, flexible, publicly published protocol, which allows devices to exchange discrete and analog data. End users are aware that specifying MODBUS as the required interface between subsystems is a way to achieve multi-vendor integration with the most purchasing options and at the lowest cost. Small equipment makers are also aware that they must offer MODBUS with EIA-232 and/or EIA-485 to sell their equipment to system integrators for use in larger projects.

Serial links with Modbus are inherently single-master designs. That means, only one device can talk to a group of slave devices – so only that one device (the master) is aware of all the current real-time data. Designers share this data with multiple operator workstations, control systems, database systems, customized process optimizing workstations and all the other potential users of the data by ending up with complex, fragile hierarchies of master/slave groups shuffling data, up the ladder. Apart from the complexity involved, lower levels of the hierarchy (even expensive DCS systems) waste valuable time shuffling data solely for the benefit of higher levels of the hierarchy.

Even with all these limitations, Modbus has the advantage of wide acceptance among instrument manufacturers and users with many systems in operation. It can therefore be regarded as a de facto industrial standard with proven capabilities.

Certain characteristics of the Modbus protocol are fixed, such as frame format, frame sequences, handling of communications errors and exception conditions and the functions performed. Other characteristics are selectable. These are transmission medium, transmission characteristics and transmission mode, viz. RTU or ASCII. The user characteristics are set at each device and cannot be changed when the system is running.

The two transmission modes in which data is exchanged are:

• ASCII – readable; used, for example, for testing. (ASCII format)

• RTU – compact and faster; used for normal operation. (Hexadecimal format)

The RTU mode (sometimes also referred to as Modbus-B for Modbus Binary) is the preferred Modbus mode.

The ASCII transmission mode (sometimes referred to as Modbus-A) has a typical message that is about twice the length of the equivalent RTU message.

Modbus also provides an error check for transmission and communication errors.

Communication errors are detected by character framing, a parity check, a redundancy check or a sixteen bit cyclic redundancy check (CRC-16).

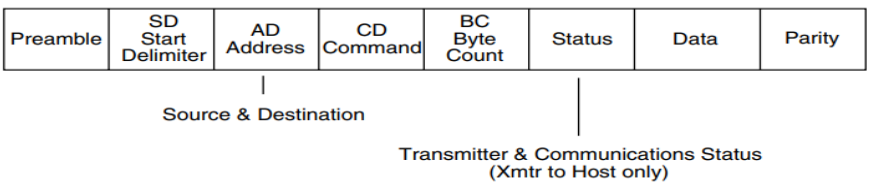
The latter varies depending on whether the RTU or ASCII transmission mode is being used. Modbus packets can also be sent over local area and wide area networks by encapsulating the Modbus data in a TCP/IP packet.

b) Explain in detail HART communication protocol. CO3 (BL2) 5M(2+3)

A: Data link layer The data link frame format is shown in Figure below.

Layer		Description	HART™
7	Application	Serves up formatted data	Hart Commands
6	Presentation	Translates Data	
5	Session	Controls Dialogue	
4	Transport	Ensures Message Integrity	
3	Network	Routes Information	
2	Data Link	Detects Errors	Protocol Rules
1	Physical	Connects Device	Bell 202

HART protocol implementation of OSI layer model



Two-dimensional error checking, including vertical and longitudinal parity checks, is implemented in each frame. Each character or frame of information has the following parameters:

• 1 start bit

• 8 data bits

• 1 odd parity bit

• 1 stop bit

Unit - IV

8. a) What is an Ethernet in the computer network? CO4 (BL2) 2M

A: During the mid-seventies, Xerox Corporation (Palo Alto) developed the Ethernet network concept, based on work done by researchers at the University of Hawaii. The University's ALOHA network was setup using radio broadcasts to connect sites on the islands. This was colloquially known as their 'Ethernet' since it used the 'ether' as the transmission medium and created a network between the sites. The philosophy was straightforward: Any station wanting to broadcast would do so immediately. The receiving station then had a responsibility to acknowledge the message, advising the original transmitting station of a successful reception of the original message.

b) Explain the concepts of 10 Mbps and 100 Mbps Ethernet standards. CO4 (BL3) 8M

a: 10 Mbps Ethernet (4+4)

The IEEE 802.3 standard (also known as ISO 8802.3) defines a range of media types that can be used for a network based on this standard such as coaxial cable, twisted pair cable and fiber optic cable. It supports various cable media and transmission rates at 10 Mbps, such as:

• 10Base2 – thin wire coaxial cable (6.3 mm/0.25 inch diameter), 10 Mbps baseband operation, bus topology.

• 10Base5 – thick wire coaxial cable (13 mm/0.5 inch diameter), 10 Mbps baseband operation, bus topology.

• 10BaseT – unscreened twisted pair cable (0.4 to 0.6 mm conductor diameter), 10 Mbps baseband operation, hub topology.

• 10BaseF – optical fiber cables, 10 Mbps, 10 Mbps baseband operation, point-to-point topology.

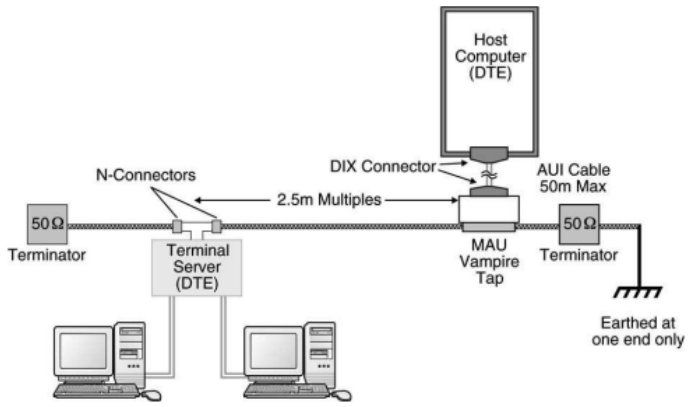


Figure 15.2
10Base5 Ethernet segment

100 Mbps Ethernet :

100BaseT is the shorthand identifier for all 100 Mbps Ethernet systems, including twisted pair copper and fiber versions. These include 100BaseTX, 100BaseFX, 100BaseT4 and 100BaseT2.

Later versions of ethernet (100BaseT and up) can also operate in full-duplex mode, in which case the CSMA/CD mechanism is switched off. Full-duplex means a node can transmit and receive simultaneously and whenever it wants, since there is no possibility of contention. Full-duplex operation is specified in 802.3x.

Fiber optic cable distances 100BaseFX

The following maximum cable distances apply:

• Node to hub: maximum distance of multimode cable (62.5/125) is 160 meters

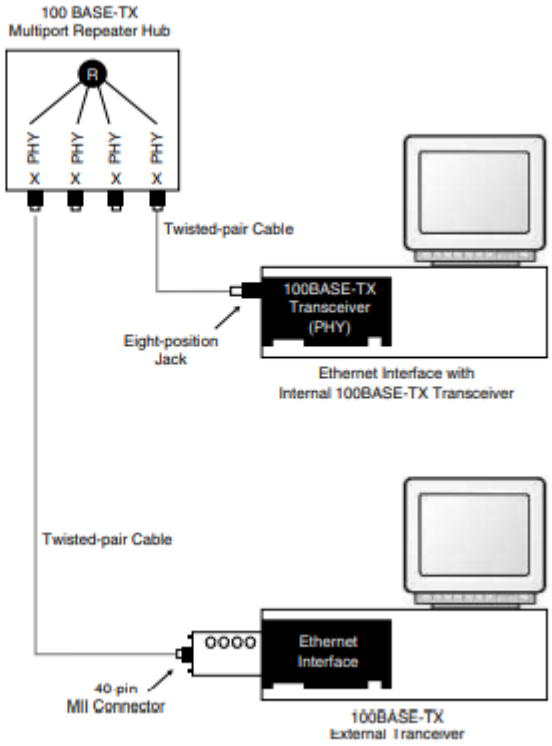
(for connections using a single class II repeater)

• Node to switch: maximum multimode cable distance is 210 meters

• Switch to switch: maximum distance of multimode cable for a backbone connection between two 100BaseFX switch ports is 412 meters

• Switch to switch full-duplex: maximum distance of multimode cable for a full-duplex connection between two 100BaseFX switch ports is 2000 meters

The IEEE has not included the use of single-mode fiber in the 802.3u standard.



(OR)

9. a) Explain different components of Radio link. CO4 (BL2) 6M(2+4)

A: Components of a radio link

A radio link consists of the following components:

• Antennas

• Transmitters

• Receivers

• Antenna support structures

• Cabling

• Interface equipment.

Figure 9.a illustrates how these elements are connected together to form a complete radio link.

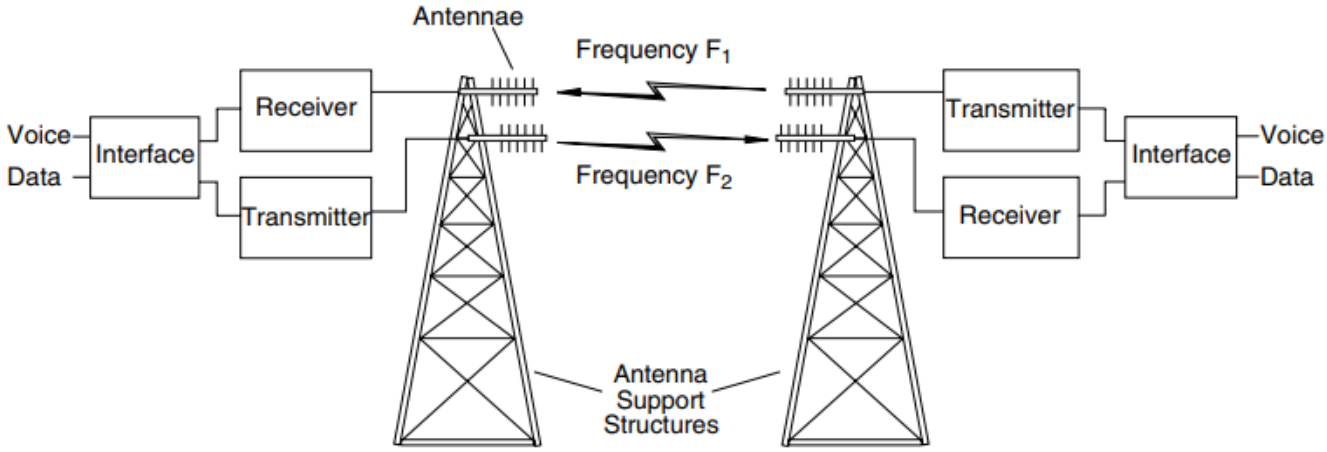


Figure 9.a.i. Fundamental elements of a radio link

Antenna

It is the device used to radiate or detect the electromagnetic waves. There are many different designs of antennas available. Each one radiates the signal (electromagnetic waves) in a different manner. The type of antenna used depends on the application and on the area of coverage required.

Transmitter

It is the device that converts the voice or data signal into a modified (modulated) higher frequency signal. Then it feeds the signal to the antenna where it is radiated into the free space as an electromagnetic wave at radio frequencies.

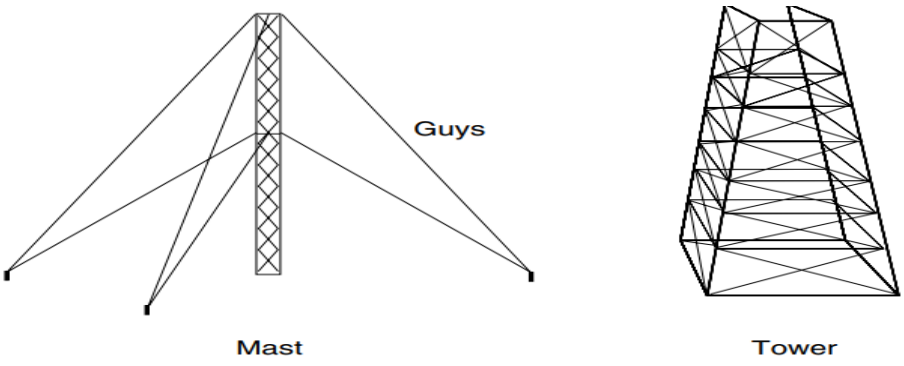
Receiver

It is the device that converts the radio frequency signals (fed to it from the antenna detecting the electromagnetic waves from free space) back into voice or data signals.

Antenna support structure

An antenna support structure is used to mount antennas, in order to provide a height advantage, which generally provides increased transmission distance and coverage. It may vary in construction from a three-meter wooden pole to 1000 m steel structure.

A structure, which has guy wires to support it, is generally referred to as a mast. A structure, which is free standing, is generally referred to as a tower.



Mast Tower 9.a.ii Figure Illustration of mast and tower

Cabling

There are three main types of cabling used in connecting radio systems:

• Coaxial cable for all radio frequency connections

• Twisted pair cables for voice, data and supervisory connections

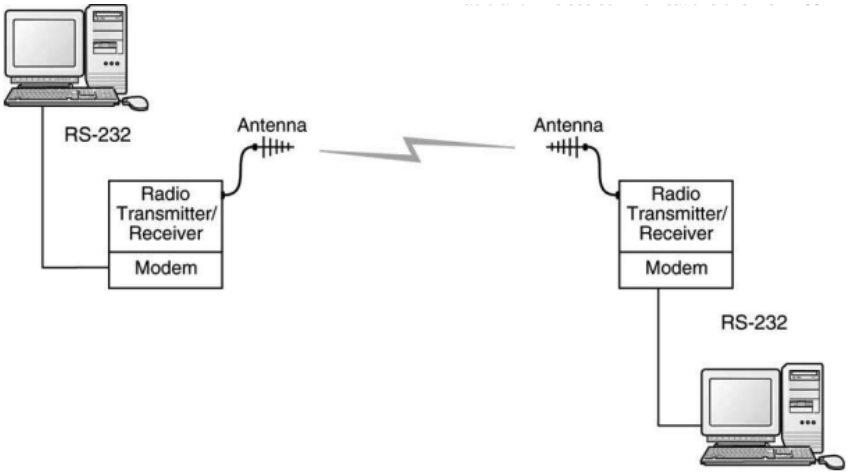
• Power cables.

Interface equipment

This allows connection of voice and data into the transmitters and receivers from external sources. It also controls the flow of information, timing of operation on the system and control and monitoring of the transmitter and receiver.

b) Briefly introduce radio MODEMs. CO4 (BL2) 4M(1+3)

A: Radio modems are suitable for replacing wire lines to remote sites or as a backup to wire or fiber optic circuits, and are designed to ensure that computers and PLCs, for example, can communicate transparently over a radio link without any specific modifications required.



Modern radio modems operate in the 400 to 900 MHz band. Propagation in this band requires a free line of sight between transmitting and receiving antennae for reliable communications. Radio modems can be operated in a network, but require a network management software system (protocols) to manage network access and error detection. Often, a master station with hot change-over, communicates with multiple radio field stations. The protocol for these applications can use a simple poll/response technique. The more sophisticated peer-to-peer network communications applications, require a protocol based on carrier sensing multiple access with collision detection (CSMA/CD). A variation on the standard approach is to use one of the radio modems as a network watchdog to periodically poll all the radio modems on the network and to check their integrity. The radio modem can also be used as a relay station to communicate with other systems, which are out of the range of the master station.

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