OPTICAL FIBRE COMMUNICATION EVOLUTION AND RESEARCH OPPORTUNITIES

M. Marciniak

National Institute of Telecommunications, Warsaw, Poland

Introduction

Actually the basic concept of communication networks is a subject of revolutionary change from classical circuit switched, connection - oriented networks to modern packet switched, connectionless transmission of data [1]. In fact this is driven by the dramatic expansion of Internet users worldwide. Efficient broadband global networking is a crucial requirement for the future Information Society needs for a seamless personal access to broadband services, for everybody to anybody and from any location to any destination and at any time. Following the ITU Next Generation Networks (NGN) 2004 initiative a seamless global access for fixed, mobile, and nomadic users is claimed for [2].

The technology of conventional connection-oriented voice networks has been developed during last century already and actually it is in a mature state. Terabit per second total throughput via optical fibre transmission links is a reality with the use of ATM/SDH (asynchronous transfer mode / synchronous digital hierarchy) over WDM (wavelength - division multiplexing) technologies. In addition, the transparent optical transmission at distances of thousands kilometres become a reality with the advent of optical fibre amplifiers.

Although the optical fibre communications still face a number of technological difficulties and physical constraints with CD (chromatic dispersion), PMD (polarisation mode dispersion) and nonlinear optical interactions as classical examples, it is still the best technology to achieve terrestrial global networking. However, a serious drawback of that technology is the lack of mobility features. In this paper a suitable combination of optical and wireless technology is addressed and discussed.

Packet traffic is the basis of Internet principle. It has a statistic nature, so in some moments of time and network points the flow of data might be much higher that the network equipment is able to handle. This means that some data have to be stored in buffers, and if available buffer capacity is insufficient, then some data have to be sacrificed, they are lost. This statistical phenomenon is called the burst of the packets and it has provoked an effort in the search for the suitable means to cope with [3]. Thus, a major problem to resolve is the Quality of Service (QoS) for a packetised traffic which faces the packet delay and especially loss of packet probability as a key challenge [4].

For some applications this is still not a critical situation since the missing data can be retransmitted. But usually retransmission is not allowed for real-time transmission, like voice or video. Nevertheless, even thought actually we design the networks to be over-provisioned, i.e. with potential performance characteristics much better that actually needed, one could easily imagine an immense and impossible to handle data flow generated by computer viruses or malicious attacks, and a complete blocking of the network resulting from.

Here we propose a combination of different technologies as connection and connectionless networks, optical cable and wireless (microwave/millimetre wave or optical wireless) suitable for a variety of purposes and services in order to achieve global broadband networking features. In addition to our recent proposal of a hybrid connection and connectionless networks superimposed on the top of a physical WDM layer, on different optical wavelengths, our new network model contains an extension to wireless world in order to achieve mobility and personalisation of the connection. From the network point of view it contains an upgrade of real-time traffic with the microwave modulated optical wave, in order to carry out conventional mobile wireless via optical fibres though long distances and without a significant distortion.

Transparent optical networking

The notion of transparency of a transmission link (not necessarily optical) is much older than optical fibre communications. Its primary meaning was that the output signal is proportional to the signal at the input of a link. Consequently, the transparency is rather an analogue feature of a link. The advent of Erbium-Doped Fibre Amplifiers in early 90s was a decisive step towards transparent optical networking [4].

An ideal transparency is not realisable in a optical fibre network, since even an ideal glass fibre exhibits attenuation, chromatic dispersion of the first and higher orders, and glass optical nonlinearities. Moreover, in real fibres Polarization Mode Dispersion (PMD) results from random local lack of circular symmetry of the fibre due to technology imperfections and local stresses caused by cable layout. Those analogue features of a fibre result in distortion, crosstalk, and noise of the transmitted optical signal.

Wireless mobile networking evolution

Wireless technology has been developed during last decade for the mobile access to the network. New increasing frequency bands are exploited in view of transmission capacity and reliability, the 60 GHz band is an example. While microwave and millimeter wave links have excellent mobility characteristics that is impossible to achieve for other transmission media (wireless optical links have very poor performance if compared with microwave ones), they still suffer from a number of constraints, most of them resulting from EMC (electromagnetic compatibility) requirements, in order to avoid the interference and the crosstalk resulting from. Also the wireless links suffer from the attenuation of the signal due to air characteristics, weather, smog, and the local shape of terrain or the occurence of trees and buildings. The line of sight between the transmitter and receives is usually an essential reqirement for reliable transmission. This also means that the microwave spectrum is expensive and limited. The fibre optic technology can help to transmit wireless signal superimposed on the top of optical wavelength, as we have proposed and analysed recently [5].

Novel hybrid optical and wireless networking approach

Here we upgrade our non-conventional approach to have real-time service subnetworks: voice subnetwork and wireless radio-over-fibre subnetwork emerged in data traffic network. Voice is transmitted via circuit-switched sub-network as well as radio-over-fibre is, while IP traffic is performed via packet-switched connectionless traffic. Here real time services include voice and radio-over-fibre transmission [6]. The three kinds of traffic are separated and interleaved in frequency (wavelength) domain, not in time domain.

Table 1 shows a comparison of main features of both types of traffic in a hybrid network [7]. The conventional mobile microwave/millimetre wave signal transmission can be included in the transparent real-time part of the network by the means of modulating the optical carrier wavelength with the mobile signal [8]. Then it can be transmitted at long distances via fibres before being detected at an optical receiver and proceeded further.

Table 1.

Real-time vs. Internet traffic

Characteristics	Real-time: Voice, Radio-over-Fibre	Internet, data
Bandwidth	Dedicated on demand	As wide as available
Basic principle	Circuit-switched	Packet-switched
Packet length	Constant	Variable
Quality of Service	Guaranteed	Best-effort
Lost packets	No retransmission	Retransmitted
Traffic	Deterministic	Statistic
Other	Instantaneous bandwidth (# of wavelengths) controlled logically in IP routers	Intelligence
	Transparent	Includes all-optical opacity
Access	Conventional twisted-pair access to public exchange offices	Broadband access to servers, e.g. via cable-TV or mobile

The network intelligence has to be located at IP routers and it has to provide the real-time subnetwork including microwave with a sufficient number of wavelengths [9]. This approach allows to profit fully from both SDH/ATM technology best suited for real time-circuit switched services, and from IP protocol developed uniquely for packet-switched traffic. Moreover, the QoS can be differentiated for various classes of services [10].

Conclusions

The novel non-conventional approach to the future hybrid network saves the well-developed classical voice technology with transparent transmission. Voice traffic is realised via dynamically allocated wavelengths in conventional way as circuit-switched traffic. The number of wavelengths is controlled by IP layer according to the instantaneous demand for real-time traffic. The all remaining wavelengths allowable are for the disposal of IP traffic, which becomes free of real-time restrictions and can adopt variable-packet length, no idle bits, and best-effort scheme. As a consequence, the whole available bandwidth can be fully exploited in the hybrid network. In the IP part of the network Quality of Service can be differentiated for various classes of packets and network reliability/survivability can be categorised for the whole hybrid network.

The approach presented here is a result of our in-depth investigation of different networking principles and traffic schemes, and physical constraints that characterise the classical fibre stationary network and new mobile wireless world. This proposal substitutes the complete and revolutionary shifting to packet traffic that a number of people foresee, with a smooth evolution and network upgrade. What is really worth to note is that real time traffic provides capabilities of security and network availability, thus this is a mean to conserve a number of connections even in an malicious attack occurs. So we believe the model presented here is a powerful tool to trace the future evolution of telecommunications worldwide for the next 25 years.

Acknowledgements

The support from the State Committee for Scientific Research under grants 632/E-242/SPB/C0ST/T-11/DZ198/2003-2005 and 632/E-242/SPB/COST/T-11/DZ 311/2003-2005 for the author's participation to Eur opean Co-operation in the field of Scientific and Technical Research COST projects *Reliability of Optical Components and Devices in Communications Systems and Networks* (COST 270), and *Towards Mobile Broadband Multimedia Networks* (COST 273), *Nanoscale and ultrafast photonics* (COST 288), *Towards Digital Optical Networks* (COST 291), *Physics of Linear, Nonlinear and Active Photonic*

Crystals (COST P11), and a support from The European Commission, IST - Information Society Technologies under a 5th FP (Fifth Framework Programme) IST-2001-37944 grant for participation to NEXWAY - *Network of Excellence in Wireless Applications and Technology* is kindly acknowledged.

1 *MarciniakM.* NEXWAY White Paper on "Towards Broadband Global Optical and Wireless Networking". 1st European Mobile eConf. 2004. http://www.telecom.ece.ntua.gr/eConference/ . 2004.
2 ITU Next Generation Networks 2004 Project http://www.itu.int/ITU-T/studygroups/com13/ngn2004/
3 *MarciniakM.* "Broadband Optical and Wireless Networking for Personal Information Services" (Invited). 7th Int. Conf. "Evolution of telecommunication transport networks. Construction, Development and Management". Yalta, 2004.
4 *Schollmeier G., Winkler C.* "Providing Sustainable QoS in Next-Generation Networks". IEEE Commun. Magazine. 2004. V. 42, № 6. P. 102-107.
Marciniak M. Optical transparency and optical opacity in future all-optical packet switched network. XXVIIth General Assembly of the Int. Union of Radio Science URSI 2002. Paper 1719. Maastricht. NL, 2002.
5 *MarciniakM.* "Broadband optical and wireless networking, - an evolutionary approach", 6th Int. Conf. on Laser and Fiber-Optical Networks Modeling LFNM'2004. Invited Paper. Kharkov, 2004.
6 *MarciniakM.* "Towards broadband global optical and wireless networking", Telecommun. and Information Technol. 2004. № 3. P. 65-70.
7 *MarciniakM.* "Towards Broadband Global Optical and Wireless Networking", 6th Int. Conf. on Transparent Optical Networks ICTON 2004 / Global Optical & Wireless Networking GOWN Seminar. Wroclaw, 2004.
8 *Marciniak L. M.* "Global Optical and Wireless Networking - emerging opportunities for electromagnetic research", 10-th Int. Conf. on Mathematical Methods in Electromagnetic Theory (MMET*04). Invited Paper ESP-6. Dniepropetrovsk, 2004
9 *Geary N., Antonopoulos A., O 'Reilly J.* "Analysis of the potential benefits of OXC-based intelligent optical networks". Optical Networks Magazine, Special Focus on Towards Intelligent Multiwavelength Optical Core Networks. 2003. V. 4 № 2. P. 20-31.
10 *KlinkowskiM., MarciniakM.* "Services differentiation in MPLS Photonic Packet Networks", The 5th IFIP Working Conf. on Optical Network Design & Modelling ONDM 2003. Conf. Proc. V. I. Budapest, 2003. P. 283-290.