- The FDDI network topology consisted of stations which were logically connected into a ring. Dual rings were used and each was capable of supporting a data rate of 100 Mbit/s, as shown in Fig 11.16 (a).
- Network operation was normally designated to the **primary ring** (Fig 11.16(a)). If this ring was broken, then ***transmission was switched*** to the ***secondary ring***. The reconfiguration of stations around a cable break, as illustrated in Fig 11.16 (b), was controlled by the station management function.
- Station failure did not affect the network operation due to the provision of optical bypass switches within all the stations. This ensured that the optical path through a station was maintained in the event of a station fault, or power down

11.2 OPTICAL ETHERNET

- *Optical Ethernet is the fourth generation of the Ethernet family which uses IP-based technology.*
- *A **Gigabit Ethernet** (GbE) network was developed in 1998 by merging together two technologies such as IEEE 802.3 Ethernet and ANSI X3T11 fiber channel to enable it to operate at higher transmission rates (i.e. 100 Mbit/s to 10 Gbit/s) using optical fiber.*

(1) Connections

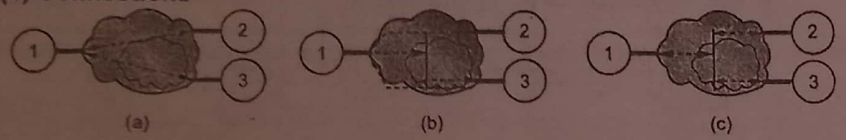

Fig 11.17 Different types of optical Ethernet connections (a) Point – to – point (b) Point – to – multipoint (c) Multipoint – to – multipoint

- Three different types of optical Ethernet connection are shown in Fig 11.17. In a ***point-to-point connection*** only a single network node is connected with another node.
- A point-to-multipoint connection which enables a single node interconnection with two or more network nodes. For example, node 1 can transmit to nodes 2 and 3 simultaneously while it can also receive transmissions from both these nodes.

- For node 2 or 3 can transmit simultaneously to other nodes only when using the multipoint-to-multipoint network connections as indicated in Fig11.17 (c).

(2) Frame Format

Preamble	Destination address	Source address	Type/length	Data	Frame check sequence

Fig 11.18 Ethernet frame format

- The basic Ethernet frame format is shown in Fig 11.18, which begins with a field called the ***Preamble*** *which informs receiving nodes that a frame is being transmitted, alerting them to start receiving the data.*
- ***Unique Destination*** and ***Source address*** fields defines the source and destination nodes. ***Type or length field*** is used *to identify the type or the length of other network protocols being carried in the data field.*
- The ***Data field*** ensures that actual data carried in the frame format. Finally, the *Frame Check Sequence (FCS)* field provides a checking procedure for the integrity of the data in the entire, that is ***error detection and correction code.***

(3) Ethernet Sublayers

- Figure 11.19 shows the Ethernet sublayers in the OSI reference model. The MAC and ***physical signaling*** below the LLC and ***MAC bridging sublayer*** are specific to an Ethernet LAN.

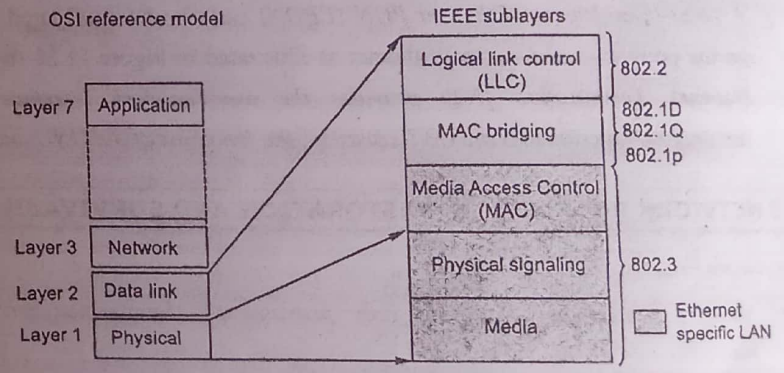

Fig 11.19 Ethernet sublayers as given by IEEE 802.3

(4) Access Network

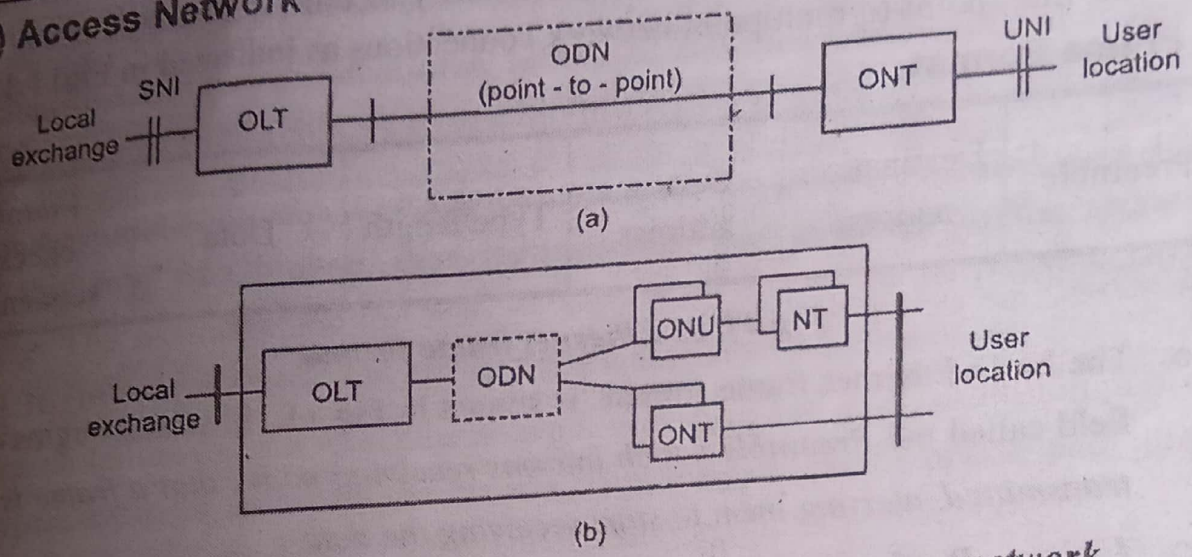

Fig 11.20 Optical Ethernet (a) Point – to – point access network (b) Point – to – multipoint access network (Ethernet PON)

- Figure 11.20 shows two configurations for an optical Ethernet network. A point-to-point optical Ethernet operating as an access network is shown in Fig 11.21 (a). *The **Optical Distribution Node (ODN)** provides point-to-point access on a bidirectional single-mode optical fiber.*
- The ***Service Network Interface (SNI)*** is connected to the ***Optical Line Termination (OLT)*** at the local exchange/office while the ***User Network Interface (UNI)*** is connected to the ***Optical Network Termination (ONT)*** at the user locations.
- A ***point-to-multipoint Ethernet PON (EPON)*** can also be configured based on the point to- point optical Ethernet as illustrated in Figure 11.21 (b). *The **Network Termination (NT)** provides the user network interface line termination function and the ONT combines the functions of the ONU and NT.*

11.3 NETWORK PROTECTION, RESTORATION AND SURVIVABILITY

Network Protection:

- *Network protection which not only provides the information when a breakdown in the network occurs but also offers the necessary protection to overcome the failure is an essential aspect of all network operations.*

- The major deployed optical fiber networks are in the area of the public telecommunications network together with on-site, or on-premises, local area networks.
- An example of a modern, complex optical network is illustrated in Fig 11.1(a) which shows a DWDM backbone incorporating add/drop channels together with a core ring feeding both metropolitan area and access networks together with enterprise and local area networks.
- Both the present and future deployment of optical networks are particularly in the constituent areas of the public telecommunications network and also in the crossover region to local area networks.

11.1.1 Long-haul Networks

Definition:

A long-haul network is a network connecting several regional or national networks together. These networks are also referred to as core or backbone networks and they also interconnect other long-haul networks to extend global interconnectivity between national domains.

- A current long-haul optical network typically comprises point-to-point DWDM links with optical regenerators at end points and with ***Erbium-Doped Fiber Amplifiers (EDFAs)*** that placed between the end terminals as shown in Fig 11.1(b).
- An ***optical 3R regenerator*** is often used at typically 600 km intervals ***to reduce overall signal degradation on the link.*** In order to ***achieve improved connectivity*** these point-to-point DWDM links can be interconnected using a ***mesh topology.***
- Using the above network structures, we can to interconnect optical networking nodes situated in different cities around the globe.
- Long-haul optical fiber networks are ***classified*** based on their *maximum achievable distance without optical signal regeneration* are,

(i) Long-haul optical networks from 600 to 1000 km,

(ii) Extended Long-Haul (ELH) from 1000 to 2000 km, and

(iii) Ultra Long-Haul (ULH) from 2000 to 4000km.

- ***Submerged*** or ***transoceanic optical fiber networks*** typically cover very long distances between the continents i.e. 3000 to 10 000 km range, where most of the optical fiber cable lies in deep sea water.
- In order to construct such long-length ultra-long-haul networks, both the *fiber* ***attenuation*** and ***dispersion*** are in ***minimum level.*** The submerged networks primarily use repeaters that only reamplify the signal.

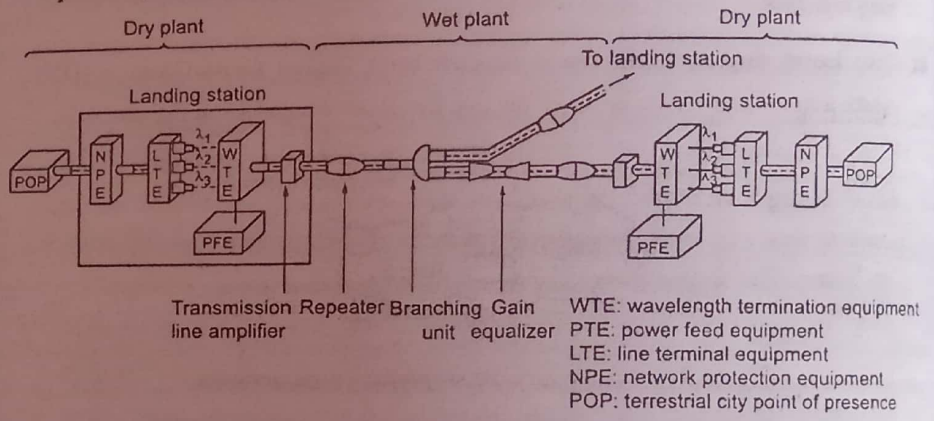

Fig 11.2 A submerged cable system

- The various elements that comprise a submerged cable system are shown in Fig 11.2. This system basically consists of two sections with dry plant residing on dry land i.e. ***landing section*** and wet plant in sea water i.e. *submerged* ***section.***
- The landing station houses the terminal equipment that interconnects the optical signal from the submerged cable and passes it on to a terrestrial system. The underwater cable includes ***repeaters, gain equalizers and branching elements*** to facilitate access to other landing stations.

Routing and Wavelength Assignment

Definition:

In Dense WDM (DWDM) networks a lightpath is established by reserving a particular wavelength on the physical links between the source and destination edge nodes.

*It is a two-stage search and select process related to both routing that is, searching/selecting a suitable path and wavelength assignment that is, searching/selecting or allocating an available wavelength for the connection. The overall process is often referred to as the **Routing and Wavelength Assignment (RWA)** or **RWA problem**.*

- The implementation of RWA can be ***static*** or ***dynamic*** depending upon the ***traffic patterns*** in the network.

Static RWA:

- ***Static RWA techniques** are employed to provide a set of semipermanent connections, which remain active for a relatively longer time.*
- The ***traffic patterns*** in this case are reasonably ***well known in advance*** and the variation in traffic pattern is not frequent. Therefore it is useful to optimize the network resources that is, ***physical links*** and ***wavelengths*** will be assigned to each connection. The static RWA problem is often referred to as the ***virtual topology design problem.***

Dynamic RWA:

- *Dynamic RWA deals with **establishing the lightpath in frequently varying traffic patterns**. In this case the **traffic patterns are not known** and therefore the connection requests are initiated in a random fashion, depending on the network state at the time of a request.*
- The resources may (or) may not be sufficient to establish a lightpath between the corresponding source and destination edge node pair. The network state provides

information about the physical path that is, *route* and wavelength assignment for all active lightpaths.

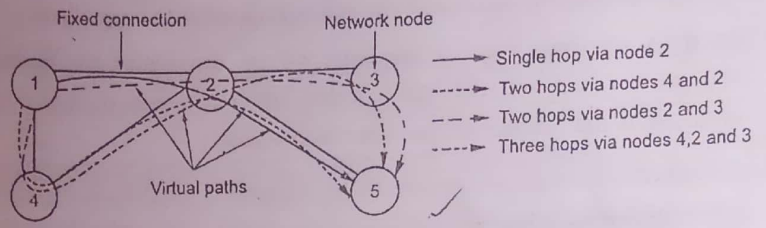

Fig 10.14 Wavelength routing and the selection of a path

- A five-node network with fixed connections where node 1 requested to establish a link with node 5 is illustrated in Figure 10.14, but there is ***no direct physical connection (or) path available***, there are ***four possibilities*** to establish the link between nodes 1 and 5 which depends on the available or assigned wavelengths between each of the network nodes.

  (i) By via node 2 using a single hop,

  (ii) By using nodes 4 and 2 that comprising two hops,

  (iii) By using nodes 2 and 3 with two hops, and

  (iv) The longest possible route stretching over three hops via nodes 4,2,3.

- Considering above four routes, the single hop remains the shortest path between nodes 1 and 5. Depending upon whether the same wavelength is available between selected network nodes, the lightpath can be set up or, alternatively, wavelength conversion will need to be employed by changing it to a compliant wavelength.
- The second shortest path will be selected if wavelength conversion can be facilitated. In the case, when there are no wavelength channels available, then no link can be set up between the desired nodes.

- An unavailability of a network link between two nodes leads to blocking of the channel. The probability of blocking increases if there are many network nodes with a small number of wave'ength channels and fewer links between them.
- An ***RWA algorithm*** plays an important role in determining the blocking probability of a network while also providing information about the availability of the path or link between the source and the destination.
- An example of wavelength assignment for a ring network given in Fig 10.15, where the ring topology consists of four nodes, namely *a, b, c* and *d*. There exist four possibilities for establishing lightpaths between the network nodes as indicated by the ***two inner*** and the ***two outer half circles***.

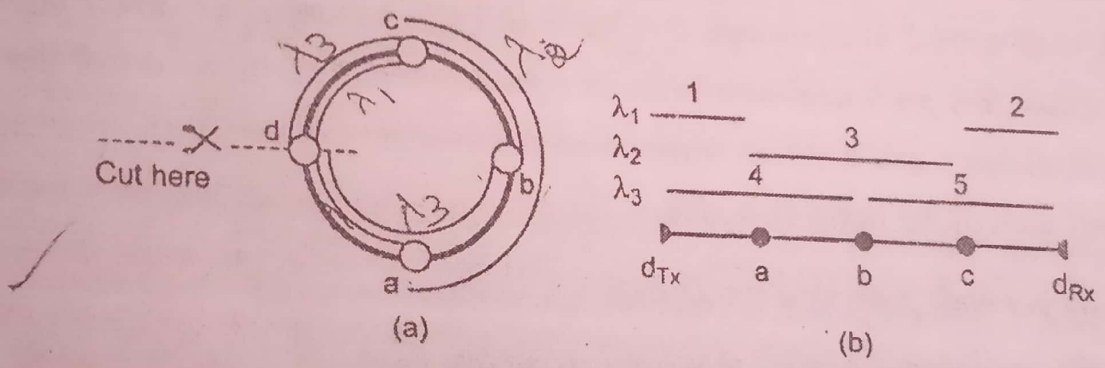

Fig 10.15 Wavelength assignment in a ring network topology (a) Light path arrangement for four network nodes (b) Wavelength assignments

- Four individual wavelengths that is, *one wavelength per half circle* may be required, when ***wavelength reuse*** is introduced ***three wavelengths*** are sufficient to provide similar connectivity, which is shown in Fig 10.15(b). A total number of five lightpaths *(i.e. links)* using only three wavelengths .i.e. λ_1, λ_2 and λ_3.

10.3 OPTICAL SWITCHING NETWORKS

- *An optical switch represents the **single most dynamic element** in an optical network which traditionally can switch data between different ports of a network.*

The electronic switching and optical switching can be broadly classified as,

(i) Circuit switching, and

(ii) Packet switching.

(iii) Ultra Long-Haul (ULH) from 2000 to 4000km.

3. ***Define MAN.***

Metropolitan Area Networks (MANs) or metro networks provide the regional interface that interconnecting the access network end users *i.e.* business or residential customers with the long-haul networks.

4. ***What is meant by access network?***

The access network is an element of a public telecommunications network that connects access nodes to either individual users (i.e. business, residential) or MANs. It can be considered as the last link in a network between the customer's premises and the first point of connection to the network infrastructure (i.e. local exchange/switching center or local office).

In case of a link failure there should be efficient and immediate solutions to recover from such faults to enable the network to both sustain and maintain customer service.

15. ***What is survivability?***

Survivability is the ability of a network to withstand and recover from network failures. It determines the capability to provide continuous service in the presence of network failures. The basic function is to restore and provide protection in case of an optical network component failure.

16. ***Name the classifications of network protection***

Network protection mechanisms are can be divided into two categories:

(i) Path protection, and

(ii) Link-oriented protections.

17. ***Define restoration.***

Restoration or provisioning to provide network protection enables the network to restore and establish new connections replacing the faulty link by establishing a new path or the link. Restoration offers increased flexibility over more rigid preconfigured protection.

1.5 REVIEW QUESTIONS

Explain in detail about long-haul networks.

data remains entirely in the optical domain that is, without optoelectrical conversion until it reaches its destination.

31. Define multi-hop network.

In a multi-hop network a transmission may take place through intermediate nodes before reaching its destination. At each intermediate node the data can be switched electronically to the next possible node and it is then retransmitted as an optical signal.

32. Compare Single-hop and Multi-hop Networks.

SINGLE HOP	MULTI HOP
There is no electro optical conversion between transmitter and receiver.	There is an electro optical conversion takes place between transmitter and receiver.
Nodes are directly connected.	There is no direct connection between Nodes.

33. What is meant by public telecommunications network?

The telecommunications network providing services in the public domain is known as the public telecommunications network where the service providers (or carriers) offer a variety of services for the provision of voice, data and video transmission.

6. ***Obtain the transmission bit rate of the basic SONET frame in Mbps.***

[NOV/DEC-2013]

One frame = 810 bytes = 810 × 8 bits = 6,480 bits

Within one second, 8000 frames will be transmitted. Hence, the total data rate of STS – 1 SONET frame is given as,

= 6,480 × 8,000 = 51,840,000 bits or 51,840 Mbps.

7. ***Write the applications of SONET/SDH.***

The main applications of SONET/SDH are,

(i) High speed backbone networks

(ii) Basic architecture for B- ISDN

(iii) Basic architecture for ATM

(iv) High speed optical network for data communication.

8. ***Distinguish between SONET and SDH.*** *[APR/MAY-2012,NOV/DEC-2015]*

SONET	SDH
Synchronous Optical Networking.	Synchronous Digital Hierarchy.
SONET standards are employed in North	SDH standards are employed in Europe or Japan.