CMR
INSTITUTE OF
TECHNOLOGY

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Improvement Test

Subject:	Optical Networking					Code:	10TE81
Date:	29/ 05/17	Duration:	90 mins	Max Marks:	50	Sem: VIII	Branch: TCE

Answer any five questions (10 × 5= 50). Figures in the right hand side square brackets indicate makes for the corresponding question.

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1. a) What are the main features of optical access networks? Explain with the help of a proper diagram showing the main components. [5]

   b) What do you mean by fiber-to-the-curb (FTTC) technology? Explain using a proper diagram for a typical FTTC system. [5]

2. a) What do you mean by hybrid fiber coaxial (HFC)? What is its importance in the local distribution networks? [5]

   b) How HFC system made the local TV communications easy for the operators? Explain with the help of a diagram and mention the scales of HFC systems. [5]

3. a) What are the main limitations of photonic packet switching? Explain with proper reasons how some of those limitations can be overcome. [5]

   b) With the help of a neat diagrams show different methods proposed for optical buffers? Explain how they can provide packet switching? [5]

4. a) Show the typical optical network hierarchy using a diagram. In it show the core network, the regional network, metro network and access networks. [5]

   b) How the framing used in SDH is different from the framing in SONET? Show the structure of an STM-1 frame and compare it with an STS-1 frame. [5]

5. a) What do you mean by an optical line layer and path layer in optical networks? Briefly, show their differences with the help of a diagram. [5]

   b) What is the distance based classification of SONET/SDH physical layer links? How the data rates larger than the SONET/SDH systems are organized? [5]

6. Using a neat diagram show the basic structure used for optical time division multiplexing (OTDM) in optical networks. Explain the main features of OTDM. How OTDM is different from TDM? [10]

7. Write short notes on **<u>any four</u>** of the following topics (in 6 to 8 sentences). [2.5×4]
   a) Synchronization
   b) SONET Architecture
   c) Optical Crossconnect (OXC)
   d) Metro Area Networks (MANs)
   e) Optical Access Area Networks
   f) Plesiochronous Digital Hierarchy (PDH)
   g) SONET Tributaries

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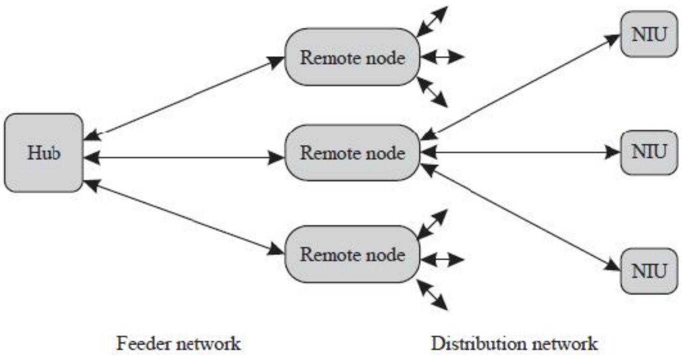
Q1. a) **What are the main features of optical access networks? Explain with the help of a proper diagram showing the main components.**

Optical access networks are: they are high speed networks; they are better than other access networks in terms of latency and bit rates; they are more expensive to deploy: they are more durable than other access networks; and they are economical when it comes to the expenses in terms of bits/s.

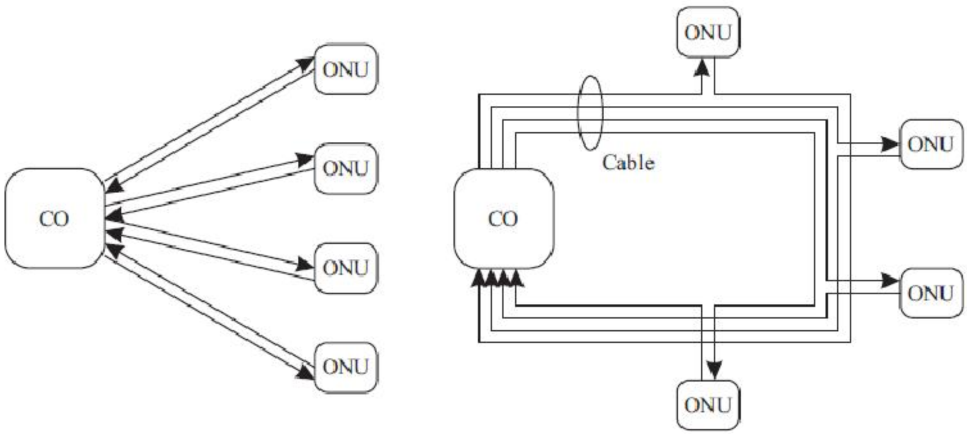


Optical access network consists of a hub, remote nodes (RNs), and network interface units (NIUs), as shown in figure. In the case of a telephone company, the hub is a central office (also called a local exchange in many parts of the world), and in the case of a cable company, it is called a head end. Each hub serves several homes or businesses via the NIUs. An NIU either may be located in a subscriber location or may itself serve several subscribers. The hub itself may be part of a larger network, but for our purposes, we can think of the hub as being the source of data to the NIUs and the sink of data from the NIUs. In many cases, rather than running cables from the hub to each individual NIU, another hierarchical level is introduced between the hub and the NIUs. Each hub may be connected to several RNs deployed in the field, with each RN in turn serving a separate set of NIUs. The network between the hub and the RN is called the feeder network, and the network between the RN and the NIUs is called the distribution network.

Q1. b) **What do you mean by fiber-to-the-curb (FTTC) technology? Explain using a proper diagram for a typical FTTC system.**

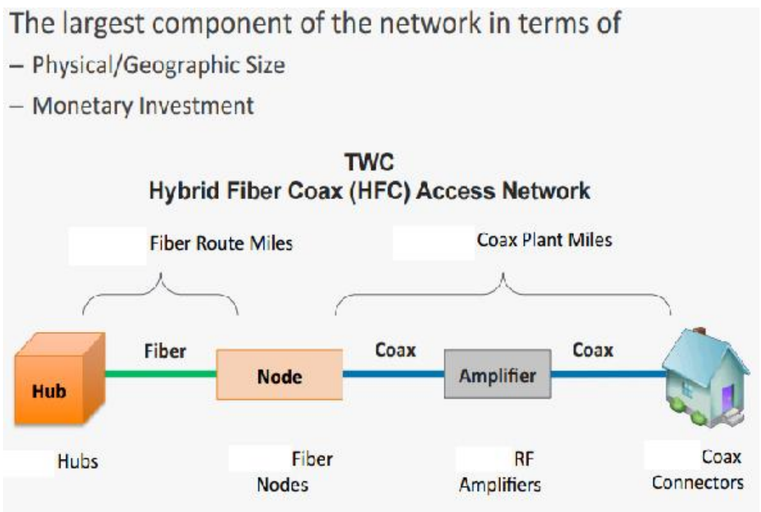
Fiber to the curb (FTTC), data is transmitted digitally over optical fiber from the hub, or central office, to fiber-terminating nodes called optical network units (ONUs). The expectation is that the fiber would get much closer to the subscriber with this architecture. Depending on how close the fiber gets to an individual subscriber, different terms are employed to describe this architecture (see Figure 11.5). In the most optimistic scenario, fiber would go to each home, in which case this architecture is called fiber to the home (FTTH), and the ONUs would perform the function of the NIUs. For the case where ONUs serve a few homes or buildings, say, 8–64, this can be thought of as FTTC or fiber to the building (FTTB). Typically, in FTTC, the fiber is within about 100 m of the end user. In this case, there is an additional distribution network from the ONUs to the NIUs. With the fiber to the cabinet (FTTCab) approach, the fiber is terminated in a cabinet in the neighborhood and is within about 1 km of the end user.

In the following figure we show how the FTTC works.

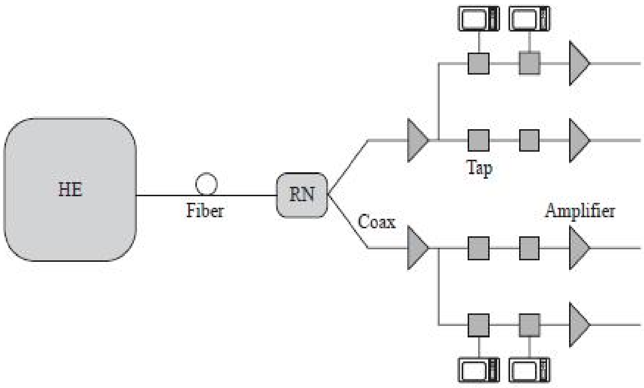


Q2. a) **What do you mean by hybrid fiber coaxial (HFC)? What is its importance in the local distribution networks?**

Hybrid fiber coaxial (HFC) is a hybrid network of optical fiber and electrical metallic coaxial cables. These hybrid networks are used for several high speed communication purposes. For instance, the cable TV distribution networks are made up of HFCs. The simplest kind of HFC has been shown below.



The cable TV networks using HFC have several changes from the basic topology. We have shown one such network below. Enhanced HFC are also possible where the performances are much better.
In a typical enhanced HFC architecture, like the existing cable network, downstream data is broadcast from the head end to remote (fiber) nodes by using a passive optical star coupler. In recent deployments, it is common to use high-power 1.55 μm transmitters in conjunction with booster amplifiers to achieve a high split ratio. In addition, signals at 1.3 μm can be multiplexed on the same set of fibers. These 1.3 μm signals can be used in a narrowcasting mode. That is, these signals can be transmitted only to a selected set of users, rather than to all users. This feature can be used to provide additional bandwidth for selected groups of users.



Q2. b) **What do you mean by dispersion management? Briefly explain with the help of a diagram how dispersion is managed in optical networks using dispersion compensated fibers.**

Solution:

Dispersion is a natural phenomenon in optical fibers. It is bound to occur in the fibers as the light propagates along it. Dispersion management is the process in which dispersion can be reduced or nullified (for medium and short ranges) at the receiver. Dispersion management provides better quality of signal at the receiver.

Special chromatic dispersion compensating fibers (DCFs) have been developed that provide negative chromatic dispersion in the 1550 nm wavelength range. For example, DCFs that can provide total chromatic dispersion of between −340 and −1360 ps/nm are commercially available. (For instance, an 80 km length of standard single mode fiber has an accumulated or total chromatic dispersion, at 17 ps/nm-km, of $17 \times 80 = 1360$ ps/nm.) Thus a DCF with −1360 ps/nm can compensate for this accumulated chromatic dispersion, to yield a net zero chromatic dispersion. Between amplifier spans is standard single-mode fiber, but at each amplifier location, dispersion compensating fiber having a negative chromatic dispersion is introduced. The chromatic dispersion map the variation of accumulated chromatic dispersion with distance of such a system is shown in the figure below. Even though the chromatic dispersion of the fibers used is high, because of the alternating signs of the chromatic dispersion, this approach leads to a small value of the accumulated chromatic dispersion so that we need not worry about penalties induced by chromatic dispersion.

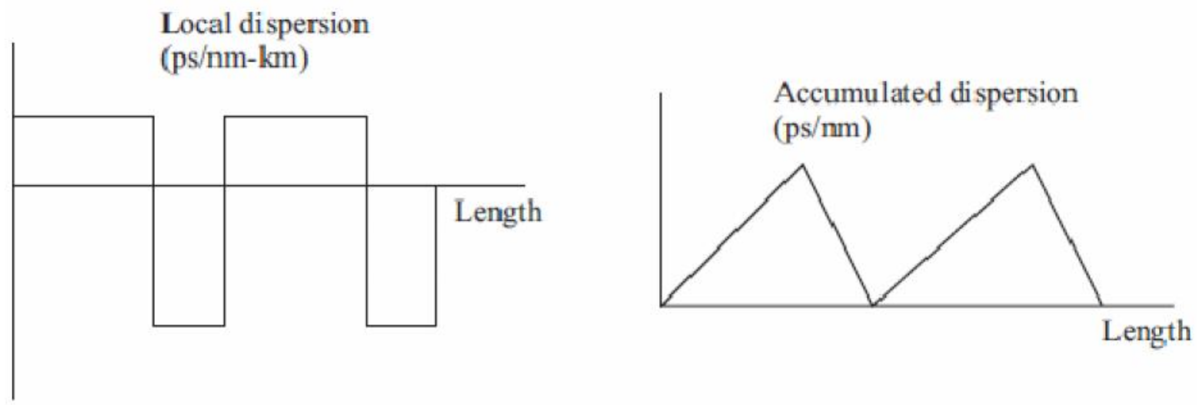
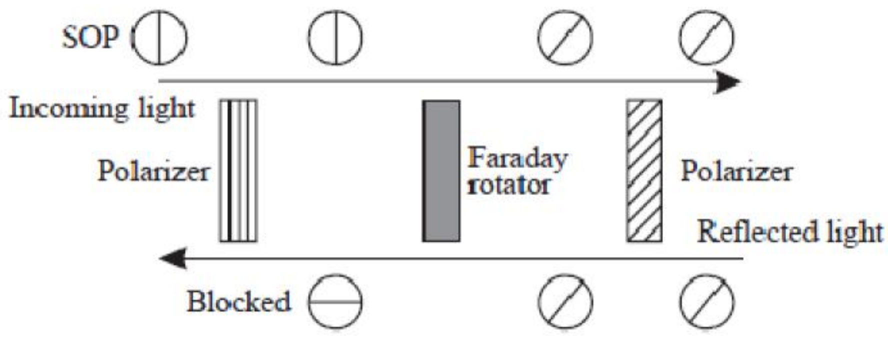


Figure 2. (b). The chromatic dispersion map in a WDM link employing chromatic dispersion compensating fiber. The left one shows (local) chromatic dispersion at each point along the fiber. The right one shows accumulated chromatic dispersion from the beginning of the link up to each point along the fiber.

Q3. a) **Explain the principle of operation of an isolator using appropriate diagram. Does an isolator depend on polarization? Explain with proper reasons.**

Solution:

An isolator is a non-reciprocal device. Its main function is to allow transmission in one direction through it but block all transmission in the other direction. Isolators are used in systems at the output of optical amplifiers and lasers primarily to prevent reflections from entering these devices, which would otherwise degrade their performance. The two key parameters of an isolator are its insertion loss, which is the loss in the forward direction and which should be as small as possible, and its isolation, which is the loss in the reverse direction and which should be as large as possible. The typical insertion loss is around 1 dB, and the isolation is around 40–50 dB.

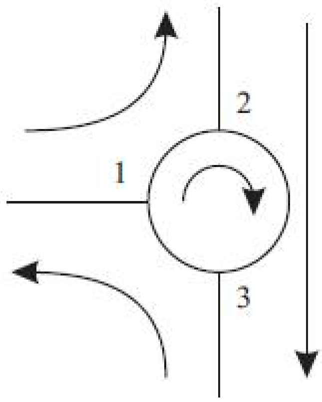


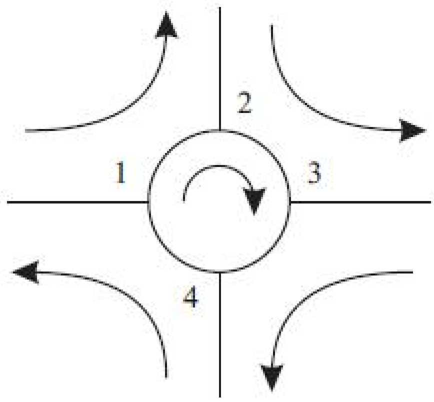
Let us assume that the input light signal has the vertical state of polarization (SOP) shown in the figure. It is passed through a polarizer, which passes only light energy in the vertical SOP and blocks light energy in the horizontal SOP. Such polarizers can be realized using crystals, known as dichroics, which have the property of selectively absorbing light with one SOP. The polarizer is followed by a Faraday rotator. A Faraday rotator is a nonreciprocal device, made of a crystal that rotates the SOP, say, clockwise, by 45◦, regardless of the direction of propagation. The Faraday rotator is followed by another polarizer that passes only SOPs with this 45◦ orientation. Thus the light signal from left to right is passed through the device without any loss. On the other hand, light entering the device from the right due to a reflection, with the same 45◦ SOP orientation, is rotated another 45◦ by the Faraday rotator, and thus blocked by the first polarizer.

Q3. b) **What is a circulator? What are its utilities in optical communication networks? How the circulators and multiplexers are different from each other?**

Solution:

A circulator is a nonreciprocal device. It is similar to an isolator, except that it has multiple ports, typically three or four. As shown below, in a three-port circulator, an input signal on port 1 is sent out on port 2, an input signal on port 2 is sent out on port 3, and an input signal on port 3 is sent out on port 1. Circulators are useful to construct optical add/drop elements. Circulators operate on the same principles as isolators.





Q4. a) Describe the principles of operation of semiconductor optical amplifiers using appropriate diagrams. Are the semiconductor optical amplifiers suitable for long term continuous operation as amplifiers in optical networks?

Solution:
Refer to the lecture notes of the class and the lecture slides. All the figures and the relevant information are presented there.

Q4. b) Using appropriate diagrams explain the principle of operation of EDFAs. Show the emission and absorption characteristics of EDFA.

Solution:
Refer to the lecture notes and the lecture slides. All the figures and the relevant information are presented there.

Q5. a) What are the different types of transmitters used in optical communication? Briefly, explain their application domains. Compare the characteristics of the transmitters with each other.

Solution:
Refer to the lecture notes and the lecture slides. All the figures and the relevant information are presented there.

Q5. b) What are the different types of detectors used in optical communication? Briefly, explain their application domains. Compare the characteristics of the detectors with each other.

Solution:
Refer to the lecture notes and the lecture slides. All the figures and the relevant information are presented there.

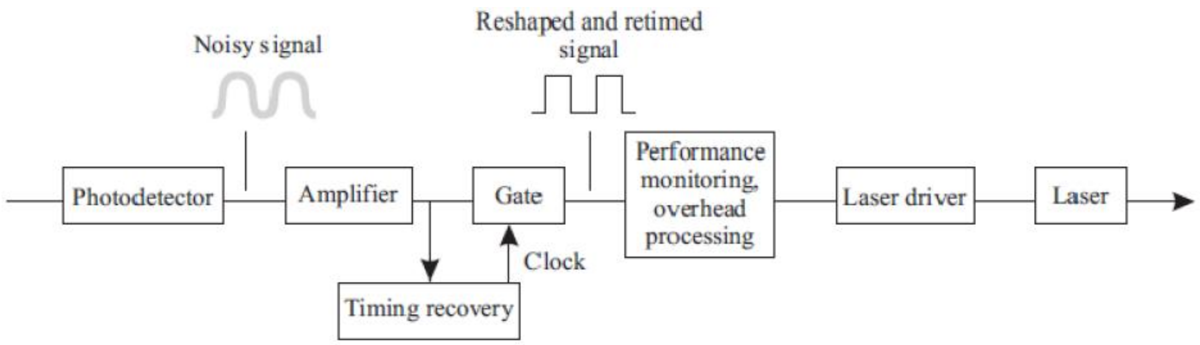
Q6. **What is wavelength converter? Why wavelength converters are needed in optical networks? What are the different principles being used for wavelength conversion. Describe each of them using appropriate physical principles and diagrams if needed.**

Solution:

A wavelength converter is a device that converts data from one incoming wavelength to another outgoing wavelength. Wavelength converters are useful components in WDM networks for three major reasons.

First of all, data may enter the network at a wavelength that is not suitable for use within the network. For example, the first-generation networks commonly transmit data in the 1310 nm wavelength window, using LEDs or Fabry-Perot lasers. Neither the wavelength nor the type of laser is compatible with WDM networks. So at the inputs and outputs of the network, data must be converted from these wavelengths to narrow-band WDM signals in the 1550 nm wavelength range. A wavelength converter used to perform this function is sometimes called a transponder. Second, wavelength converters may be needed within the network to improve the utilization of the available wavelengths on the network links. Finally, wavelength converters may be needed at boundaries between different networks if the different networks are managed by different entities and these entities do not coordinate the allocation of wavelengths in their networks.
There are two broad principles available for the wavelength conversion. The first one is the optoelectronic method and the second one is the all-optical method. In the first method, the wavelength conversion happens in the electrical domain. However, in the second, it is done completely in the optical domain.

Optoelectronic method is the simplest, most obvious, and most practical method today to realize wavelength conversion. As shown in figure below, the input signal is first converted to electronic form, regenerated, and then retransmitted using a laser at a different wavelength. This is usually a variable-input, fixed-output converter. The receiver does not usually care about the input wavelength, as long as it is in the 1310 or 1550 nm window. The laser is usually a fixed-wavelength laser. A variable output can be obtained by using a tunable laser.



Optoelectronic method of wavelength conversion

In the optical domain, optical gating, optical interference and optical mixing principles can be used for the design of wavelength converters. Optical gating makes use of an optical device whose characteristics change with the intensity of an input signal. This change can be transferred to another unmodulated probe signal at a different wavelength going through the device. At the output, the probe signal contains the information that is on the input signal. Like the optoelectronic approach, these devices are variable-input and either fixed-output or variable-output devices, depending on whether the probes signal are fixed or tunable. In all these three methods, SOA are required for the new wavelength generation.

Q7. Write short notes on **any four** of the following topics (in 6 to 8 sentences).

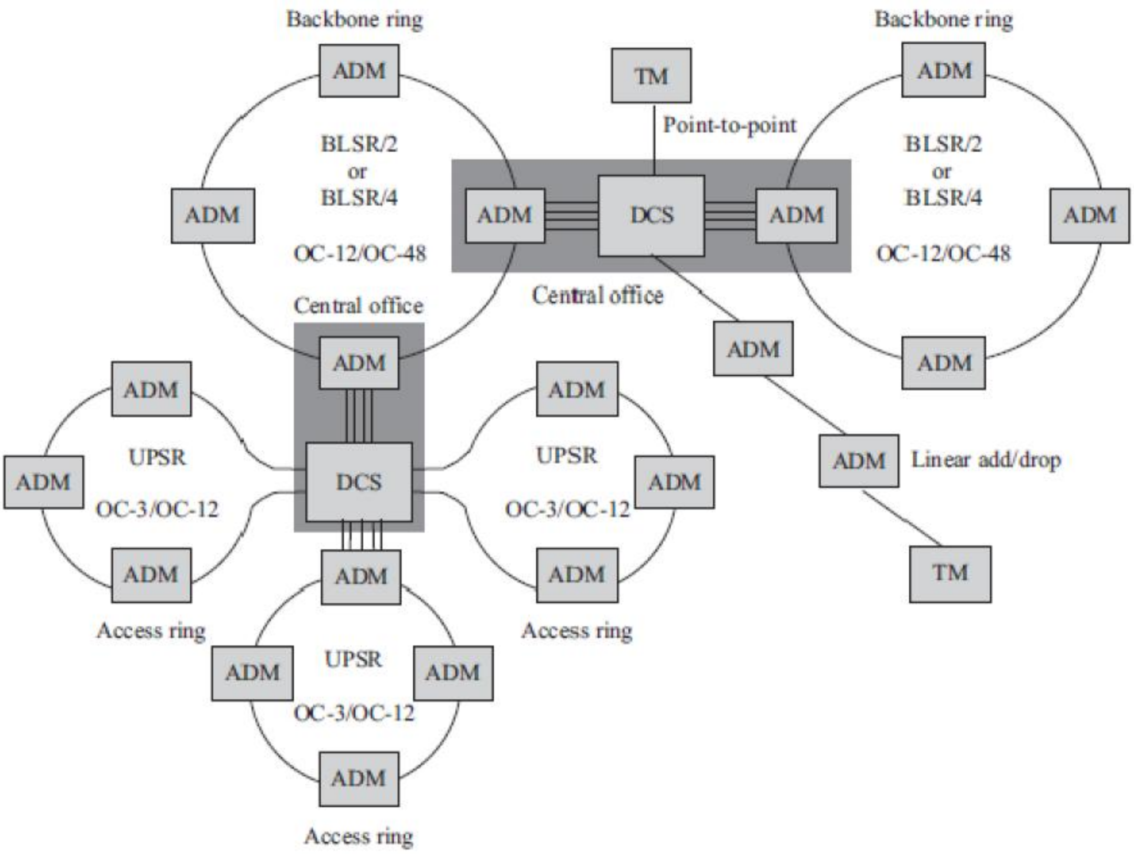
a) Synchronization

Synchronisation is a basic need in any communication networks. It maintains order in the packet communications. Precise timing is mandatory for running a high-performance network. It is mandatory to ensure the continued success of your network and your business. From the core to the last mile, our technology is the first in the industry to provide end-to-end timing distribution and assurance. The first in the industry to provide you with full visibility.

Our end-to-end timing distribution and assurance solution is fueled by Oscilloquartz expertise. Acquired in April, 2014, Oscilloquartz is the world's longest-standing expert in precise network timing sources and distribution solutions. Together we provide you with a smooth evolution across multiple generations of synchronization technologies: from legacy SONET/SDH to highly accurate frequency-and-time solutions for packet-based networks. Together we are the first to integrate the delivery and assurance of synchronization. Together we are the first to ensure everything remains in sync.

b) SONET Architecture

Knowledge of SONET architecture is needed for the design of optical networks. In the following diagram we show SONET architecture.



c) Optical Crossconnect (OXC)

An optical network element is required to handle more complex mesh topologies and large numbers of wavelengths, particularly at hub locations handling a large amount of traffic. This element is the optical crossconnect (OXC).We will see that though the term *optical* is used, an OXC could internally use either a pure optical or an electrical switch fabric. An OXC is also the key network element enabling reconfigurable optical networks, where lightpaths can be set up and taken down as needed, without having to be statically provisioned.

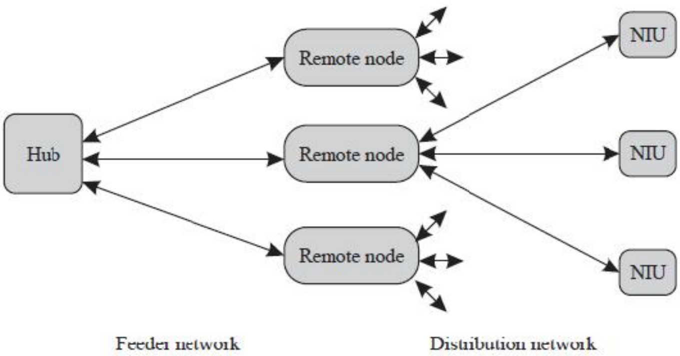
Typically, some OXC ports are connected to WDM equipment and other OXC ports to terminating devices such as SONET/SDH ADMs, IP routers, or ATM switches. Thus, the OXC provides cost-effective pass through for express traffic not terminating at the hub as well as collects traffic from attached equipment into the network. Some people think of an OXC as a crossconnect switch together with the surrounding OLTs. However, our definition of OXC does not include the surrounding OLTs because carriers view cross connects and OLTs as separate products and often buy OXCs and OLTs from different vendors. An OXC provides several key functions in a large network:
Service provisioning;
Protection;
Bit tare transparency;
Performance monitoring, test access, and fault localization;
Wavelength conversion;
Multiplexing and grooming.

d) Metro Area Networks (MANs)

Metro area networks (MANs) are the third level networks in the network hierarchy. These networks are connected with the national or regional networks as tributaries and provide services to the end customers through the access networks. This MAN connects either via fiber optics or wireless more than a hundred of public buildings in the area of coverage. MANs can be deployed as either high speed fiber networks, optical Ethernet or even as PONs if the distances are small. These days most of the MANs are optical due to the robust services provided by the optical networks.

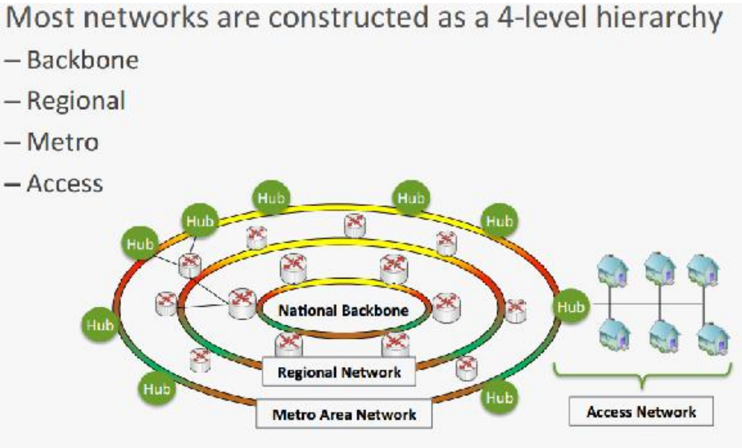
e) Optical Access Area Networks

Optical access networks are the last mile optical network which directly connects with the end customers. These networks are deployed where high speed is required. These networks are very much passive in nature as they do not use optical amplifiers. We show a typical optical access area network below.



Optical access network consists of a hub, remote nodes (RNs), and network interface units (NIUs), as shown in figure. In the case of a telephone company, the hub is a central office (also called a local exchange in many parts of the world), and in the case of a cable company, it is called a head end. Each hub serves several homes or businesses via the NIUs. An NIU either may be located in a subscriber location or may itself serve several subscribers. The hub itself may be part of a larger network, but for our purposes, we can think of the hub as being the source of data

to the NIUs and the sink of data from the NIUs. In many cases, rather than running cables from the hub to each individual NIU, another hierarchical level is introduced between the hub and the NIUs. Each hub may be connected to several RNs deployed in the field, with each RN in turn serving a separate set of NIUs. The network between the hub and the RN is called the feeder network, and the network between the RN and the NIUs is called the distribution network.
In the following diagram we have shown the optical access network hierarchy diagram below.



f) Plesiochronous Digital Hierarchy (PDH)

The plesiochronous digital hierarchy (PDH) is a telecommunications network transmission technology designed for the transport of large data volumes across large scale digital networks. The PDH design allows the streaming of data without having isochronous (clocks running at identical times, perfectly synchronized) to synchronize the signal exchanges. PDH clocks are running very close, but not exactly in time with one another so that when multiplexing, signal arrival times may differ as the transmission rates are directly linked to the clock rate. PDH allows each stream of a multiplexed signal to be bit stuffed to compensate for the timing differences so that the original data stream could be reconstituted exactly as it was sent. PDH is now obsolete and has been replaced by synchronous optical networking and synchronous digital hierarchy schemes, which support much higher transmission rates.

g) SONET Tributaries

SONET has several tributaries. A tributary is a structure used for the transport of low rate sub-STS-1 synchronous signals. Virtual tributary information is organized inside an STS-1 channel of Sonet frames and routed through the network to a specified destination from a given source location.

There are four types (VT1.5, VT2, VT3, VT6) or sizes of virtual tributaries defined for Sonet. A VT1.5 has the lowest payload capacity with a data rate of 1.728 Mbit/s. Progressing in size, a VT2 has a data rate of 2.304 Mbit/s, a VT3 operates at 3.456 Mbit/s, and a VT6 offers a data rate of 6.912 Mbit/s. The different size tributary options are provided to maximize available bandwidth in an STS-1 channel. For example, if the end user requires the transport of DS-1C signals requiring 3.152 Mbit/s, a virtual tributary VT3 size would be the ideal solution as opposed to a VT6 size that provides much more bandwidth than what is needed. Other common low rate signals such as DS1, E1, and DS2 fit into virtual tributary types VT1.5, VT2, and VT6, respectively. As a note, lower-rate end user services must be mapped into the appropriate virtual tributary container to handle rate and format discrepancies prior to insertion into the SONET frame.