CONVERGED OPTICAL AND WIRELESS NETWORKING – CHALLENGES FOR PHOTONICS AND ELECTRONICS

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ABSTRACT

Fixed and mobile communications will continue to converge coming years. Amongst other, this is also a goal of the Next Generation Networking initiative adopted by The International Telecommunication Union for the 2005-2008 Study Period. While a general belief is the Internet will support the majority of services, it should be carefully noted to select and separate the services in the network is a necessary condition to assure the Quality of Service and security for the individual ones. This paper proposes to allocate different services with different kinds of traffic and QoS requirements to different wavelengths in a single wavelength-division multiplexed optical network in order do satisfy the requirements of the customer specific to particular service used.

INTRODUCTION

Nowadays communications target to transmit a variety of of services. Those are classical telephony, faxsimile transmission, but also the Internet traffic, data transmission, radio and television broadcasting etc. Consequently, various transmission media are used as metal and fibre cables, and microwave, millimetre wave, and otical free space communication links. However, owing to top performance of contemporary optical fibres there is a tendency to exploit optics as far as possible. Thus fibres are used not only for digital voice or Internet traffic transmission, but also for analogue cable television transmission, and for expanding Radio-over-Fibre transmission applications that exploit the optical carrier wave amplitude modulation with a microwave carrier [1].

As the user perceives the Quality of Service level necessary for his/her satisfaction (and payment), two classes of services are commonly distinguished: real time services which are transmission delay sensitive (voice calls, videophone), and non real time services which allow short transmission delays as Internet and data transmission. On the other hand, two entirely different basic traffic principles are dominating today. Those are: classical circuit switched, connection oriented traffic, and packet-switched, connectionless traffic that has emerged with the advent of the Internet. Consequently, twe two kinds of traffic differ widely non only in their performance, but also in the kinds of service requirements they are specifically suited for. For example, the Quality of Service is automatically guaranteed for circuit switched networks by the oveprovisioning of the network resources (that means the network parameters are much better than actually needed), while Internet is based on the ‘best-effort’ principle (a packet network does it best, but no more).

In this paper we present a novel non-conventional approach to the future optical and wireless hybrid transport network that is capable to support the dominating kinds of traffic, i.e. real time voice, wireless, and packet traffic in a single transport network. The proposed model combines different technologies as connection and connectionless networks, optical cable and wireless (microwave/ millimetre wave or optical wireless) and it is suitable for a variety of purposes and services in order to achieve global broadband networking features. From the networking point of view it consists of an upgrade of real-time traffic with the microwave modulated optical wave (*Radio-over-Fibre*), in order to transmit the conventional mobile wireless via optical fibres though long distances and without a significant distortion [2].

The paper is organised as follows. It reviews the International Telecommunication Union (ITU) policy for introducing Next Generation Networks (NGN) in the ITU Study Period 2005-2008. The guidelines for the actual network evolution in order to efficiently combine real-time delay-sensitive services and non-real time services including mobile services in a single optical transport network with a maximised use of the available bandwidth are outlined. The Quality of Service guarantees for real-time and non-real time services are discussed in the concluding part. We believe this is of a special relevance at the present moment when the world communications prepare to cross the Next Generation Networking door.

NEXT GENERATION NETWORKING

The expansion of Internet traffic worldwide forces the global communication community to shift from classical circuit switched, connection oriented networks to modern packet switched, connectionless transmission of data, with a strong interest in guarantees of the network reliability and availability as well as the security of the information and of the infrastructure, generalized mobility etc. [3]. This revolutionary change is reflected in the International Telecommunication Union (ITU) policy on the Next Generation Networks (NGN). NGN are expected to be deployed widely starting from the ITU Study Period 2005-2008.

NGN is a packet-based network capable to provide a variety of services services including conventional telecommunication services and new NGN services. It should assure an unrestricted access by users to different service providers, supports generalized mobility, and it allows consistent and ubiquitous provision of services to users. In fact the changes to the NGN service provision infrastructures have already started in the industry. The specific objectives of the ITU Next Generation Networks project are to facilitate convergence of networks and services, to coordinate all ITU-T activities related to the establishment of implementation guidelines and standards for the realisation of the Next Generation Network, to ensure that all elements required for interoperability and network capabilities to support applications globally across the NGN are addressed by ITU-T standardization activities.

NGN target is a generalized mobility allowing a consistent provision of services. The user is considered as a single person even if s/he temporarily changes the access point whatever it is. NGN will connect both existing customer terminals such as analogue telephone sets, fax machines, ISDN sets, cellular mobile phones, GPRS terminal devices, Ethernet phones through PCs, cable modems, etc., and emerging 'NGN aware' devices. Till now, similar services are offered to users both on fixed accesses and on mobile networks. However, they are still considered as different customer classes, with their specific service configurations. No efficient bridging occurs between fixed and mobile services. The user may be able to roam between similar public wireless accesses only. A limited nomadism is allowed between some fixed accesses.

An important NGN issue is the security of information, of the transport functions and infrastructure, and the customer's privacy and rights. This problem stretches far beyond telecommunications as computing and networking have begun to touch almost every aspect of our life. The move to a complete IP-based infrastructure will lead to even greater challenges. Security in NGN is inherent but nevertheless crucial and is touching many areas as: network architecture, QoS, network management, mobility, billing, and payment. Thus NGN security mechanisms should be able to protect its infrastructure, to fight against the fraudulent use of the services, and to protect the own infrastructure from outside attacks. The NGN networks are no longer conceived as a monolithic systems with clear interfaces. The ITU NGN work on security concentrates on the development of a compound security architecture for NGNs, and on the development of NGN specific security protocols. The lack of adequate security in particular in the Internet is very serious and fast becoming worse. Without proper security, the Internet may become unusable in a few years' time. Moreover, mobile phones are more and more replicating the functionality of PCs, thus mobile networks are increasingly susceptible to malicious attack.

CONVERGED OPTICAL AND WIRELESS NETWORK

While microwave and millimeter wave links have excellent mobility characteristics impossible to achieve for other transmission media (wireless optical links have rather 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 requirement for a reliable transmission. This also means that the microwave spectrum is expensive and limited.

The transparent analogue nature of modern fibre communications provides a potential to modulate and detect the optical wave power with microwave or millimeter wave envelope. Broadband wireless signal might be transmitted as an optical wave properly modulated in an analogue way. This works very well in a DWDM network with Erbium-Doped Fibre Amplifiers (EDFA). A question arises, do we really need separate networks for different services? Or separate fibers in a single network? Why do not use separate wavelengths for that? In modern DWDM optical networks, one has to distinguish the physical network infrastructure (fibers and cables) from the virtual infrastructure (wavelengths).

Our non-conventional approach consists of voice (and other real-time services) subnetwork emerged in data network. Voice is transmitted via circuit-switched subnetwork, while IP is realised via packet-switched connectionless traffic. The mobile microwave/millimetre wave signal is included in the transparent real-time part of the network by the means of modulating the optical carrier wavelength with the mobile signal. Then it can be transmitted at long distances via fibres before being detected at an optical receiver and proceeded further. The two kinds of traffic are separated and interleaved in frequency (wavelength) domain, not in time domain. 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 [4]. 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. Table 1 reports the main features of a hybrid network [5].

Table 1 – Comparison of main characteristics of real-time and 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, or broadband wireless	Broadband access to servers, e.g. via cable-TV or mobile

Thus the hybrid network concept assumes that the voice and broadband wireless signals are transmitted via circuit-switched subnetwork with digital (voice) or analogue (wireless) coding, while IP is transmitted as packet-switched connectionless traffic. Voice/wireless is carried on dynamically allocated wavelengths, according to instantaneous demand for real-time services. All remaining wavelengths are for the IP traffic. The two kinds of traffic are separated and interleaved in frequency (wavelength) domain, not in time domain. 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, i.e. in the 'Radio over Fibre' fashion. Radio over Fibre technology is especially well suited to transmit the 60 GHz frequency that otherwise is highly attenuated in the air [6]. Then it can be transmitted at long distances via fibres before being detected at an optical receiver and proceeded further.

CONCLUSIONS

The statistic nature of the packet traffic does not allow to achieve any arbitrary level of performance in all circumstances. This poses serious challenges to ensure a good network performance and satisfactory Quality of Service level for as far as possible. Morever, Internet is inherently vurnerable to an unhonest use and malicious attacks. One has to recall that while the origins of the Internet were to cope with a large network infrastructure destroyment, however the actual threats are of different nature and the information inserted to the network might affect and even potentially block the network.

We strongly believe the hybrid network model presented here is an optimised approach to the future network design, assuring maximal use of the available bandwidth and optimising the network availability for various kinds of traffic and services. The model overcomes the serious drawbacks of an all-IP network, and it accommodates the real-time circuit-switched transmission of a high reliability and security necessary for a number of services with the more flexible but also highly vurnerable packet traffic. 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. The security of information and the reliability and survivability of the network can be categorised for different services. However, Radio-over-Fibre transmission of microwaves, being of an analogue nature, is especially challenging both for the photonic and the electronic layers, especially when the 60 GHz band is concerned.

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