Abstract

Over the past few years, Internet has grown at an exponential rate and bandwidth demands have been continuously increasing. At the beginning, the introduction of Wavelength Division Multiplexing (WDM) allowed to accommodate such a demand, without combine a replacement of the current redundant and inefficient multi-layer structure. The challenges have recently migrated from transmitting high-capacity optical signals over long distances to effectively switching and managing that data in optical domain. These functions, currently performed in the electronic domain, are the main causes of the large bottleneck to the scalability and growth of Internet.

On the other hand, it is expected that future networks should transport heterogeneous traffic services including multimedia and interactive applications which require proper treatments (e.g. delay or bandwidth guarantees). QoS provisioning seems therefore a mandatory task.

Definitely, optical networks with QoS capabilities are the main goal for the next generation telecommunication infrastructures. An intense debate has been ongoing about which is the optical network model to adopt, aiming at identifying the degree of optical transparency to be achieved, and the proper flexibility of optical interconnection. In the perspective of network optimization, the implementation of packet switching techniques directly in the transport network will bring more statistical sharing of the physical resources to reduce the connection costs and cope with the gap between transmission speed and switching capacity. In this direction, two different approaches have been currently developing in the research community, namely Optical Burst Switching (OBS) and Optical Packet Switching (OPS) which are an attractive solution to the electronic bottleneck with promises of transparency, high capacity, flexibility, and little electromagnetic interference.

In this thesis we focus on the OPS solutions which pretends to be a long-term solution requiring very fast all-optical switches (switching time in the order of nanoseconds), and advanced optical components such as tunable wavelength converters and 3R optical regenerators. Since OPS is based on statistical multiplexing, packet contentions may arise at the nodes. Therefore, a contention resolution policy must be applied to reduce the packets losses and make the statistical multiplexing more efficient. In the electrical packet switching, contention resolution techniques typically exploit the space domain, by means of deflection routing, and the time domain, by means of queuing. In the optical packet switching, the lack of optical RAMs imposes the use of a pool of fiber delay lines (FDLs) which are bulky and not scalable and offer limited buffering capabilities (few tens of delays at maximum). In contrast, the use of WDM links and wavelength converters allows to solving contention also in frequency domain, by means of wavelength multiplexing.

In this context, we deal with the problem of providing QoS capabilities for both metropolitan and wide area environments.

For the metro environment, the networks are generally *buffer-less*, in the sense that once information enters the network, it remains in the optical domain and does not face any buffers until it is delivered to its destination. In order to avoid collision on the individual WDM channels, Medium Access Control (MAC) protocols are needed

which may integrate the support of QoS provisioning.

Different network architectures can be envisaged from this simple concept. We focus on two particular network architectures, namely multi-PON and multi-ring respectively. Both architectures with their respective functional mechanisms (including the MAC protocols) have been proposed by the DAVID consortium which is a project funded by the Fifth Information Society Technologies program of the European Union. Our contributions on this topic have concentrated into different tasks. We firstly identify the service requirements for the generic OPS-based metro networks according to what developed in electrical MAN. Afterwards we perform an extensive and exhaustive performance evaluation to evaluate the mechanisms proposed in previous works and identify their weakness. We hence design optimized mechanisms to improve the performance and provide QoS support to all types of services previously identified. Finally, in order to assess the benefits of the OPS-based solutions considered in this thesis, we perform a benchmarking study in terms of cost/effectiveness. This study also compares the results with non-OPS technologies based on electrical switching such as SDH, RPR and Ethernet.

For the wide area environment, we focus on the connection-oriented OPS network scenario where nodes have limited buffer capabilities and are subject to asynchronous variable length packets. In such a scenario, we address two problems, namely the problem of setting up of the optical virtual connections (OVC), properly configuring the forwarding table at the nodes, and the problem of providing QoS.

Concerning the former problem, at the OVC setup, each node must assign both the output port and the output wavelength to the OVC in such a way that the packets belonging to that OVC are always switched to the same output. This double setup problem is different with respect to the *classical* RWA problem in circuit-switched network because here the wavelengths are shared among several OVCs (in a packet-switched basis). In this study we do not deal with the problem of selecting the output port which depends on the routing protocol but we are interested in the election of the wavelength which may be set locally by each node using a *OVC-to-wavelength setup assignment* (OWSA) algorithm. In particular we show that intelligent OWSA procedures can considerably improve the performance of the switches. The intelligence relies on grouping the flows coming from the same input wavelength which allows to obtain the conflict-free situations and hence reduce the contention probability.

Concerning the latter problem, existing solutions to provide QoS in OPS networks are based on the following strategy: 1) design a contention resolution algorithm which minimizes the Packet Loss Rate (PLR), 2) apply a QoS mechanism (some form of resources reservation on top of the contention resolution algorithm) able to differentiate the PLR among two or more classes. Given that we are dealing with a connection-oriented model, here we suggest a new method based on the well known ATM scheme of defining different service categories which consists of defining different OPS service categories, each one based on a different contention resolution algorithm specifically designed to cope with the requirements of that category. With this technique, besides the PLR, also the packet delay and the computational complexity are considered as QoS metrics.

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Finally, it has to be underlined that this work will continue to be developed and will be part of the new Integrated Project NOBEL (Next generation Optical network for Broadband European Leadership) founded by the European Union within the Sixth Framework Programme.