PART II

OPS-based metro area networks

Chapter 3

Introduction to the OPS-based metro area networks

Some traffic estimates for the UK network over the next few years [39] indicate that when access is primarily over copper-based technology the total traffic volume will be a few Terabit/s. On the other hand, in the event of a mass take-up of FTTH these traffic estimates would reach the order of tens of Terabit/s. In this eventuality, the DAVID project has been developed two advanced network architectures based on composite topologies able to achieve more than 1 Terabit/s throughput, namely multi-PON (on the left side in Figure 3.1) and multi-ring (on the right side in Figure 3.1). They are also known as interconnected WDM PONs and interconnected WDM rings, respectively.

In this thesis we exclusively focus on these architectures. They have common features that we discuss below; the description concerns to the multi-PON architecture while between brackets we refer to the multi-ring case. In the following chapters we separate the studies: at first we focus on the multi-PON and thus on the multi-ring architecture describing for both cases the state-of-the-art and our contributions.

Multi-PON network consists of several uni-directional slotted optical WDM PONs [ring in the case of multi-ring] interconnected in a star topology by Hub. The Hub connects the PONs [rings] in a metro area to at least one optical packet router in the backbone. Nodes are connected to PONs [rings] and provide an electro/optical interface to edge routers/switches at the end of access networks via a variety of legacy interfaces (e.g., IP routers or Ethernet switches). Nodes belonging to the same PON [ring] share the same set of resources (i.e., a given fixed number of wavelengths) in such a way that a MAC protocol is required to arbitrate the access.

Nodes use a statistical time/wavelength/space division multiple access scheme. Indeed, time is divided into slots (Time Division Multiple Access, TDMA), lasting 1 μs (1250 bytes at 10 Gbit/s) since previous studies [30] [13] have shown this is a good compromise between filling ratio optimisation (sufficient level of aggregation in the electrical domain) and delay. Several slots are simultaneously transmitted on different wavelengths (Wavelength Division Multiple Access, WDMA) on the same PON [ring], and PONs [rings] are disjoint in space (Spade Division Multiple Access, SDMA). The network is synchronous and time slots are aligned on all wavelengths

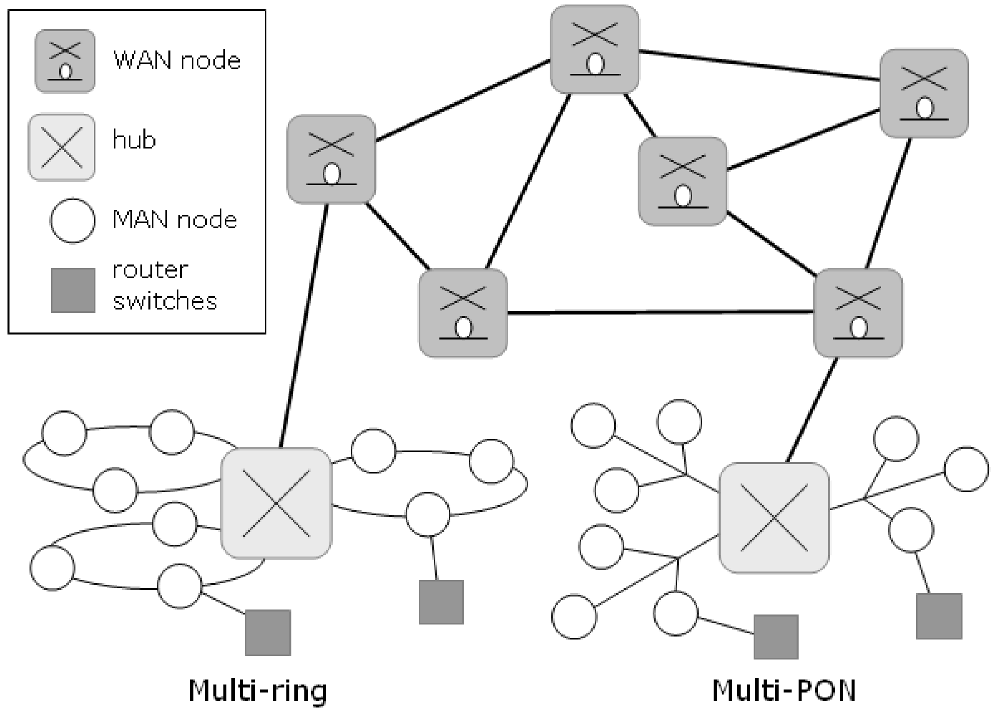

Figure 3.1: Architectures considered in the DAVID project

of the same PON [ring]; thus, a *multislot* (i.e., a set of slots, one per wavelength) is available at each node in any time slot. The information on the status and availability of network resources is transported out-of-band in a control channel, i.e., a dedicated additional wavelength on each PON (ring). This means that each multislot includes one *control* slot and several *data* slots.

No packet buffering is available at the Hub; therefore buffering is done electronically at nodes. The Hub behaves as a switch between PONs [rings]. PON [ring] interconnections are dynamically modified following a scheduling algorithm. It also arbitrates the allocation of network resources and nodes' access to slots. It is typically run in a centralized fashion at the Hub, although some decisions can be decentralized at network nodes. Nodes must have access opportunities in proportion to a request matrix while avoiding collisions (i.e., transmission in busy slots) and contentions (i.e., sending in different slots at the same time more than one packet addressed to the same node). The request matrix is created at the Hub and can be calculated using explicit bandwidth requests issued by nodes, estimated with traffic measurements or pre-defined by the network management operator.

For these scenarios it is reasonable to think that multimedia and interactive applications will take an important share of the bandwidth, and hence techniques to provide QoS must be designed. The simplest way to do that is by introducing at least two traffic classes having different priority [97]. A drawback of such strategy is that if high-priority traffic is not controlled by any form of Call Admission Control (CAC), the traffic fluctuations can cause two different undesirable situations: 1) high-priority traffic with strict priority over low priority traffic can prevent the transmission of the latter and 2) it may not be possible to guarantee neither delay nor bandwidth bounds even to high-priority traffic. To avoid this situation in public networks, centralized bandwidth management functions (i.e., traffic engineering) are required. Network operators need to have the possibility to control the amount of high priority traffic injected in the (optical) MAN segments.

To attain this objective, at first we need to determine which services are required in a metro environment. According to what developed in the electrical MAN, we can consider that 3 different classes of service must be supported. These classes are:

- *Guaranteed service.* It refers to data that have real-time constraints that require a guaranteed bandwidth and low jitter. This service must have absolute priority over the other types of services, and must be shaped at the ingress. To provide such services, a reservation mechanism is usually adopted.

- *Priority service.* It is dedicated to near-real-time applications that are less delay and bandwidth-sensitive. In contrast to the guaranteed service, the bandwidth for priority service is not statically allocated but some forms of priority mechanism over best-effort service are usually used.

- *Best-effort service.* It refers to data that can be sent at the leisure of the node. This service is usually weighted by a fairness mechanism in order to ensure that each node gets its fair share of the bandwidth available.

In the following chapters, we present the works done by other partners of the DAVID project and our contributions which complete the investigations on these network architectures.