Department of Electrical Engineering

Assignment

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Course Details

Course Title:	Mobile and Broadband Networks	Module:	3rd
Instructor:	Pir Mehr Ali Shah	Total Marks:	50

Student Details

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ANSWERS:

Ans 1:

The four main PON variations developed by the ITU and IEEE can be categorized into two groups .The first kind of architecture is based on Asynchronous Transfer Mode(ATM)and includes ATMPON (APON), Broadband PON(BPON)and Gigabit PON(GPON)and the second group consists of Ethernet PON(EPON).EPON and GPON are the most popular PON variations found in use today . A conventional PON architecture is presented in Fig. 2

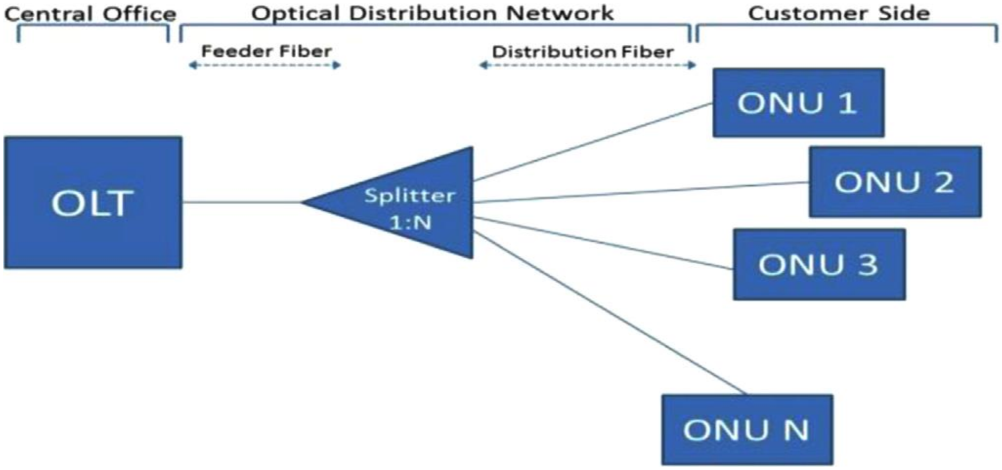


Figure 2

In the figure, it can be seen that the PON architecture consists of an Optical Line Terminal (OLT), Optical Distribution Network(ODN), and Optical Network Units(ONU).The OLT is placed at the Central Office (CO) and connected to the splitters by fiber .The optical splitters connect to customer premises making PON appoint to multi-point architecture(P2MP) . The EPON and the GPON standards have the same general principle in terms of frame work and applications but their operation is different due to the implementation of the physical and data link layers. EPON is defined by IEEE 802.3 and it is widely deployed in As ia whilst GPON is deployed in a number of other regions. GPON's requirements were defined by the Full Service Access Network(FSAN) group that was ratified as ITU-TG.984andisimplementedinNorthAmerica,Europe,Middle East, and Australasia .In this paper the advancement of PON technology is classified into three generations :the first generation(deployed PON),next generationstage1(NG-PON1),andnextgenerationstage2(NG- PON2). The evolution of the PON architectures and their corresponding capacity features are shown in Fig. 3.

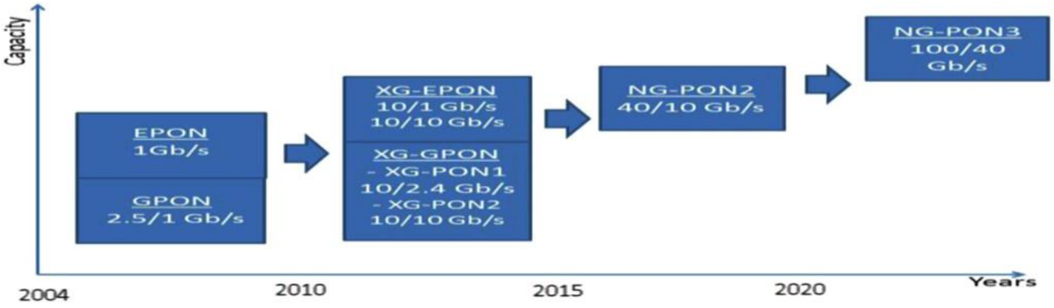
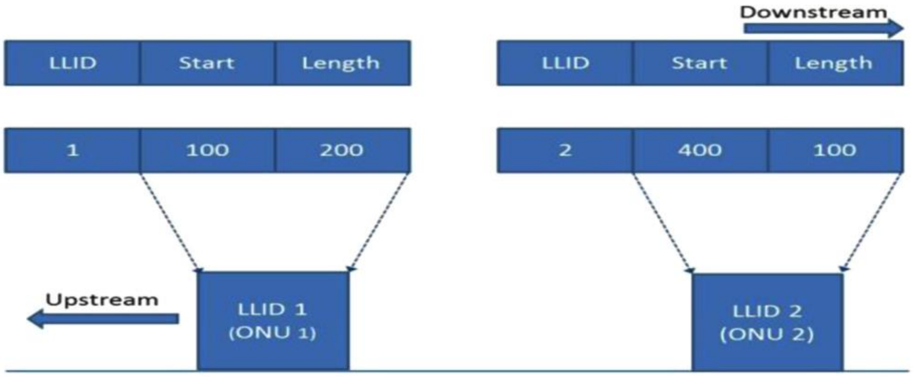
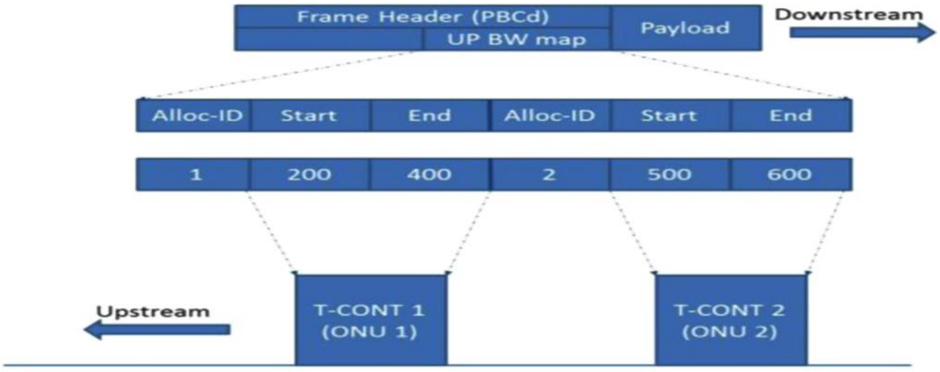


Figure 3

The first generation of PON Is based on Time Division Multiple Access (TDMA) and provides an EPON downstream rate of 1Gbps and a GPON downstream rate of 2. 4Gbps.The NG-PON1increases the data rate upto10Gbps for both standards There are two main scenarios to achieve an upgrade that are the upgrade from deployed EPON to XG-EPON and from deployed GPON to XG-GPON. An upgrade from deployed GPON to XG-EPON is another potential pathway that can be considered. However, with the rapid increase in high bandwidth applications and Internet servicestheNG-PON1wouldnotbeabletomeetthe future demand for band width and Quality of Service(QoS) requirements .To find an acceptable future upgrade pathway ,the researchcommunityisinvestigatingtheoptionsforNG-PON2and severaltechnologiesthatmightbeusedinNG-PON2havebeen studied extensively in order to meet the future requirements of users and network operators;. Four multiplexing technologies are being considered for NG- PON2 toprovideadownstreamtransmissionof40Gbpsand upstreamtransmissionof10Gbps. Thetechnologiesincludehigh speed Time Division Multiplexing PON(TDM-PON),Wavelength Division Multiplexing PON(WDM-PON),Optical Code Division Multiplexing PON(OCDM-PON),and Orthogonal Frequency Division Multiplexing PON(OFDM-PON).The multiplexing techniques that have been identified toprovideaP2MPconnectionbetweenasingle OLT and multiple ONUs .However , each technology has its own pros and cons(Cvijeticetal.,2010). To eradicate the multiplexing-specific limitations, hybrid approaches that combine the advantages of multiple technologies have been introduced as a dominant option for theNG-PON2.In the literature, several hybrid technologies have been studied including TDM/WDM-PON,OCDM/WDM-PON,OCDM/TDM- PON, OFDM/WDM-PON ,and OFDM/TDM-PON .Among them ,hybrid TDM/WDMPON(TWDM-PON)has been selected as the base element fortheNG-



(a) EPON frame structure.



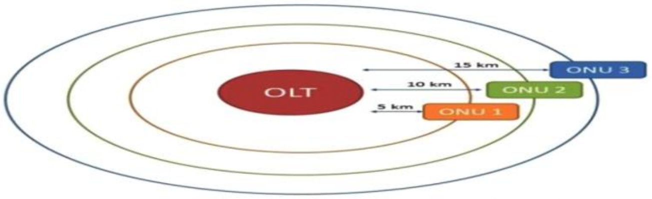
(b) GPON frame structure.

Figure 4

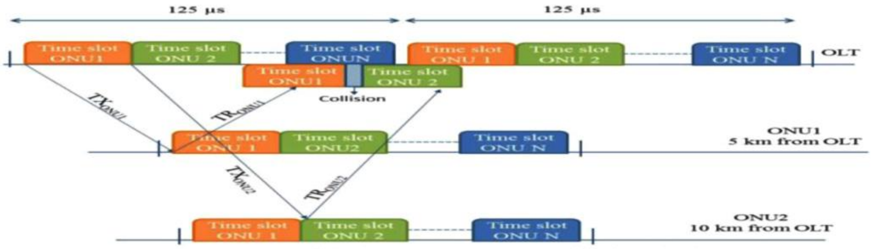
Fig. 4(a) presents the EPON frame structure, which uses the native Ethernet frame to transmit traffic. The downstream MAC layer has the same operation as a standard Gigabit Ethernet MAC (GbE MAC) , where the traffic is broadcast to all users .In the down stream frame ,the preamble field contains a logical link identifier (LLID)which is a unique identifier assigned by the OLT to each ONU . The ONUs identify received traffic by matching the LLID of the received frame with its own LLID and if there is a match then it will accept the received frame , otherwise it is discarded. For upstream traffic, the MAC layer has been modified by the IEEE to operate using a TDMA approach , where the OLT assigns a specific times lot to every ONU taking into account the distance between each ONU and the OLTFig. 4(b) shows the frame structure of GPON . The downstream MAC layer operates in the same manner as a GFP-framed SONET . It supports aframeof125 ms long that uses TDM to divide the available bandwidth among the users , whilst the upstream MAC layer is based on TDMA. GPON supports two layers of encapsulation where the Ethernet frame is encapsulated into a GPON Encapsulation Method(GEM) frame which is encapsulated again into a GPON Transmission Convergence(GTC) frame . The GTC frame also includes pure ATM cells and TDM traffic. The down stream frame is broadcast to every ONU and the ONUs use the information in the Physical Control Block down stream (PCB d) field to extract its own data . Incase there is no data to be transmitted , the down stream frame will be transmitted continuously and utilized for time synchronization The upstream frame contains multiple transmission bursts arriving from the ONUs . Along with the pay- load, each of the upstream burst frames consists of the Physical Layer Overhead (PLOu),a bandwidth allocation interval which contains the Dynamic Bandwidth Report upstream (DBRu), and allocation identifiers (Alloc-IDs).When traffic reaches the OLT, ONU traffic is queued based on Classes of Service(CoS) with a diverse QoS dependent on the type of the Traffic Containers(T- CONTs) that is specified in the Alloc-ID (Segarra etal.,2013). GPON introduces five types of T-CONTs that provide QoS in the upstream direction . The T-CONT frame is used in GPON to establish a virtual connection between ONU and OLT as well asto manage fragment transmission.

1) T-CONTtype1:
   Supports fixed bandwidth that is sensitive to time .The jitter of T-CONTtype-1 is 0 which enhances the suitability it has for Constant Bit Rate(CBR)traffic.
2) T-CONTtype2:
   This type supports Assured bandwidth where it has a higher delay than T-CONT1.It is used with Committed Information Rate (CIR)traffic.
3) T-CONTtype3:
   Supports assured and non-assured band widths providing a guaranteed minimum CIR and surplus Excess Information Rate (EIR).
4) T-CONTtype4:
   This type is appropriate for Variable Bit Rate(VBR)traffic that does not guarantee delay.
5) T-CONTtype5:
   This type is mix of all the above T-CONT types . It is appropriate for general traffic flows Selmanovic andSkaljo,2010). ONUs are located at different distances from the OLT as shown in Fig. 5(a). When each ONU transmits its upstream traffic during the assigned timeslot , there is a possibility that frames from different ONU scollide at some point due to the difference in propagation delay . This scenario is illustrated in Fig. 5(b). In order to guarantee that the upstream transmissions do not collide , arranging process is performed by the OLT during the activation and registration of the ONUs . The ranging process is based on calculating a specific delay time for each ONU according to its distance from the OLT to equalize its transmission delay with other ONUs. This delay is called Equalization Delay(ED) . Each ONU will store and apply its ED to all the upstream transmissions . The ED values are broadcast to other ONUs using Physical Layer Operations and Maintenance (PLOAM) messages and each ONU resumes its transmission based on the ED. Fig. 6 shows an ONU in arranging state . While one ONU is active and sending traffic, transmissions from other ONUs must be suspended(Kramer,1999). Multipoint control protocol(MPCP) has been introduced to facilitate dynamic bandwidth all location process . This is executed at the MAC layer For EPON , MPCP can be run in one of the two modes .

   Fig. 5. (a) ONUs at different location from OLT. (b) ONU sup stream collision.



(a) ONUs at different location from OLT



(b) ONUs upstream collision [24]

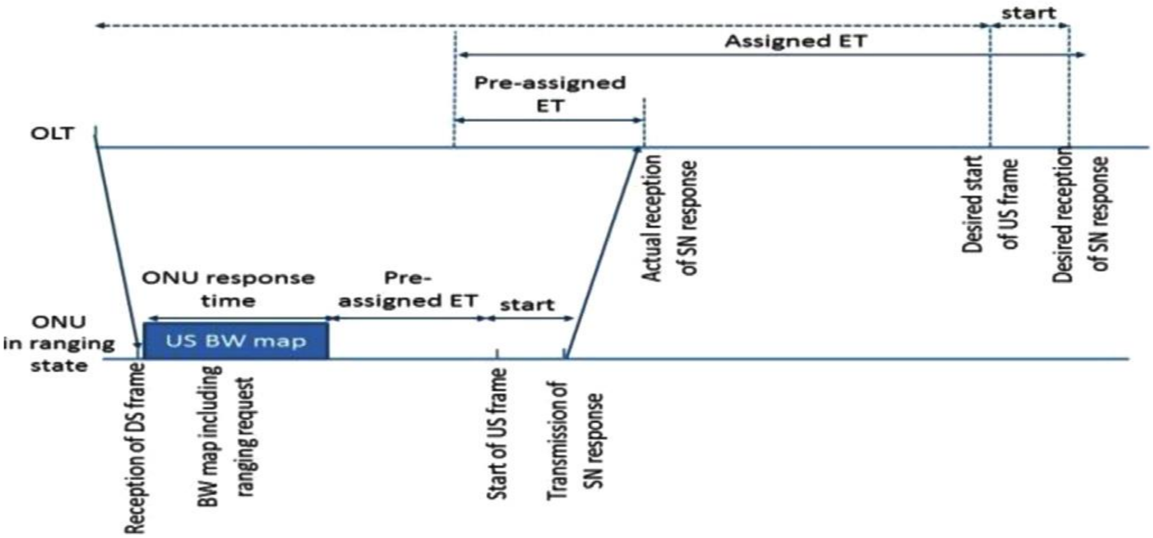


Fig. 6. Ranging state (Kramer, 1999).

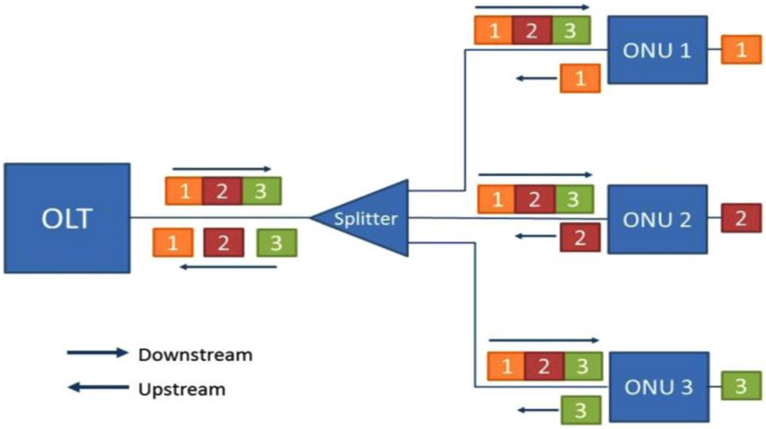
Firstly, in the normal mode , it makes use of the two control messages to control the allocation of band- width, which are GATE and REPORT messages .In the downstream direction, the GATE messages travel from the OLT to ONUs and carry the allocated bandwidth information In the upstream direction , the REPORT messages that contain bandwidth request information are sent by ONUs to the OLT.A specific algorithm misused to determine the grant allocation for each of the ONU. These comd mode is the auto- discovery. It is based on three control messages that are REGISTER, REGISTER_ REQUEST, and REGISTER_ ACK . These messages are used to discover and register a new ONU . In addition, it reports in formation about the ONU including MAC address and round-trip delays.In the GPON scenario, grant messages are sent based on T-CONT . Like EPON, MPCP protocol is impelled minted to facilitate the dynamic bandwidth allocation in GPON. Two main approaches supported in GPON to deduce the occupancy of the buffer status of each T-CONT which are status reporting Dynamic Bandwidth Allocation (DBA) and traffic-monitoring DBA. In the case of status-reporting DBA, each ONU directly sends status report information to the OLT . Whereas, in the traffic monitoring DBA, the inference of the T-CONT's buffer status at the OLT is reliant on the historical information of band- width use and the amount of defined bandwidth. The header in the down stream frame includes the upstream bandwidth map (BWmap) field that depicts the start and end time for upstream transmission for each ONU

Ans 2:

Next generation passive optical networks (NG- PONs) is the natural development of PONs toward achieving higher data rates, larger counts of wavelength channels, and longer fiber ranges. NG-PON can be implemented as high speed time division multiplexing (TDM), wavelength division multiplexing (WDM), Hybrid TDMIWDM, optical code division multiplexing (OCDM) PON. Many enhancements and adaptations are occurring in order to offer higher bandwidths with higher number of subscribers. This includes coverage area that is increasing to reach of l00km and more, e.g. the LR-PON. In addition, the wireless access network is gradually going to be integrated with PON systems, e.g. FiWi network.

ING-PON2 pure technologies:

Studies have been conducted for several NG-PON2 technologies that offer up to 100 Gbps. This includes high speed TDM-PON, WDM-PON, OCDM-PON, OFDM-PON, and hybrid technologies



High speed TDM-PON:

TDM-PON allows multiple users to share the same bandwidth using a single wavelength. A typical TDM-PON structure is shown in Fig. 8. The downstream traffic is broadcast to all users and a specific time is assigned by the OLT to every ONU to control upstream transmissions. These time slots are allocated in downstream and upstream frames where a complex algorithm is required to arrange and assign the bandwidth in order to avoid collisions (Esmail and Fathallah, 2013; Muciaccia et al., 2014). TDM-PON is a simple and cost effective technology, however; it has limited scalability due to the fact that ONUs share bandwidth. Increasing the bit rate for all of the users will be a challenging task because every ONU receiver operates at a bit rate that is higher than the bit rate assigned per ONU. Utilizing a high speed digital signal processor and field-programmable gate array to increase the bitrate to higher than 10 Gbps increases cost and complexity (Muciaccia et al., 2014; Sotiropoulos et al., 2013). In addition, TDMPON is not very secure due to the shared infrastructure which opens the possibility of eavesdropping and other attacks. Moreover, the variation in the distance between ONUs and the OLT is another drawback that causes variation in the optical power and consequently, the OLT receiver operates in burst mode (Hara et al., 2010; Yoshima et al., 2012). In order to upgrade the current TDM-PON to meet the NGPON2 requirements, a number of approaches have been investigated to increase the capacity of TDM-PON, including:

Conventional ON OFF Key (OOK) systems:

Applying OOK is the easiest way to increase the capacity of TDM-PON. However, this solution is not favorable for future PONs because it requires a 40 Gbps burst-mode receiver, high cost 40 GHz electronics and photonics as well as it requires highly sensitive receivers (Sotiropoulos et al., 2013). Due-binary modulation: this scheme is similar to the deployed PON system that uses one wavelength for downstream and another one for upstream. Invest such modulation in the downstream grants the ONUs with 20 GHz bandwidth and reduce the disruption (Nesset, 2015).

Bit interleaving:

This approach employs two wavelengths, one for downstream that supports a 40 Gbps signal and another wavelength for upstream transmission that supports 10 Gbps. Bit interleaving is introduced in the downstream frame where each ONU is pre-assigned an offset and an interval. This technique requires the ONU receiver operating at a rate lower than 40 Gbps. It simplifies the transmission process, reduces power consumption, and reduces the electronic circuitry of the ONU receiver (Luo et al., 2012).

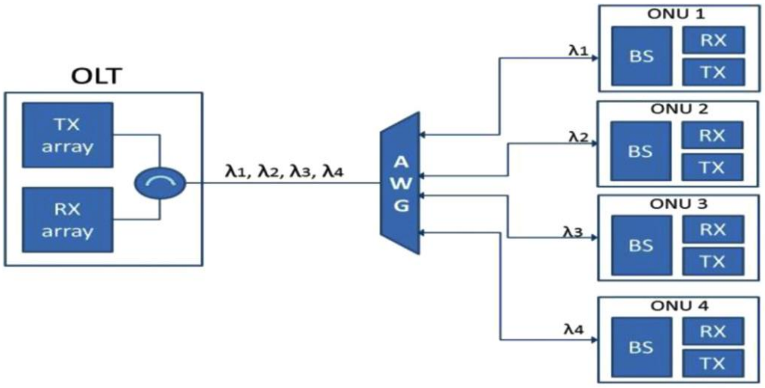
Serial 40G NRZ- 40G serial Non-Return-To-Zero (NRZ): is another approach that has been investigated to increase the capacity of legacy TDM-PON. However, it has a transmission distance limitation due to chromatic dispersion and the associated optical power requirement at the receiver (Srivastava, 2013).

WDM-PON:

WDM-PON has been considered as an alternative technology to TDM-PON. A typical WDM-PON structure is shown in Fig. 9. It provides a virtual point-to-point connection between the OLT and several ONUs; where, each ONU is assigned a different wavelength for transmission.

The major difference between the implementation of WDMPON and TDM-PON is that WDM-PON employs a WDM device in the ODN such as an Array Wavelength Gratings (AWG) instead of a power splitter. This leads to dramatic reduction in the power loss and consequently supports a large number of ONUs (Nesset, 2015). This type of WDM is called Wavelength routed. Each port of the AWG is assigned to a specific wavelength; each transmitter at the ONU transmits a signal on the wavelength that is specified by the port. This architecture offers lower insertion loss and a simple ONU receiver structure. However, the OLT is required to install a standard receiver and a wavelength de-multiplexing device.

Upstream transmission in a WDM loop back structure is achieved by utilizing a single or two fiber link. In the case of a single fiber link, bidirectional transmission of the light and the modulated signal leads to Rayleigh Backscattering (RB) noise. This issue affects the performance of downstream and upstream transmissions and consequently degrades the transmission distance and the receiver sensitivity.



There are several schemes that can be used to mitigate RB noise, for example:

Using phase modulation. In (Chow and Yeh, 2013) the authors claim that the RB noise can be reduced by using WavelengthShifted amplitude-shift keying (WS-ASK) modulation. In addition, the role of phase modulation non return to zero (PM-NRZ) modulation format has been investigated in (Talli et al., 2008) to reduce BR noise which can be farther reduced by utilizing an optical filter.

Using dual parallel Mach-Zehnder modulator (DP-MZM)

Four-wave mixing (FWM).

A key advantage of WDM-PON is that it allows every ONU to transmit at the peak speed as the OLT bandwidth is not shared. Thus, it is capable of supporting a higher data rate (Yoshima et al., 2012; Srivastava, 2013). Another type of WDM-PON is based on splitter and known as WDM-PON wavelength switched in which the power splitter is implemented to distribute incoming signals equally into all ONUs. However, each ONU is required to equip with a wavelength filter to select specific wavelength. Although wavelength switched PON considers simple and distributed structure, its signal loss is higher than wavelength routed PON (Banerjee et al., 2005).WDM-PON is classified into two classes based on the number of wavelengths supported and the wavelength spacing between the individual wavelengths transmitted over a single fiber. The first class is Dense WDM (DWDM) and its wavelength plan is defined by ITU-T G.694.1 and the second class is Coarse WDM (CWDM) and its wavelength plan is defined by ITU-T G.694.2. The main objective of DWDM is to increase the network capacity by minimizing the wavelength spacing; CWDM aims to reduce the cost where the wavelength spacing is sufficiently high to permit the transmitters to be more accurately controlled (Muciaccia et al., 2014; Ragheb and Fathallah, 2011).

In the literature, there are number of approaches that have been proposed to be implemented in WDM-PON. The approaches are discussed below.

1) Externally seeded WDM-PON:

In a wavelength-splitter based ODN, a light source is splitted spectrally and distributed to reflective ONUs. This approach is mature and available with the commercially existing systems. However, the commercially available systems require that the wavelength splitter operate over the power splitter, which imposes the major challenge in terms of link budget. Additionally, the possibility of attaining more than 1 Gbps of data rate is not clear as it exceeds the capability of the current system (Nesset, 2015).

2) Wavelength re-use WDM-PON:

This approach assigns a wavelength to each user for downstream and upstream transmission. The re-use of the wavelength is enabled by the transmitter based on semiconductor amplifier. This amplifier modulates the downstream signal in inverse Returnto-Zero format and the upstream signal in Return-to-Zero format (Nesset, 2015).

3) Tunable WDM-PON:

This approach is based on a low cost tunable transmitter module instead of the conventional module. The reduction of the cost is achieved by removing thermoelectric coolers and the wave-lockers from the conventional modules. Tuning at the upstream is performed utilizing the shared OLT based wave-locker. However, tunable receivers are needed at each ONU to perform colorless function (Nesset, 2015).

4) Ultra-dense Coherent WDM-PON:

This approach is based on coherent detection where the channels are tightly spaced (around 3 GHz). 1 Gbps data rate is allocated to every user utilizing dedicated Quadrature Phase Shift Keying (QPSK) modulated wavelength. However, the transmitters and the receivers are very complex systems and expensive. Thus, more improvements in photonic integration are essential to be used in practical implementation (Nesset, 2015).

5) Self-seeded WDM-PON:

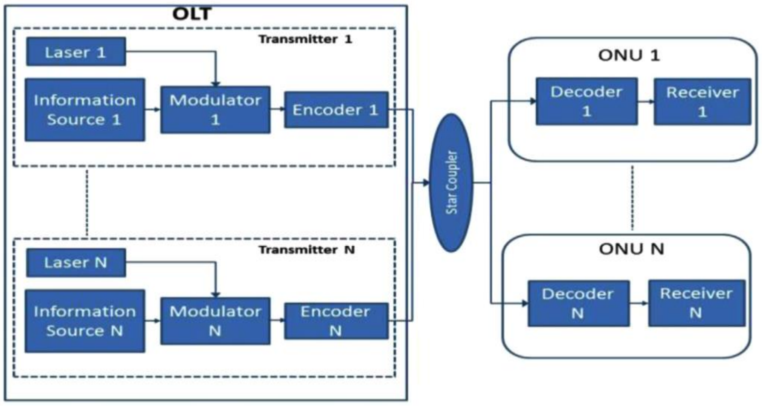
In this scheme, the seed light of the ONU is self-generated by a reflector at the common port of the wavelength splitter. However, the length of the drop fiber (the fiber between the splitter and the ONU) is limited (Nesset, 2015).

OCDM-PON:

Introducing OCDM-PON technology leads to considerable improvements for NG-PON2. The advantages include highly efficient use of bandwidth, good correlation performance, asynchronous transmission, flexibility of user allocation, low signal processing latency as well as improving network security

OCDM can be classified into two main categories: coherent system and incoherent system. In coherent system, OCDM is implemented through a bipolar approach that requires information about the phase of the carriers. On the other hand, the incoherent system is implemented through a unipolar approach. Owing to the simplicity of incoherent hardware as well as its nonreliance on phase synchronization detection, incoherent system has emerged as the preferred detection scheme structure of the OCDM network, which has four main components including transmitter, encoder, decoder, and the receiver. At the transmitter, an information source provides a data bit for a laser at every T second. The encoder then multiplies the data bit "when it equals 1" by a code-word. The code-word can be formed by one-dimensional encoding using the time or wavelength domain or by a two-dimensional encoding scheme, which is a combination of both domains. Yet, recent studies have shown advantages of three dimensional codes .The pulses generated are referred to as chips and have a duration of Tc¼T/n, where T donates the duration of each bit and n denotes the code length.

The multiplexed signal is broadcast to all of the users. The signal arrives at the receiver and passes through the decoder. The decoder matches the code and accepts only the intended user's signal. Then the output of the decoder passes through photodetection and integration. Later, the output power is sampled for each bit interval and compared to the threshold value to provide an estimation of the transmitted .



The performance of the OCDM network is reliant on the performance of the address codes that have been designed to be orthogonal in order to reduce Multiple-Access Interference (MAI) and performance of the receiver structure that must successfully operate in an environment including various noise sources.

OFDM-PON:

OFDM-PON is considered as the most attractive system because of its scalability and ability to provide bit rate up to 40 Gbps per user. OFDM for NG-PON2 is used as multiplexing technique as it is spectrally efficient modulation method. OFDM technique offers flexibility on dynamic bandwidth allocation, enables multiple services, and attains high spectral efficiency. OFDM utilizes a large number of orthogonal subcarriers that are closely–spaced in order to carry traffic. These subcarriers are modulated at a low symbol rate utilizing conventional or advanced modulation techniques.

FDM-PON architecture is similar to the conventional PON. It utilizes two different wavelengths for downstream and upstream transmissions. The OLT generates multiple orthogonal subcarriers that are assigned to different ONUs. Each subcarrier is divided into different time slots. The OLT performs the partitioning process and distribute the total bandwidth over the subcarriers, over the timeslots or on both to different ONUs according to their demand. For downstream transmission, each ONU recognizes its own OFDM subcarriers and/or time slots based on information obtained by the OLT's schedule. For upstream transmission, the OLT works to assemble the sub-frames coming from different ONUs to generate a complete OFDMA frame.

Various benefits can be achieved by applying the OFDM multiplexing technique. Firstly, the total cost is reduced because of the cost of the complex optical modulation at the OLT can be shared between the users. In addition, the ONU implements a simple and inexpensive optical modulation in order to identify data for that ONU. Moreover, OFDM-PON technology helps to reduce the cost by using cost-effective electronic devices instead of optical devices. The overlapping characteristic of OFDM produces no interference which results in the effective utilization of the spectral resources. Furthermore, in comparison with other technologies, OFDM-PON provides a two dimensional bandwidth map with finer granularity, offering flexibility for assigning the bandwidth at different levels.

Despite the enormous advantages of OFDM, some limitations have been identified. OFDM-PON requires complex receivers that are reliant on high speed DSP and FPGAs. Furthermore, OFDM-PON is disadvantaged by noise and a high Peak Average Power Ratio (PAPR). The PAPR issue appears as a result of sinusoidal signals from multiple OFDM subcarriers that interfere constructively in the time domain. This generates a higher amplitude value than the average amplitude value of the signal. The noise is generated as a result of interference when multiple signals from multiple users are detected on the photodiode at the OLT. Such interference leads to performance degradation. Frequency offset is also a disadvantage of OFDM technique which occurs due to mismatch of carrier frequencies.

UNI-PON:

High costs, wastage of resources are the main limitations in the existing multiplexing techniques insist researchers to think about more appropriate and effective methods. Some researchers cameup with the idea of UNI-PON.

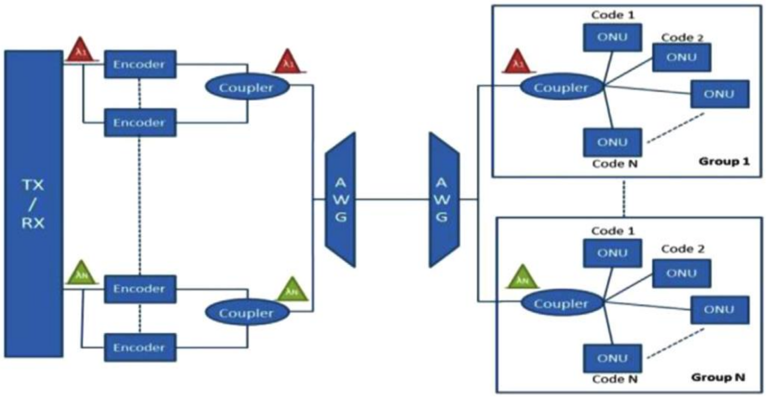
In UNI-PON data manipulation is done at OLT using cloud computing. The advantages of UNI-PON include access of all services for all users, lower cost, and connectivity of radio remote units, multi-rate adjustment, and dynamic bandwidth allocation. a physical layer adaptive algorithm is used to attain multi-rate and dynamic bandwidth allocation. With the rapid advancement in technology the systems should be resilient to adopt future changes. Therefore, UNI-PON can be a suitable choice for future networks.

OCDM/WDM-PON:

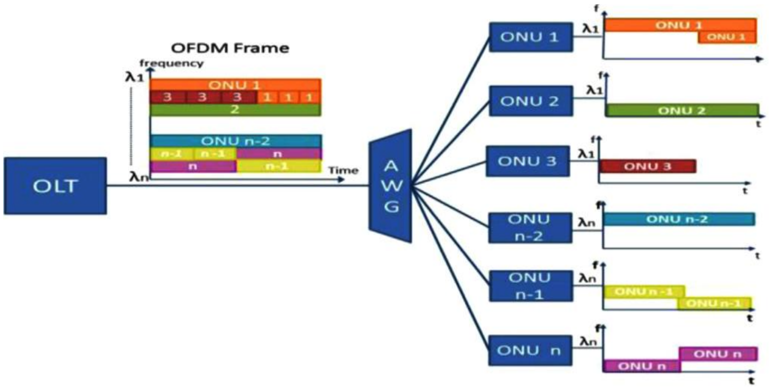
The combination of WDM and OCDM introduces advantages to the network including asynchronous multiplexing, high transmission speed, simplifying the management of the network, supporting a large number of users up to 3000 , reduction in the cost, expand coverage up to 100 km and improvement in the security. Another advantage of OCDM/WDM-PON technology is that it reduces circuitry by eliminating the need of encoder and decoder at each ONU. As it requires just one pair of encoder/decoder at ONU and OLT sides.

OCDM/WDM-PON was proposed as a system that offers symmetric transmission in PON. the basic architecture of OCDM/WDM-PON, which works by superposing OCDM channels over WDM channels. With every WDM grid (1–N), M users could be added using various optical codes. Thus, the total number of users in the network will be N M. The bandwidth offered by one wavelength can be shared between M users and every code in each wavelength can be repeated. However, implementation of such a system would need to upgrade all ONUs, generate cost-effective optical orthogonal code, manage MAI and reduce the spectral due to increment in the network capacity.

In new architecture of OCDM/WDMPON has been presented based on Differential Quadrature Phaseshift Keying (DQPSK). Few advantages of the DQPSK method are large dispersion tolerance, PMD and nonlinearity tolerance, high spectral efficiency, narrower spectrum width, and strong crosstalkresistant capability. The proposed system shows less complex integration process, reduced number of decoder and encoder, smooth upgrade, and seamless integration.



OFDM/WDM-PON:



In OFDM/WDM-PON configuration, a group of OFDM subcarriers are transmitted over a group of wavelengths to different users as shown in Fig. 16. OFDM/WDM-PON is able to increase the capacity of the system up to few Tbps over a long distance providing services for multiple users and offering an efficient use of the bandwidth. In such a system, the generated OFDM subcarriers are modulated optically using a continuous wave (CW). In downstream transmission, all the wavelengths are multiplexed and transmitted through the fiber. A Local Exchange (LE) is needed in order to route and amplify the signals. At the ONUs side, every ONU is tuned to a wavelength, and an OFDM subcarrier. In the upstream transmission, the OFDM subcarrier is tuned to the upstream wavelength. All the wavelengths are integrated and amplified at the LE and transmitted to the OLT .

The challenges in implementing OFDM/WDM-PON are the need for advanced digital signal processing at the transceivers, a high speed converter (Analog to Digital/Digital to Analog), and a fast radio frequency.

The bidirectional hybrid OFDM/WDM-PON presented in has advantages of high bit rate, high spectral efficiency, low effect of RB, and power fading. For downlink, the system uses single side band OFDM. Whereas, for uplink transmission RSOA re-modulation is used. Another approach presented in (Vujicic et al., 2013), describes the experimental results of compatible single side-band (SSB) based technique by using mode locked combo source. After 50 km, the penalty of o1 dB was obtained at BER of 3x10^-3 .

The performance of this technology can be enhanced by decreasing the tunable mode-locked laser (TMLL) free spectral range (FSR).

Stacked WDM/OFDM-PON can also be used to achieve 30.4 dB power budget to support 1:256 split ratio and 25 km range. In the proposed architecture, tuneable band pass filter was used for the selection of downstream and upstream. In OLT, outputs of four DFB lasers are fed into Mach-Zehnder Modulator (MZM) operated by OFDM signals.

XDM/TDM hybrid technologies:

OCDM/TDM-PON OCDM/TDM-PON is a scalable technology that allows multiplexing time intervals over multiple optical codes over a single channel without losing the original line bit rate. OCDM/TDM-PON is able to increase the system capacity up to N 10 Gbps. However, such a system requires additional equipment including one multiport OCDMA encoder/decoder at the OLT and a Super-Structured Fiber Bragg grating SSFBG at every ONU. However, the main drawback of such a configuration is the difficulty of detecting the upstream burst signals.

In a demonstration of OCDM/TDM-PON has been presented focusing on reducing the crosstalk issues neighboring WDM using SSFBG encoder/decoder. This study shows that the crosstalk crosstalk can be negligible with intervals of 200 and 400 GHz. A long reach with 65 km 10G OCDM/TDM-PON has been proposed. The architecture is based on implementing a pair of multi-Port encoder and decoder at the OLT and at the RN instead of t implementing encoder/ decoder at each ONU. The extended reach is achieved by tailoring optical spectrum using narrow band optical band pass filter NBOBPF. The demonstration shows a successful transmission without dispersion compensator.

OFDM/TDM-PON:

OFDM/TDM-PON is another approach that can be considered for NG-PON2. This approach works by dividing each OFDM subcarrier among several services or users for each time slots.

In the author proposes a new architecture that is based on OFDM/TDM for EPONs. This architecture eliminates the delay results from bandwidth allocation process (by sending and receiving the control messages) in the centralized scheme. The architecture is decentralized where the OLT will not be responsible for allocating bandwidth rather each ONU run a bandwidth demand determination algorithm. In this algorithm, each ONU reports its queue status to other ONUs through signaling channel. In a short time, each ONU will be aware of the load of the other ONUs. Accordingly, the load will be calculated and the bandwidth will be allocated dynamically for every cycle.

Hybrid XDM/TDM/WDM:

Hybrid XDM/TDM/WDM is a possible approach that would enhance NG-PON2 performance. Technologies such as WDM/TDM/ OFDM-PON and WDM/TDM/OCDM-PON have been presented in the literature and the nature of the possible hybrid combinations brings forth several advantages including greater dynamic bandwidth allocation flexibility, high scalability and extending the reach up to 100 km The main drawback of this technique is its high cost.

NG-PON2 challenges:

The NG-PON2 is to extend the coverage area, increase the bandwidth, increase the transmission speed, and save cost and energy. Despite the extensive research in developing NG-PON2 technologies, these factors still enforce challenges and remain under questions. In this section, these challenges are addressed and the recent developing progresses are discussed.

Increase the capacity:

One of the most important challenges of NG-PON2 is offering a high bit rate (at least 40 Gbps downstream and 10 Gbps upstream), where each ONU is expected to support a data rate of 1 Gbps. Network capacity can be increased using one of the three techniques discussed below.

Increase the number of wavelengths that are transmitted over the same fiber. This technique can be obtained by utilizing WDM and/or OFDM technologies that were discussed in the earlier sections.

Increase the bit rate supported by each wavelength. This option can be achieved by using "larger signal constellations such as Dual Polarization Quadrature Amplitude Modulation (DP MQAM) or Dual Polarization Modulation Quadrature Phase Shift Keying (DP-MQPSK). Utilizing a modulation technique with a low Signal to Noise Ratio (SNR)" improves performance; however, as a result of the nonlinear Shannon's limit an increase in the data rate is also constrained. Additionally, this technique is considered expensive due to the use of the transponder that increases the cost by a factor of "2 or 2.5 with each fourfold increase in bit rate".

Nonlinearity compensation. The capacity of the fiber is restricted by the nonlinearities. "In the absence of noise, a single channel signal is limited by Self-Phase Modulation (SFM). Whilst, WDM systems are restricted by cross-phase modulation (XPM) as well as Four-Wave Mixing (FWM). The Nonlinear Schrodinger Equation (NLSE) is deterministic; this means that SPM, XPM, and FWM could be compensated with DSP" techniques that might become practical as a result of the capacity improvement; consequently, the system strives to obtain the highest capacity achievable.

The approaches described are discussed in the literature as possible avenues that might lead to an increase in the network capacity. However, all of these approaches utilize advanced modulation formats. Modulation schemes being investigated include Quadrature Amplitude Modulation (QAM), Phase Modulation Quadrature Phase Shift Keying (PM-QPSK), Polarization multiplexing, and OFDM. Among these, PM-QPSK with a coherent receiver is the most popular modulation scheme in the industry

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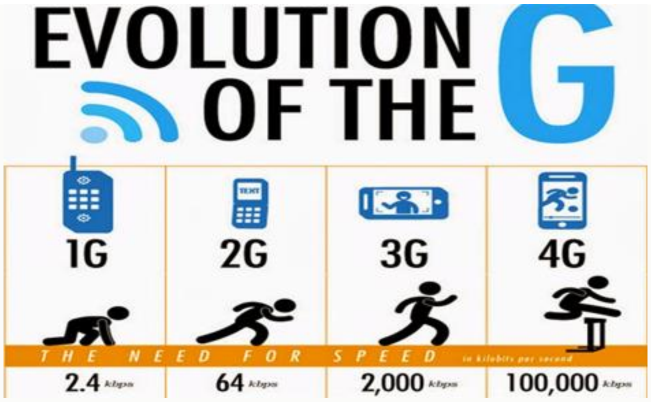
Ans 3 :



1G, 2G,...& 5G: The evolution of the G's

Telecommunication and networking has been and will be one of the core technologies in helping the evolution of mankind and technology itself. If it wasn't for it for these channels of communications and data transmission, we would probably still be in an era where technology isn't as advanced as today.

Wireless communication technology inside cell phones and other mobile devices has evolved over several decades. Starting with the then revolutionary 1G (referred to as the earliest form of voice only network) all the way to the 4G of today and the 5G of the near future. But what has really changed? and what is the core driving principles of these wireless communication technology?

First off, the G in "4G" or "5G" stands for generation and the number is just a representation of the evolution of technology. Currently, as you may know, we are using the 4th generation of wireless communication technology. But lets start from where it all began:

1G: Where it all began

The first generation of mobile networks – or 1G as they were retroactively dubbed when the next generation was introduced – was launched by Nippon Telegraph and Telephone (NTT) in Tokyo in 1979. By 1984, NTT had rolled out 1G to cover the whole of Japan.

In 1983, the US approved the first 1G operations and the Motorola's DynaTAC became one of the first 'mobile' phones to see widespread use stateside. Other countries such as Canada and the UK rolled out their own 1G networks a few years later.

However, 1G technology suffered from a number of drawbacks. Coverage was poor and sound quality was low. There was no roaming support between various operators and, as different systems operated on different frequency ranges, there was no compatibility between systems. Worse of all, calls weren't encrypted, so anyone with a radio scanner could drop in on a call.

1G and 2G

There never was something called as 1G at first. It basically was a network with only voice call capabilities and only got the name 1G after 2G was put to use. During the 2G era, that lasted for quite a while from 1980's to 2003, there were quite a few advancements made within the spectrum itself such as GSM, GPRS and EDGE.

- GSM: Short for *Global Systems for Mobile Communication e*nabled data transfer on top of voice communication at speeds that are seen as a joke today (30-35 kbps). It played a critical role in the evolution as mobile technology as right about the time it was being used mobile phone connectivity and popularity exploded.
- GPRS: *General Packet Radio Service* operated on the similar 2G technology as GSM with a few refinements with gave it higher data speeds (110 kbps)
- EDGE: *Enhanced Data rates for GSM Evolution* introduced in 2003 was somewhat known to be 2.9G or 3G due to its significant advancements over GPRS and GSM. It offered high speeds of 135 kbps and continues to be used on many mobile networks even today as is satisfies the basic needs of both carriers and users in various parts of the world.

3G

This was a big revolution in terms of technological advancement for network and data transmission. 3G had and has speed capabilities of up to 2 mbps. It enabled smartphones to provide faster communication, send/receive large emails and texts, provide fast web browsing, video streaming and more security amongst others. It was widely based on CDMA2000 (Code-division multiple access) and EDGE technologies. Now you might wonder why EDGE? Well, because EDGE was so advanced it was able to provide enough capabilities to be considered as 3G. CDMA2000, on the other hand, operated on similar key concepts but did it better. It enabled multiple channels to communicate at one same thus improvising on the over speed and connectivity.

3G was launched by NTT DoCoMo in 2001 and aimed to standardize the network protocol used by vendors. This meant that users could access data from any location in the world as the 'data packets' that drive web connectivity were standardized. This made international roaming services a real possibility for the first time.

3G's increased data transfer capabilities (4 times faster than 2G) also led to the rise of new services such as video conferencing, video streaming and voice over IP (such as Skype). In 2002, the Blackberry was launched, and many of its powerful features were made possible by 3G connectivity.

4G

The 4G standard sets several requirements for mobile networks

including mandating the use of Internet Protocol (IP) for data traffic and minimum data rates of 100 Mbps. [LifeWire] which was a huge jump from the 2 mbps for 3G. It is often referred to as MAGIC

- M – Mobile multimedia
- A – Anytime anywhere
- G – Global mobility support
- I – Integrated wireless solution
- C – Customized personal service

It is not much to do with the technology it uses but rather than the requirements set forth by International Telecommunication Union's Radio communication Sector (ITU-R). These standards are known as International Mobile Telecommunications-Advanced (IMT-Advanced). The list of standards is quite complicated and thus were a barrier in fast adoption of the 4G spectrum.

Soon after 4G, 4G LTE was introduced. LTE stands for Long Term Evolution and it isn't as much a technology as it is the path followed to achieve 4G speeds. It was a complete redesign and simplification of 3G network architecture, resulting in a significant reduction in transfer latency and thus, increasing efficiency and speeds on the network.

The catch was that while transitioning from 2G to 3G was as simple as switching SIM cards, mobile devices needed to be specifically designed to support 4G. This helped device manufacturers scale their profits dramatically by introducing new 4G-ready handsets and was one factor behind Apple's rise to become the world's first trillion dollar company.

5G

It is still quite in its early stages and the the technology likely to appear in the market only by 2020 at the earliest. Goals for future 5G include significantly faster speeds (a minimum of 1 Gbps and perhaps up to 10 Gbps) plus lower power requirements to better support huge numbers of new Internet of Things (IoT) devices. It will have capabilities to provide faster dialing speeds, multiple device connectivity, higher data speeds just to name a few.

During an interview with Tech Republic, Kevin Ashton described how he coined the term "the Internet of Things" – or IoT for short – during a PowerPoint presentation he gave in the 1990s to convince Procter & Gamble to start using RFID tag technology.

The phrase caught on and IoT was soon touted as the next big digital revolution that would see billions of connected devices seamlessly share data across the globe. According to Ashton, a mobile phone isn't a phone, it's the IoT in your pocket; a number of network-connected sensors that help you accomplish everything from navigation to photography to communication and more. The IoT will see data move out of server centers and into what are known as 'edge devices' such as Wi-Fi-enabled appliances like fridges, washing machines, and cars.

Conclusion

There has been a lot of advancements in the field of wireless network communication over the years in terms of overall development and change in core functionality, which has been crucial to put us in a era that is driven by technology all around us and with 5G a couple years away, technologies such as IoT, Cloud computing and AI will completely redefine our world by 2025.

Ans 4 :

The two integral parts of the VLC system: the transmitter and receiver generally consist of three common layers. They are the physical layer, MAC layer and application layer. The reference model of the VLC communication system is shown in Fig. 11 [23]. In IEEE 802.15.7, only two layers (such as PHY and MAC) are defined for simplicity.

MAC layer:

The tasks performed by Medium Access Control (MAC) layer include:

(1) Mobility support,
(2) Dimming support,
(3) Visibility support,

(4) Security support,
(5) Schemes for mitigation of flickering,
(6) Color function support,
(7) Network beacons generation if the device is a coordinator,
(8) VPAN disassociation and association support,
(9) Providing a reliable link between peer MAC entities.

The topologies supported by the MAC layer are peer-to-peer, broadcast and star as illustrated in below (Fig), The communication in the star topology is performed using a single centralized controller.

All the nodes communicate with each other through the centralized controller as shown in Fig. below.

The role of the coordinator in the peer-to-peer topology is performed by one of the two nodes involved in communication with each other as illustrated in Fig.below.

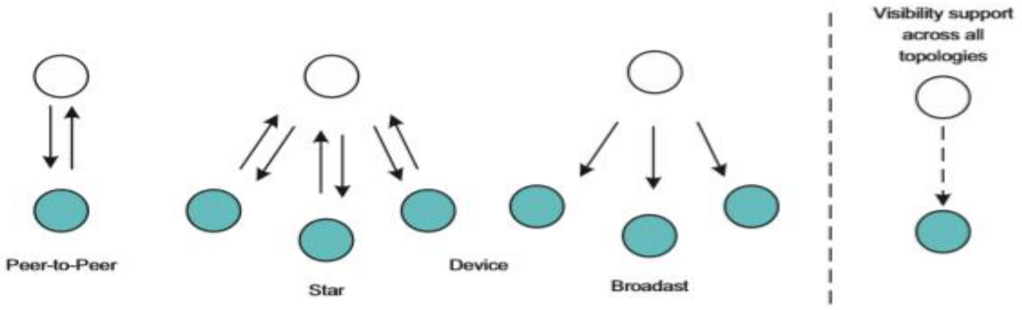


Fig. 10. Supported MAC topologies by IEEE 802.15.7 [25].

Physical layer:

The Physical layer provides the physical specification of the device and also, the relationship between the device and the medium. Fig. 12 shows the block diagram of the general physical layer implementation of the VLC system. First of all, the input bit stream is passed through the channel encoder (optional). Linear block codes [26], convolutional codes [27] and the state of the art turbo codes [28] can be used to enhance the performance of the VLC system. Then, the channel encoded bit stream is passed through the line encoder to yield the encoded bit stream. After line encoding, modulation (such as ON–OFF keying, PPM and PWM, etc.) is performed and finally, the data is fed to the LED for transmission through the optical channel.

Different implementations of the visible light communication systems are given. In [29], a full-duplex bi-directional VLC system utilizing RGB LEDs and a commercially available phosphor-based LED in downlink and uplink, are proposed respectively. Wavelength Division Multiplexing (WDM) and Subcarrier Multiplexing (SCM) are used to achieve the bi-directional transmission. Furthermore, Orthogonal Frequency Division Multiplexing (OFDM) and Quadrature Amplitude Modulation (QAM) were employed to increase the data rate. The speed of the VLC system in [30] was increased to 3.75vGb/s as compared to that in [29] which was 575Mb/s downlink and 225Mb/s uplink. At the receiver side, the receiver (such as a silicon photo diode and PIN photodiode) received the optical signal. After demodulation and line decoding, the bit stream passed through the channel decoder to yield the output bits.

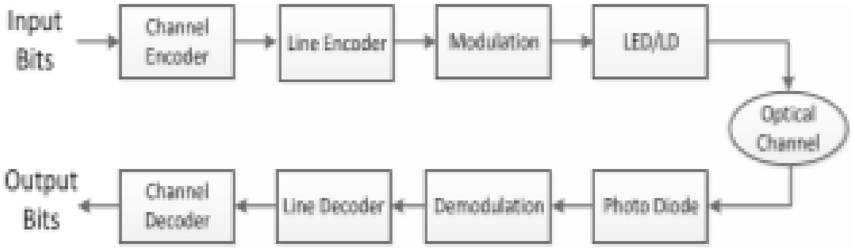


Fig. 12. Typical physical layer system model of VLC.

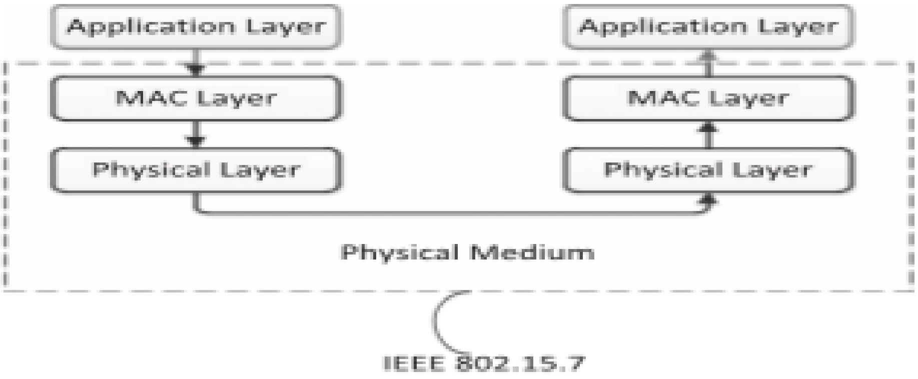
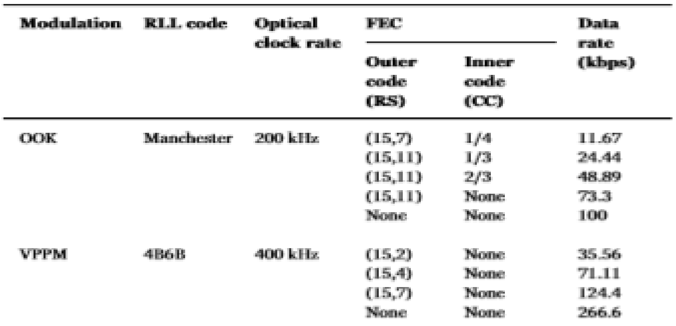


Fig. 11. Layered architecture of VLC.

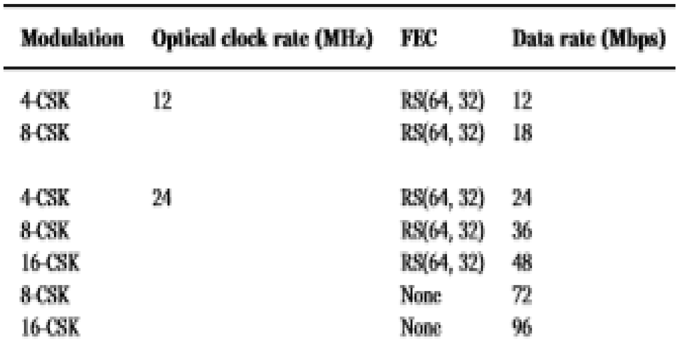
Three different types of physical implementations of VLC are given in IEEE 802.15.7. The operating range of PHY I, PHY II and PHY III are 11.67–266.6 kbps, 1.25–96 Mbps and 12–96 Mbps, respectively. The different channel coding schemes supported by 802.15.7 are listed in Table 1, Table 2 and Table 3 [25]. Convolutional codes and Reed Solman (RS) codes are used by the PHY I because of its design for outdoor use and PHY II (intended for indoor use) provides support for Run Length Limited (RLL) code to address flicker mitigation and DC balance. The different optical rates and data rates provided by IEEE 802.15.7 are also listed in Table 1, Table 2 and Table 3.

Table 1
PHY I operating mode specifications [25].



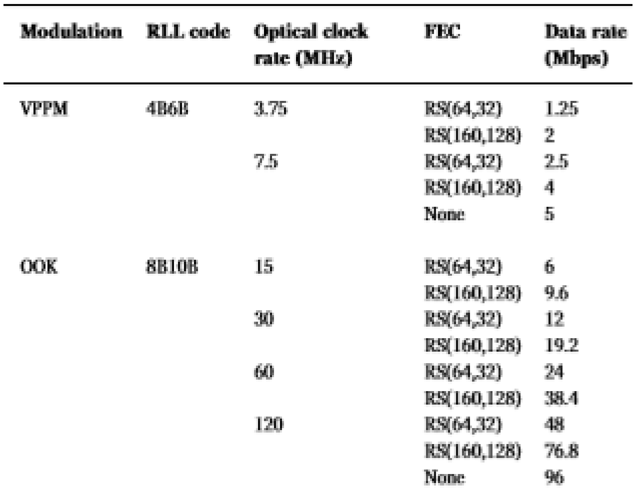
Modulation	RLL code	Optical clock rate	FEC		Data rate (kbps)
			Outer code (RS)	Inner code (CC)	
OOK	Manchester	200 kHz	(15,7)	1/4	11.67
			(15,11)	1/3	24.44
			(15,11)	2/3	48.89
			(15,11)	None	73.3
			None	None	100
VPPM	4B6B	400 kHz	(15,2)	None	35.56
			(15,4)	None	71.11
			(15,7)	None	124.4
			None	None	266.6

Table 3
PHY III operating mode specifications [25].



Modulation	Optical clock rate (MHz)	FEC	Data rate (Mbps)
4-CSK	12	RS(64, 32)	12
8-CSK		RS(64, 32)	18
4-CSK	24	RS(64, 32)	24
8-CSK		RS(64, 32)	36
16-CSK		RS(64, 32)	48
8-CSK		None	72
16-CSK		None	96

Table 2
PHY II operating mode specifications [25].



Modulation	RLL code	Optical clock rate (MHz)	FEC	Data rate (Mbps)
VPPM	4B6B	3.75	RS(64,32)	1.25
			RS(160,128)	2
		7.5	RS(64,32)	2.5
			RS(160,128)	4
			None	5
OOK	8B10B	15	RS(64,32)	6
			RS(160,128)	9.6
		30	RS(64,32)	12
			RS(160,128)	19.2
		60	RS(64,32)	24
			RS(160,128)	38.4
		120	RS(64,32)	48
			RS(160,128)	76.8
			None	96

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