MODULE 5

CHAPTER 5

Packet Switching and Access Networks

Syllabus

5.1 OTDM, multiplexing and de-multiplexing, synchronization and broadcast OTDM networks.

5.2 Network architecture overview, optical access networks. FTTH Network.

5.3 Optical Burst switching Networks.

5.1 OPTICAL TIME DOMAIN MULTIPLEXING (OTDM)

UQ. Explain OTDM in detail. **MU – Q. 6(a), Dec. 15, Q. 5(a), May 17, Q. 6(b), Dec. 17, 10 Marks, Q. 6(e), May 18, 5 Marks**

- There are two type of multiplexing Electrical multiplexing and Optical Multiplexing. Basic difference between Electrical multiplexing and Optical multiplexing. Usually the Time Division Multiplexing (TDM) is performed in electrical domain. If TDM is used in optical domain; then it becomes difficult to attain high bit rates.
- Optical Time Division Multiplexing (OTDM) is identical to the normal Time Division Multiplexing (TDM); but in OTDM the multiplexing and demultiplexing operations are performed at high speed. Thus at the input side of optical network, lower speed data is optically multiplexed into higher speed data and at the output side, the higher speed data is optically demultiplexed into lower speed data.
- A strategy for increasing the bit rate of digital optical fiber systems beyond the bandwidth capabilities of the drive electronics is known as optical time division multiplexing (OTDM). OTDM can provide users with better throughput delay performance, faster single-channel access times for high-data-rate end users.
- Generally two options are used in OTDM namely bit interleaving and packet interleaving. In both interleaving techniques, framing pulses are used. In case of bit interleaving suppose 'n' input data streams are to be multiplexed then a framing pulse is used after every n bits. In case of packet interleaving techniques; framing pulse is used to separate out different packets.
- In order to have some tolerance in multiplexing and demultiplexing operations; some guard time is provided between successive pulses.

Principle

- The principle of this technique is to extend ETDM by optically combining a number of lower speed electronic baseband digital channels.
- The optical multiplexing and de-multiplexing ratio is 1: 4, with a baseband channel rate of 40 Gbit/s. Hence the system can be referred to as a four-channel OTDM system.

Features

(1) Single wavelength (2) High bit rate (up to 640Gb/s)

(3) Immature technology (4) Chromatic dispersion & timing jitter

A block schematic of an OTDM system which has demonstrated 160 Gbit /s transmission over 100 km is shown in Fig. 5.1.1.

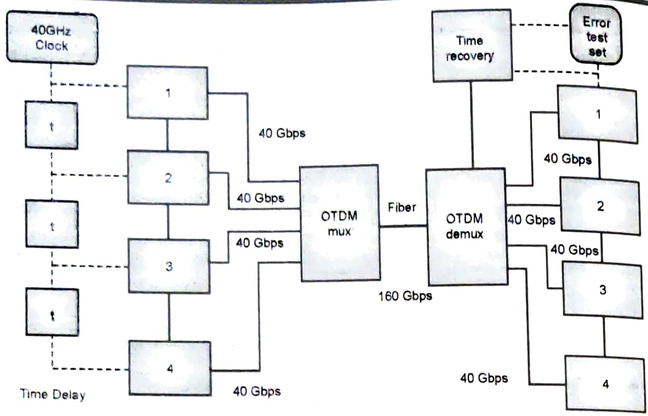

Fig. 5.1.1 : Block schematic of an OTDM system

Working

- The four optical transmitters are driven by a common 40 GHz clock using quarter bit period time delays. Mode-locked semiconductor laser sources which produced short optical pulses were utilized at the transmitters to provide low duty cycle pulse streams for subsequent time multiplexing
- Data was encoded onto these pulse streams using integrated optical intensity modulators which gave return-to-zero transmitter outputs at 40 Gbit/s.
- These IO devices were employed to eliminate the laser chirp which would result in dispersion of the transmitted pulses as they propagated within the single-mode fiber, thus limiting the achievable transmission distance.
- The four 40 Gbit /s data signals were combined using an OTDM multiplexer. Although four optical sources were employed, they all emitted at the same optical wavelength. The 40 Gbit /s data streams were bit interleaved to produce the 160 Gbit/s signal.
- At the receive terminal the incoming signal was decomposed into the 40 Gbit/s baseband components in a de-multiplexer. Hence single-wavelength 160 Gbit/s optical transmission was obtained with electronics which only required a maximum bandwidth of about 40 GHz as return-to-zero pulses were employed.
- The transmitter and receiver employed electro absorption modulators to provide for operation at the high transmission rate and furthermore negative dispersion fibers were also incorporated to compensate for the positive dispersion of the standard single-mode fiber (SSMF).
- Moreover, a field trial employing such transmitters and receivers at a transmission rate of 160 Gbit /s over deployed SSMF has been successfully carried out.

Advantages

(1) The user gets full bandwidth of the channel in a particular time slot

(2) For busty signals such as voice TDM gives maximum utilization of the channel

(3) Most suitable technique for digital transmission

Disadvantages

(1) It is not much suitable for continues signal.

(2) Extra guard is necessary.

(3) Synchronization is necessary.

5.2 TYPES OF OTDM MULTIPLEXING TECHNIQUES

UQ. What is the concept of bit interleaving and packet interleaving ?

UQ. What do you mean by bit interleaving and packet interleaving?

UQ. Explain in Bit interleaving and packet interleaving techniques used in OTDM.

MU - Q. 1(b), May 16, 5 Marks

MU - Q. 3(b), Dec. 16, 7 Marks

MU - Q. 5(a), Dec. 18, Q. 5(a), May 19, 10 Marks

There two way to multiplexed OTDM signal.

(1) Bit Interleaving (bit by bit) (2) Packet interleaving (Packet by Packet)

5.2.1 Bit Interleaving (bit by bit)

MU - Dec. 2015, May 2016, Dec. 2016

In this case, the optical signals corresponding to the data stream are interleaved in time. Then a single stream is generated and it is transmitted through optical cable.

Multiplexing

- The block diagram of point to point multiplexing and demultiplexing is shown in Fig. 5.2.1. A mode locked laser source is used to generate the periodic optical pulse train. Due to the pulse broadening there may be the effect of chromatic dispersion ; to avoid this usually Return to Zero (RZ) pulses are used.
- Let the repetition rate of these pulse is B and this rate can be in the range 2.5 to 40 Gb/sec. Optical splitter is used to generate 'N' separate streams from this data stream. Each of these channels is modulated externally at the bit rate B.
- Then output of each channel is delayed by different amount. This delay is obtained by passing individual data stream through a particular length of optical cable. Usually the velocity of light is silica fiber is 2×10^8 m/sec. Thus if optical data stream is passed through silica cable of 1 meter length; then it products a delay of 5 nsec.
- Likewise using different lengths fiber cables; different amount of delay can be produced. Undelayed pulse train is used as framing pulse. The outputs of electrical modulators and framing pulse stream are combined to generate bit interleaved multiplexed signal.
- If 'N' data streams are multiplexed then the bit rate of multiplexed signal will be N·B. To make the demultiplexing process easy, the power level of framing pulse is kept high.

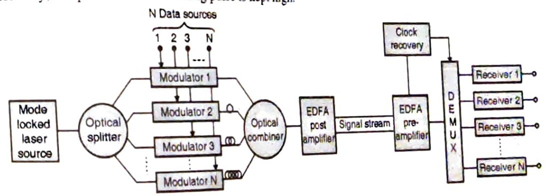

Fig. 5.2.1 : Block diagram of point to point multiplexing and demultiplexing

Demultiplexing

- In order to overcome the losses due to attenuation and scattering; preamplifier and post amplifier is used. The demultiplexer is used to separate out N data streams from the combined multiplexed data stream.
- To drive and synchronize the demultiplexer; a clock recovery circuit operating at bit rate B is used. In order to extract the framing pulse; thresholding operation is performed. To make this operation easy, initially at the multiplexing stage, high power level was assigned to framing pulse.

5.2.2 Packet Interleaving (Packet by Packet)

MU - Dec. 2015, May 2016, Dec. 2016

If the data is in the form of packets then packet interleaving multiplexing technique is used. Usually the size of each packet is fixed; so it becomes simple to identify the boundary of each packet.

Multiplexing

- Similar to bit interleaving ; a laser source generates periodic bit stream and it is modulated using external modulator.
- If the bit interval is 'T' then the gap between successive bits is also 'T'. But in packet interleaving, this gap is reduced to τ, which represents the higher multiplexing rate. This is achieved using number of compression stages as shown as Fig. 5.2.2.

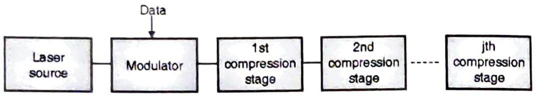

Fig. 5.2.2 : Number of Compression stages

- Each compression stage produces different amount of delay. This j^{th} compression stage produces a delay of 2^{j-1} $(T - \tau)$. The first compression stage produces a delay by $T - \tau$, second compression stage produces a delay of $2(T - \tau)$ and so on.
- A compression stage consists of 3 dB couplers at its input and output sides, two semiconductor optical amplifiers to act as ON-OFF switches and delay lines, as shown in Fig. 5.2.3.

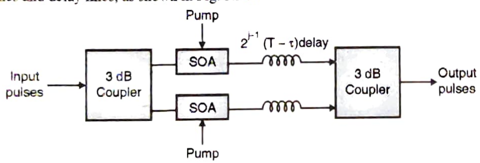

Fig. 5.2.3 : Compression Stage

Demultiplexing

- In the multiplexing stage, compressed packets are generated. Thus to perform demultiplexing; the data is transmitted through the number of decompression stages.
- The number of required decompression stages are, K = log (l) where 'l' represents the length of packet in terms of bits.

5.3 SYNCHRONIZATION

- The synchronization means alignment of two optical pulses. In case of packet interleaving; framing pulses are used to separate out two successive packets. That means the framing pulses are used to represent the packet boundaries. In this case the period of framing pulses must be same.
- Consider two periodic pulse streams as shown in Fig. 5.3.1.

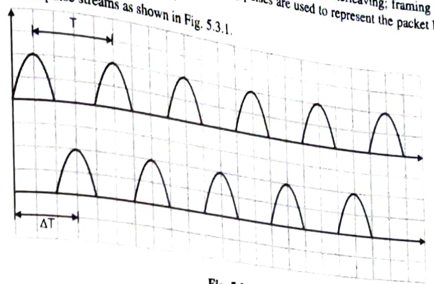

Fig. 5.3.1

- These two pulse streams are not synchronized because the second pulse stream is starting late by amount ΔT. That means the second pulse stream is delayed by an amount ΔT compared to first pulse stream.
- The synchronization means, there should not be any time delay if we compare two optical streams. These two optical streams can be synchronized if we delay the first pulse stream by the same amount ΔT. In this case, there will not be any time gap between two optical pulse streams and these streams are said to be synchronized.
- The delay of amount ΔT can be provided to the first pulse stream by passing this pulse stream through a fixed length of optical cable. By calculating the required amount 'ΔT'; we can decide the length of optical cable.
- But this technique of synchronization is applicable if we know the delay amount (ΔT) in advance. Practically this delay amount may change; in such cases, optical cables of fixed length cannot be used. In order to obtain adjustable delay; tunable delay elements are used.

5.3.1 Tunable Delays

- Tunable delay consists of number of stages and each stage produces fixed amount of delay to incoming optical stream. Typically there are "K – 1" number of stages, connected by 2 × 2 optical switches as shown in Fig. 5.3.2.
- The delay amount is $\frac{T}{2^{K-1}}$, thus the number of stages produce delay in the range $\frac{T}{2}, \frac{T}{4}, \frac{T}{8} \dots \frac{T}{2^{K-1}}$. Each stage produces a fixed amount of delay. But all these stages are connected using optical switches.
- If the switch is closed, then only a particular delay is introduced and if the switch is open then that particular delay amount is not added. $C_1, C_2, \dots C_K$ indicates control signals applied to optical switches.

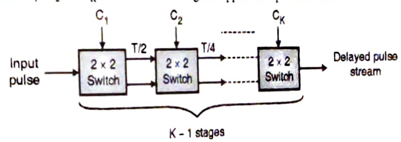

Fig. 5.3.2

5.4 NETWORK ARCHITECTURE OVERVIEW (BROADCAST NETWORKS)

- The general architecture of access network is shown in Fig. 5.4.1.

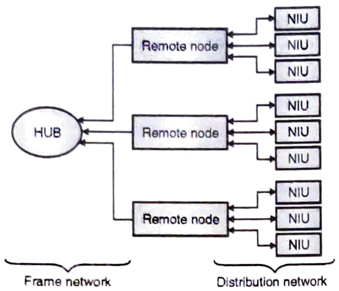

Fig. 5.4.1

- Basically access network consists of frame network and distributed network. The major elements of access network are hub, Remote Node (RN) and Network Interface Units (NIUs). The common examples, where access network is used, are telephone company and cable company.
- In case of telephone exchange, hub is a central office and in case of cable company it is head end. Every hub is connected to many Remote Nodes (RNs) and then different Network Interface Units (NIUs) are connected to RNs.
- The network connecting hub and RNs is called as frame network and the network connecting RNs and NIUs is called as distribution network.
- In case of telephone exchange NIUs are located at subscribers location. The communication between hub and NIUs takes place through RNs. The distribution network is of two types namely broadcast network and switched network.
- A common example of broadcast networking is cable television and a common example of switched networking is telephone network. In broadcast network, RNs accepts the data from hub and it broadcasts the data to all NIUs.
- Broadcast network is cheaper and all NIUs are identical. In case of switched networks; RN distributes the different data to all NIUs. So, data security is provided. It is easier to find the fault location in switched network, compared to broadcast networks.
- According to the type of feeder network; that means according to the type of connection between hub and RNs, access networks are classified into two types as follows :
  - (i) The feeder network assigns a specific frequency band for each NIU and each NIO operates using different frequency range. Due to a dedicated bandwidth; a certain quality of service is assured for each NIV.
  - (ii) The total available bandwidth is shared by all NIUs. That means, the feeder network assigns entire available bandwidth for each NIU on the time division multiplexing basis.
- But the drawback of sharing entire bandwidth is that, each NIU contains optical components that are capable of supporting entire bandwidth. The telephone network provides a dedicated bandwidth to each user and cable network allows all users to share a common available bandwidth.

5.4.1 Telephone Access Network

- It is a switched network which provides a separate frequency band for each NIU. It consists of a twisted pair copper cable. Due to the twisting of two wires, crosstalk is reduced. Individual twisted pairs are connected between the central office and individual user as shown in Fig. 5.4.2.
- Each NIU operates on its dedicated bandwidth of 4 kHz and it makes use of switching network.

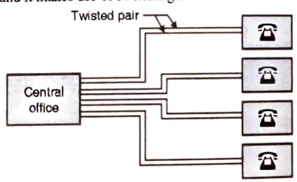

Fig. 5.4.2

5.4.2 Cable Network

- It is a broadcase network and each user share a total available bandwidth. It is also called as hybrid fiber co-axial network. As shown in Fig. 5.4.3; the head end and remote nodes are connected using optical fiber.

- The head end is similar to the central office of telephone network and it broadcasts the signal to Remote Nodes (RNs) through optical cable. Then from remote nodes; the signals are transmitted to individual home television, through co-axial cable.
- Usually the cable bandwidth is in the range 50 MHz to 550 MHz and each remote node serves between 500 homes.
- It is an example of unidirectional communication and the switching is not provided. Thus it requires simple management compared to the telephone access network.

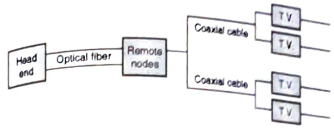

Fig. 5.4.3

5.5 OPTICAL ACCESS NETWORK

UQ. Explain optical access networks.
MU - Q. 6(b), Dec. 15, 10 Marks

UQ. Comment on optical assess networks.
MU - Q. 5(b), May 16, 5 Marks

UQ. Write short note on : Optical access network.
MU - Q. 6(iii), Dec. 16, Q. 6(d), May 18, 5 Marks, Q. 6(c), Dec. 17, 10 Marks

- The classification of optical access network is dependent on the type of their distribution network, that means whether it is broadcast or switched. Depending upon the feeder network, optical access networks are classified as dedicated bandwidth or shared bandwidth networks.
- We have already discussed the telephone and cable networks in the previous section. Now-a-day some other techniques are also used to improve the performance of optical access network. The Integrated Services Digital Network (ISDN) gives the bandwidth of 144 kb/sec using same twisted pair network.
- In order to provide more bandwidth than ISDN; another technique called as Digital Subscriber Line (DSL) can be used for existing twisted pair network. It provides the bandwidth which is sufficient to transmit the compressed video signal.
- For this technique, it is required to have DSL modem, both at the central office as well as at the home.
- **The major drawback of DSL technique is that, the bandwidth in inversely proportional to the distance.**
- Geostationary satellite is another options to provide broadcast networking services. Geostationary satellite provides more bandwidth and it can handle large number of channels. Since a single satellite has to cover a wide area; it is difficult to handle the spatial reuse of bandwidth. Wireless access network is another better option but it is applicable for limited range. As well as it bandwidth is limited.
- ***Two common wireless access networks are as follows :***
  - (i) Muluchannel Multipoint Distribution Services (MMDS)
  - (ii) Local Multipoint Distribution Services (LMDS)
- MMDS provides a bandwidth of 2 to 3 GHz and it can provide total 33 channels of 6 MHz each.
- LMDS provides a bandwidth of 1.3 GHz and it is more suitable of short range distances, typically 3 km to 5 km.

5.6 FUTURE ACCESS NETWORKS

MU - Dec. 2015

For the next generation access network; two common types of architectures are available. These are as follows :

1. Hybrid Fiber Co-axial (HFC) architecture
2. Fiber To The Crub (FTTC) architecture.

5.6.1 Hybrid Fiber Co-axial (HFC) Architecture

MU - Dec. 2015

- This network architecture is same as that of hybrid fiber co-axial cable network. It is basically a broadcast network and both optical cable and co-axial cable carries multiple subcarrier modulated data; this architecture is also called as Subcarrier Modulated Fiber Coaxial Bus (SMFCB).
- In conventional HFC, the frequency range is 500 MHz but in case of enhanced HFC, it is increased upto 1 GHz. Quadrature amplitude modulation technique is used, it provides the spectral efficiency of 8 bits/Hz. The overall capacity of system can be increased by using multiple fibers and multiple wavelengths.
- In recent systems a high power 1.55 μm transmitters are used along with booster amplifiers. It produces a high split ratio. A narrowcasting mode can be implemented, that means the signals can be transmitted to selected users instead of all users. Thus additional bandwidth can be provided to these selected users.

Basically Network Interfacing Units (NIUs) are used to serve many homes.

- The different co-axial cables are connected from Remote Nodes (RNs) to NIUs. The function of NIU is to separate out the telephone signals and video signals. All telephone signals are send to number of users through twisted pair and video signals are broadcasted on co-axial cables. Individual co-axial cable can provide connection to 50 – 500 homes.
- The broadcast video signals are sent on analog subcarrier channels. Using the same infrastructure, digital videos and data services can be transmitted.
- By using cable modems at head end and at homes, internet access services can be provided. Since HFC network is basically a broadcasting network; the peak data rate is shared among all users.
- Enhanced HFC is compatible with existing analog equipments but it has limited upstream bandwidth and limited reliability.

5.6.2 Fiber To The Crub (FTTC) Architecture

MU - Dec. 2015

- In this case, the data is transmitted digitally from the Central Office (CO) to the fiber terminating nodes. The fiber terminating nodes are called as Optical Network Units (ONUs). Here the signals are broadcast from central office to ONUs. The ONUs share a common total bandwidth using time division multiplexing.
- Depending on the connection of fibers; different terms are used to describe the FTTC architecture. These are as follows :

(i) Fiber To The Home (FTTH)
(ii) Fiber To The Building (FTTB)
(iii) Fiber To The Cabinet ($FTTC_{ab}$)

- All these different types of structures are shown in Fig. 5.6.1.

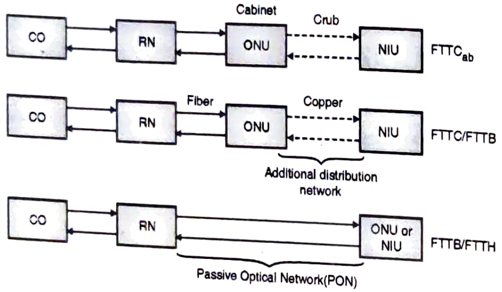

Fig. 5.6.1

(i) **FTTH :** In this case connection to every home is using optical fibers. The Optical Network Units (ONUs) perform the job of Network Interfacing Units (NIUs).

(ii) **FTTB :** In this case the fiber connection is upto the building or a group of 8 to 64 homes. Here an additional distribution network is required from ONU to NIU.

(iii) **$FTTC_{ab}$:** As the name indicates; optical fiber is terminated into the cabinet. Usually the fiber cable is within 1 km range from individual home. Basically in case of FTTC architecture; the Remote Nodes (RNs) are placed in the Central Office (CO) and not in the field. The network from CO to ONU is Passive Optical Network (PON).

5.7 PASSIVE OPTICAL NETWORK (PON)

UQ. Explain in brief different types of PON (Passive Optical network) architecture.

MU - Q. 5(b), Dec. 18, Q. 5(b), May 19, 10 Marks

- The different structure are available to realize the optical access network. Usually passive architectures are preferred over active architectures because in passive architecture, the network does not contain any switching and controlling of network is not required. In passive architecture, the passive components are used for example an optical star coupler is used as remote node.
- The optical path which consists of passive components like fibers, couplers and connectors, is called as **Optical Distribution Network (ODN).**
- For $FTTC_{ab}$, ONU (Optical Network Unit) is located at the crub and for FTTH or FTTB, ONU is located at the end user location. This provides broadband voice, data and video services.

5.7.1 PON Architectures

The various PON architectures are as follows :

1. All fiber PON	2. TPON	3. WPON	4. WRPON

1. All fiber PON

- It is the simplest PON architecture as shown in Fig. 5.7.1.
- Here each ONU is connected to the Central Office (CO) using pair of optical fibers.
- Practically the fibers are arranged in the form of ring.
- A pair of fiber is used for bidirectional communication.

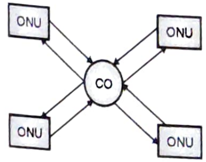

Fig. 5.7.1

- We can use a single optical cable between CO and ONU; but for bidirectional communication same wavelength cannot be used.
- For upward and downward communication; a separate wavelength is to be used. But if we use single wavelength then using time division multiplexing approach; bidirection communication can be achieved.
- Use of a separate optical fiber cable for each ONU, increases the total cost of system. Instead of this, a single pair of fiber can be shared by many users for example SONET or SDH ring.

2. TPON

- TPON stands for PON used for telephony. This architecture is shown in Fig. 5.7.2. A laser transmitter used in CO, broadcasts the downstream traffic to all ONUs using a passive star coupler. For upstream traffic, all ONUs use a single channel using time division multiplexing approach.
- The upstream and downstream signals are transmitted through a single optical cable, by using different wavelengths.
- The laser transmitter used in CO, transmits a wavelength of 1.55 μm and laser transmitter used in ONU, transmits a wavelength of 1.33 μm.

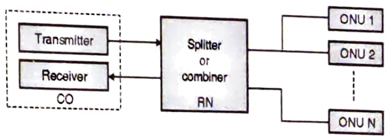

Fig. 5.7.2

3. WPON

- It represents implementation of WDM in TPON. This architecture is shown in Fig. 5.7.3.
- Here the CO consists of WDM array of transmitters or it may contain a single laser transmitter which is tunable. The central office, broadcasts multiple wavelengths and each ONU selects a particular wavelength.
- In this case the data transmission takes place at the rate of receiving data. The optical network units share upstream and downstream channels at different wavelengths.

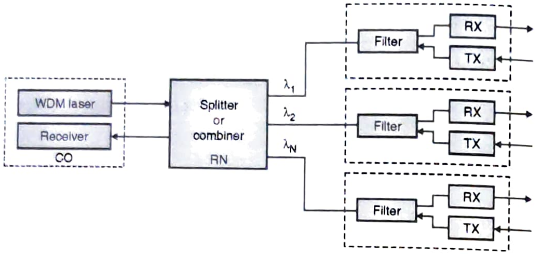

Fig. 5.7.3

4. WRPON

- In the PON architecture; always there is a problem of power splitting at the star coupler. It can be avoided by using wavelength routing technique. The architecture of Wavelength Routing PON (WRPON) is shown in Fig. 5.7.4. It makes use of wavelength router. For this purpose the Arrayed Waveguide Grating (AWG) is used to monitor the downstream traffic.
- AWG routes different wavelengths to different ONUs for the downstream traffic. For the upstream traffic; ONU time shares the wavelength.

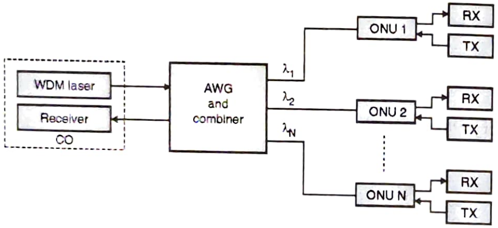

Fig. 5.7.4

Advantages of PON Architecture

Due to the use of passive components; the PON architecture has following advantages :

1. A local loop PON can operate for a distance upto 20 km whereas DSL can operate upto 6 km.
2. Due to sharing of optical fibers between CO and optical combiner; the cost is reduced.
3. PON provides higher data capacity, so higher line rates can be achieved.
4. Electronic devices are shared by large number of subscribers, so the cost is reduced.

5. Entire bandwidth is shared by all PON subscribers, so the line rates can be increased.
6. Multiplexers and demultiplexers are not required at the splitting locations; so the cost of maintains is reduced.
7. In PON architecture, higher bit rates or additional wavelengths can be easily upgraded.

5.8 OPTICAL BURST SWITCHING NETWORK (WRITTEN BY ME)

- Combining important aspects of optical circuit switching and optical packet switching results in optical burst switching (OBS).
- Moreover, as OBS operates at the subwavelength level it therefore provides for rapid setup and teardown of optical network light paths. This hybrid switching and routing technology uses electronics to control routing decisions but keeps data in the optical domain as it passes through each optical node.
- Packets with a common destination are aggregated in edge routing nodes into larger transmission units called a burst or a data burst (DB), each of which is transmitted separately from the data control packet called the burst header cell(BHC) containing necessary information (i.e. for switching and destination address).

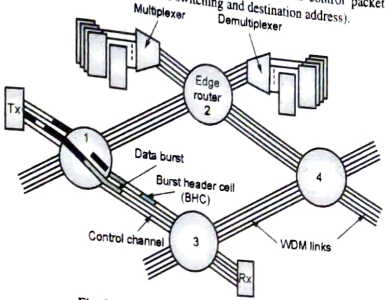

Fig. 5.8.1 : Optical Burst Switching Network

- Fig. 5.8.1 shows the concept of OBS where four edge routers of a large network are shown to establish links between data sources (Tx) and receivers (Rx) individually or by using multiplexers or demultiplexers, respectively.
- Optical bursts containing both the data burst and the BHC travel on a control channel.
- An idle channel on the access link is selected when a data burst is required to be sent, whereas the BHC travels on the control channel ahead of its associated data burst in time and is processed electronically at every node along the path.
- The OBS edge router, on receiving the BHC, assigns the incoming burst to an available channel on the outgoing link leading towards the desired destination and establishes a path between the specified channel on the access link and the channel selected to carry the burst.
- It also forwards the BHC on the control channel of the selected link, after modifying the cell to specify the channel on which the burst is being forwarded.
- This process is repeated at every routing node along the path to the destination. The BHC also includes an offset field which contains the time between the transmission of the first bit of the BHC and the first bit of the burst, and a length field specifying the time duration of the burst.
- One or several channels on each link can be reserved for control information that is used to control the dynamic assignment of the remaining channels to user data bursts.
- It should be noted that the WDM transmission links shown in Fig. 5.8.1. carry a number of wavelength channels and the user data bursts can be dynamically assigned to any of these channels by the OBS routers.

(a) Optical Burst Edge Router's Function

- Fig. 5.8.2 shows the edge router's function providing burst assembly and disassembly operations at ingress and egress, respectively.
- In Fig. 5.8.2(a) each of the users operating on different formats (i.e. IP, SONET, ATM, WDM/DWDM, etc.) sends different data to the edge router.
- The router disassembles the data and issues BHCs (i.e. C1 and C2 shown in Fig. 5.8.2(a)) on the data control channel (DCC) in advance for Burst 1 and Burst 2, respectively.

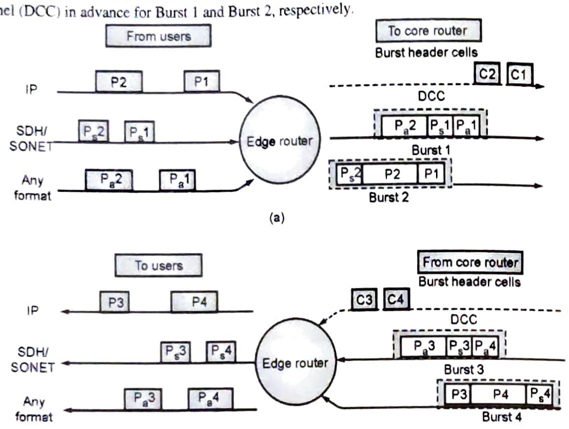

Fig. 5.8.2 Optical burst switch edge router operation showing burst assembly at ingress and disassembly at egress: (a) from users to core router; (b) from core router to users

- Each burst may contain different data: for example, Burst 1 contains data P_a2, P_s1 and P_a2, where the subscripts a and s represent any format and SDH/SONET, respectively.
- In order to perform burst assembly as shown in Fig. 5.8.2(b) the control channel provides BHCs (i.e. C3 and C4) for the data bursts Burst 3 and Burst 4, respectively.
- The users then receive their corresponding disassembled data that the edge router received from the core router.
- It should be noted from Fig. 5.2.8 that the disassembly at egress edges (i.e. sending to users) is simpler than the assembly (or transmission) of the burst (i.e. burstification) at ingress edges. In the latter case, since different signal formats may be used then various signaling and control protocols can be employed to enable optical burstification and OBS routing.

(b) Reservation and Scheduling of resources

- The reservation and scheduling of resources for the burst switching in this process are important factors where the former considers end-to-end burst transmission and the latter focuses on assigning and managing resources for individual bursts within OBS nodes.
- Depending on the network dimension and granularity (i.e. burst size), either one- or two-way signaling protocols are used at the edge routers of an OBS network.
- With two way signaling, sending back an acknowledgment signal to confirm the safe arrival of the signal is required, whereas no such feedback mechanism is available when using one-way signaling protocols.

- One-way protocols include tell-and-go (TAG) and just enough- time (JET). These are also referred to as one-pass reservation protocols
- Examples of two-way signaling protocols are tell-and-wait (TAW) and just-in-time (JIT) [Ref. 89], which are predominantly used for the purpose of burst reservation and scheduling.

(c) One-way protocol

- In case of the JET or TAG protocols, the burst transmission does not wait for the acknowledgment of successful end-to-end path setup and the burst transmission is initiated immediately, or shortly after the burst has been assembled following the control packet being sent out.
- If the burst transmission with the TAG protocol is delayed with respect to the control header, then the delay is referred to as offset time and can be reduced by compensating the processing times. In this scheme less bandwidth is therefore wasted but the burst drop rate increases and it is not considered to be as reliable.
- Due to the submillisecond burst duration assumed in TAG burst management, this scheme is usually considered for application in metropolitan and access networks where distances are comparatively short.

(d) Two-way Protocol

- The JIT and TAW protocols utilize ATM delayed transmission and they wait for an acknowledgment before sending a burst. This process assumes conventional end-to-end transmission (i.e. virtual path) leading to a setup delay for the optical bursts (i.e. in the millisecond range for long-haul networks).
- If the intermediate switches are set in advance during the setup phase to avoid this delay, then the bandwidth wasted can be much higher than the bandwidth actually needed for burst transmission.
- In addition to burst reservation, burst scheduling assigns and manages the resources for individual burst switching nodes. Burst scheduling schemes can be classified based on the duration for which resources are scheduled for a burst.
- The reserve-a-limited duration (RLD) and reserve-a-fixed duration (RFD) schemes are commonly adopted for burst reservation.
- The RLD requires the sender to signal the start and end of a burst and resources are explicitly reserved until the end of burst transmission. For each resource, the idle time (i.e. the duration when the resource is free or available) is recorded.
- The RFD scheme, however, considers the exact start and end time of bursts for resource scheduling. For example, the gaps (or voids) between already reserved bursts can be used for newly arriving bursts.
- Moreover, several designs have been used to optimize resource allocation of both the RLD and RFD schemes by improving wavelength selection or by minimizing voids.
- Advanced techniques referred to as adaptive and autonomic OBS have also been proposed which can learn and adapt new routes after acquiring network information such as wavelength routing, wavelength selection, protection and the information related to the restoration mechanisms.
- Such OBS techniques use a feedback mechanism to optimize the selection of control and routing information and therefore they are capable of being both self-protecting and self-optimizing.

Chapter Ends...

□□□