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Recent Advancements in High Speed Optical Networks

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Abstract-An attractive feature for future optical networks is the ability to process information entirely in the optical domain for the purpose of amplification, multiplexing, de-multiplexing, switching, filtering, and correlation. In such networks, all signals processed in the optical domain, without any form of electrical manipulation. Advances in technology have enabled more data to be conveyed through a single optical fiber over long distances.

1. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

With the rapid growth of digital communication in recent years, the need for high speed data transmission is increased. Moreover, future wireless systems are expected to support a wide range of services which includes video, data and voice. Orthogonal Frequency Division Multiplexing (OFDM) is a promising candidate for achieving high data rates in mobile environment because of its multicarrier modulation technique [1]. OFDM is a unique instance of multicarrier transmission, where a single data stream is transmitted over various lower-rate subcarriers (SCs). One of the principle motivations to utilize OFDM is to increase robustness against frequency selective fading or narrowband interference. In a single carrier system, entire link can fail even if a single fade or interferer can occur, but in a multicarrier system, only a small percentage of the SCs will be affected [2]. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the bandwidth into many carriers; each one is modulated by a low rate data stream. In term of multiple access technique, OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users [3]. OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. OFDM converts a frequency-selective channel into a parallel collection of frequency flat subchannels. The subcarriers have the minimum frequency separation required to maintain orthogonality of their corresponding time domain waveforms.

2. OPTICAL CODE DIVISION MULTIPLE ACCESS (OCDMA)

With the help of OCDMA technique, we can combine the gains extracted from CDMA technology and fibers enormous bandwidth, to achieve high-speed seamless connectivity. The last decade has seen huge development in optical based networking, which includes dense optical networking such as Wavelength Division Multiplexing and Code Division Multiple Access. Optical version of these technologies known as OCDMA has left huge impact on the real time networking to satisfy user's needs. Optical CDMA permits various users to access the network resources asynchronously, capability to support flexible data rate and bursty traffic and privacy in communication [4]. The OCDMA network comprises: encoding, decoding, types of codes and nature of codes. Most commonly used codes in communication are bipolar and unipolar. In bipolar type of codes, for the purpose of encoding the data, both negative and positive levels are considered whereas in the case of unipolar scheme only single level i.e. positive level is earmarked. Optical communication systems generally employ unipolar codes because optical power is required to convey the information and the point with optical power is that it can never be made negative. On the other hand RF communication systems generally use the bipolar codes, as voltage levels are used to convey the information and voltage can either be negative or positive [5].

The advantages of Optical CDMA include its easy and smooth functioning and it has emerged as a strong option to ultra-high speed LANs. Here it is never required to have full control over time and frequency components for the communication. In addition to its ability to transmit asynchronously without any overlapping of data, gives it a definite edge over its competitors [6]. Every user channel in OCDMA network is known by an exclusive signature sequence code and as such achieved multiplexing gains are high. As compared to TDMA and WDMA, where the communication capability can only be increased with the increase in total number of time or wavelength channels, OCDMA permits flexibility of network design because here effective code generation decides the number of supported subscribers in a network i.e. approach is soft-limited and hence is more user friendly than TMDA and WDMA.

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3. PASSIVE OPTICAL NETWORK (PON)

In passive optical networks, the optical signal is switched through passive splitters. Passive splitters do not require external power source for their operation. Also, these networks require N+1optical transceivers and there is no need of electro–optical conversion. This technology ensures to support the upcoming interactive multimedia services. PONs topologies are classified as Point to Point and Point To Multipoint topologies. In point to point topology, there is direct fiber link between central office and end user, which is very expensive [7]. To reduce the installation costs, point to multipoint architecture is used where different users transmit/ receive data using single fiber link. Various standards have been recommended for passive optical networks. The main PON technologies are standardized as the Broadband PON (BPON) ITU-T G.983, Gigabit PON (GPON) ITU-T G.984 by International Telecommunication Union (ITU) and Ethernet Passive Optical Network (EPON) IEEE 802.3 by IEEE (Institute of Electrical and Electronics Engineers).

3.1 SWITCHING IN PASSIVE OPTICAL NETWORKS

The collection of devices that subscribers employ for communication is known as station. A network is a set of interconnected stations with transmission paths. For data transmission from source to destination, switching is used. To perform the switching in PONs, switches are used. A switch is a device to establish temporary connections between the devices to provide a link for communication between them [8]. The three main types of switching are as follows:

3.1.1. Packet Switching

The packet switching is a connectionless switching. The information is sent in the forms of packets. So, the permanent connection or reserve path/ bandwidth is not required for this type of switching. Also, the time is not fixed for processing of packets i.e. they can transmit at any time. The allocation is performed on first come, first serve basis. The packet switching is of two types:

A. Datagram Switching: In this type of switching, the packets are sent out independently called as datagrams. The network treats each datagram as individual even if it is a part of a multi packet transmission.

B. Virtual Circuit Switching: The virtual switching has both type of advantage of circuit switching and datagram switching. In this, firstly a virtual connection is established and then information is sent in the form of packets. All the packets having identical source and destination will move through the same link path. Due to resource allocation is on demand; it may be possible that the packets will arrive at the destination with different delays [9].

3.1.2 Circuit Switching

In the circuit switching, firstly a connection is established and then data is transmitted from source to destination at the physical layer. The permanent link is established up to the completion of data transfer entirely. Information transferred between the source and destination is not packetized. There is a continuous flow of information between the source and destination station in a scheduled time, although there may be periods of silence. The main advantage of circuit switching is that there is no requirement of header (for addressing) during data transfer [10].

3.1.3 Cell Switching

In the packet switching, the size of the packet may vary upto 65000 bytes. This size is too large to send. Also, this switching is not economical to send such type of packet as loss of data can be possible. Cell switching is used to overcome this problem. In the cell switching, the information is sent in the form of small packets. In this the packet size is as small as of 53 bytes. This switching is also connectionless switching and provides a high speed of 155.52 Mbps [11].

4. RADIO-OVER-FIBER TECHNOLOGY

Due to various limitations such as geographical condition, economical balance, provider's strategy and damage situation in the case of disasters high-speed connections based on an optical fiber such as a fiber to the home cannot always be deployed everywhere. Therefore, a radio transmission link is considered for aggregating large network traffics, which has prior characteristics in system deployment, such as flexible arrangement and easy installation. So integration of optical and wireless network is done to provide sufficient bandwidth to individual users. This network is called Radio-over-Fiber (RoF) technology [12]. The United States introduced the integration of wireless and optical fiber in the early 1980s, to accommodate military requirements, such as radar systems where optical fiber were utilized as an interface between the central station (CS) and the wireless antenna. In order to meet ever increasing user bandwidth and wireless demands in broadband, interactive and multimedia wireless services RoF technology has been proposed as a promising cost effective solution. RoF is an analog optical link to transport information over optical fiber by transmitting modulated RF signals to and from central station to base station or Remote Antenna Unit (RAU). This modulation can be done directly with

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the radio signal or at an intermediate frequency. In other words, radio over fiber means to transport information over optical fiber by modulating light with the radio signal.

The use of radio-over-fiber to provide radio access has a number of advantages including low attenuation, large bandwidth, immunity to radio frequency interference, reduced power consumption, multi-operator and multi-service operation, dynamic resource allocation etc. RoF applications range from mobile cellular networks, wireless local area network (WLAN) at mm-wave bands broadband wireless access networks to road vehicle communication (RVC) networks for intelligent transportation system (ITS) [13]. For reducing the deployment and maintenance costs of wireless networks while providing low power consumption and large bandwidth, the RoF system seems to be a promising solution that will make extensive use of many communication standards, such as wireless local area networks (also known as Wi-Fi), digital video and audio broadcasting standards, digital subscriber loop (DSL) and Worldwide Interoperability for Microwave Access (WiMAX).

A radio system enables the significant mobility, flexibility and easy access. Therefore, the system integration can meet the increasing demands of subscribers for voice, data and multimedia services that require the access network to support high data rates at any time and any place inexpensively. RoF has the potentiality to the backbone of the wireless access network and it has gained significant momentum in the last decade as a potential last-mile access scheme. RoF serves as a high speed wireless local or personal area network. The frequencies of the radio signals distributed by RoF systems span a wide range (usually in the GHz region) and depend on the nature of the applications [14]. In RoF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. Most of the signal processing processes (including coding, multiplexing, and RF generation and modulation) are carried out by the Central Office (CO), which makes the Base Station (BS) cost-effective. Each base station is adapted to communicate over a radio link with at least one user's mobile station located within the radio range of said base station. Therefore, RoF will become a key technology in the next generation of mobile communication system.

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