New Ethernet Based Optically Transparent Network for Fiber-to-the-Desk Application

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ABSTRACT

We present a new optical local area network architecture based on multimode optical fibers and components, short wavelength lasers and detectors and widely used Fast Ethernet protocol. Presented optically transparent network represent a novel approach in fiber-to-the-desk applications. It is made to minimize the costs associated with a passive optical LAN implementation. The biggest issues in the realization of the network were the synchronization of bursty traffic and the collision detection. We present here in details the solution for the synchronization problem by introducing an analog sinusoidal carrier that is in addition to data signal only sent during the data packet duration. The extraction of data and the synchronization signal is made by using a simple filtering facilitating the receiver realization.

Keywords: Optically Transparent Network, Fiber-to-the-Desk, Fast Ethernet, Burst-traffic synchronization.

1. INTRODUCTION

The boom of Telecom industry at the end of the last century actuated by the extensive growth of Internet traffic led to massive deployment of the fiber but mostly in core and metropolitan networks. In order to reduce the created overcapacity in these networks and put more investments into this area Telecom companies are trying to find the best way to bring broadband access to users in offices within large companies, schools, at homes, etc. Having reliable local area networks (LANs) is an important issue since these networks often play a vital role in the communications within an organization. This role can be so dominant that the company's success completely relies on it.

A problem that network designers often encounter is that most of the times networks have to operate in environments that are "polluted" by interfering electromagnetic radiation, for example power plants, airport buildings, some military facilities etc. In these environments running copper could result in long packet delay and inherently low throughput. Optical fibers, on the other hand, offer an excellent non-emissive transmission medium and at the same time are completely insensitive to incoming radiation.

Although some practical proposals for optical local area and access networks and their realizations are available, the copper interconnects still run to most desktops due to economical reasons since the price of optical and opto-electrical components, places a strong barrier to massive deployment of optical networks. Finding new fiber-to-the-desk (FTTD) solution that will minimize the overall cost of the optical network and still offer a good performance is a challenge for many researchers nowadays.

In this paper we present an optically transparent network architecture that is expected to bring users a large bandwidth offering a better performance than copper-based networks: less downtime, lower maintenance cost, extended geometrical spans and larger headroom for future capacity increase. This LAN that represents a novel approach in fiber-to-the-desk (FTTD) application is based on most widely used Fast Ethernet protocol offering the upgrade possibility using Gigabit Ethernet.

To achieve affordable application of optical transmission in the LANs we have used multimode fibers, which are less vulnerable for misalignment and dust particles and short wavelength components to make the system more economically attractive. LDs and VCSELs operating at 850 nm are cheaper than lasers operating at 1300 nm and 1550 nm. Moreover they offer the possibility to integrate a Si photodiode with the receiver front-end using straightforward CMOS technology [1]. Furthermore, integrated multimode optical devices based on polymers are used that potentially can be realized at low costs [2]. Moreover, fiber-to-the-optical chip coupling is facilitated using those devices since they contain larger waveguides that commensurate multimode fiber cores.

2. NEW FIBER-TO-THE-DESK ARCHITECTURE

To facilitate a smooth transition from existing copper-based networks to future optical LANs we have chosen Ethernet technology since it is the most successful networking technology till now and is expected to remain so for the coming years. It has been deployed in nearly every corporate and campus network [3]-[5]. The use of Ethernet technology provides low-costs and high performance architectures.

Proposed optically transparent network is presented in Fig. 1.

Figure 1. Optically transparent LAN for FTTD application based on multiple single-wavelength optical stars using deferent wavelength for each star.

The segmentation of the network is done by means of coarse WDM. The configuration of the network is a star, segmented in mini-stars, which offers geographical advantages. Each segment of the LAN uses its own specific wavelength in the range of 790-850 nm. A common signal transfer path to the router is created by inserting a multi-mode coarse WDM (de-)multiplexer. In this way cabling length is reduced. An extra cabling saving can be accomplished by using one fiber for both transmission and reception of the signals but at the cost of introducing extra 1x2 star couplers close to the end nodes. Performance analysis of this network showed that we can achieve a network span that is equal to the maximal fiber length in the 100BASE-LX standard (412 m), thus more than 100 m larger than the fiber length prescribed in the 100BASE-SX. The stability requirements for the LDs and VCSELs are not so stringent since we use multimode fibers and the wavelengths are not so densely packed as in PSTN applications.

To enable Fast Ethernet protocol to run on this network changing of the Physical Layer in the ISO-OSI model is required. However, the Medium Access Control (MAC) Layer and the upper ones should remain unaltered, so that the network realization is facilitated and the overall cost decreased. Such a realization is supported by the Medium-Independent Interface (MII) between the MAC and the Physical Layer, by means of which several different Physical Layer Devices (PLD) can work on the same Network Interface Card (NIC) equipped with MII interface [6].

The main problems to be solved in making this new PLD are synchronization and collision detection. Collision detection has been solved by using a special construction of the multimode star coupler [7], and two bias currents at the transmitting side.

Synchronization of bursty traffic is solved by introducing a sinusoidal synchronization carrier that is sent through the fiber together with the data packet switched on and off with it.

3. SYNCHRONIZATION OF BURSTY TRAFFIC

Since our architecture is based on passive star couplers we have really a common shared medium for the signal transmission, inherited from the original 10BASE-T Ethernet standard in contrast to 100BASE-T Fast Ethernet where each user has a separate path to a bridge or a switch. In the latter, synchronization is facilitated since continuous transmission between the end node and a bridge or a switch can be maintained. When no packets are transmitted the IDLE signal is transmitted for synchronization. On the other side, having really a shared medium in our new architecture excludes this possibility, and we had to find a solution for the synchronization of bursty traffic.

Since the power spectral density of the 4B/5B NRZ-I encoded data signal that is to be transmitted on the fiber is Sinc squared shaped, with the first null at the signaling rate of 125 MHz, this gives us an opportunity to introduce a sinusoidal carrier at this frequency from which the clock signal has been made. This is presented in Fig. 2. To separate the synchronization and data signals we use bandpass and low pass filters, respectively, having in mind that more than 95 % of the data signal power is contained in the spectrum between the frequencies of 0 and 0.75 times the data rate.

At the transmit side, sending the synchronization signal requires that the laser operating point always lays around the middle of the linear part of the P-I curve. On the other side, when there is no data packet to be sent, the operating point must be just above the lasing point such that very low power is transmitted to facilitate

collision detection.

A solution to this problem has been found in having two bias currents, which is presented in Fig. 3. One will set up the operating point when there is no data to be transmitted (I_{bias1}), and the other, (I_{bias2}), when data is transmitted. Since both currents will be larger than the threshold current, transition from one bias point to another is fast enough to satisfy specifications. This transition is activated by using the TX_EN signal coming from the MAC Layer.

Figure 2. Power spectral densities of the NRZ-I encoded signal and synchronization signal.

Figure 3. Direct modulation of the laser with added data and synchronization signals.

4. EXPERIMENTS AND DISCUSSIONS

Digital data coming from the MAC Layer is processed in the digital part of the transmitter in our new PLD. Processed serial data output is in the analog part of the transmitter added to the DC current (increased to I_{bias2}) and the synchronization signal. The total signal (data+synchronization signal+DC), which is presented in Fig. 4, is used to modulate the light source.

A bandpass filter that is used for clock recovery is a SAW filter with a 3 dB bandwidth of about 3 MHz, which corresponds to the measured response time of about 400 ns. This is very important for clock extraction since we have to achieve synchronization within the first 480 ns of the data packet. A measured response of the filter on the input synchronization signal is presented in Fig. 5.

The analog 125 MHz signal is after filtering supplied to the limiting amplifier. The clock signal obtained at the output of this amplifier is delayed such as to become in phase with the digital data and brought to a decision circuit for data extraction. Extracted clock and data signal, along with the carrier sense signal, are further processed in the digital part of the receiver before they are transported to the MAC Layer via the MII interface.

5. CONCLUSIONS

In this paper we presented the network architecture that is expected to minimize the costs associated with a passive optical LAN implementation for FTTD application. This architecture is based on the short-wavelength optical light components, multimode integrated devices and fibers and Fast Ethernet protocol. Moreover we

presented how the synchronization of bursty traffic can be solved by introducing a switched inband sinusoidal carrier.

Figure 4. The upper signal depicts two bias levels, synchronization signal and data (preamble) at the output of the transmitter. The lower signal TX EN activates the transmission.

Figure 5. (a) The response (lower trace) of the bandpass filter on the synchronization signal (upper trace), (b) zoom-ed version of the signals at the moment the synchronization is achieved.

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