

PART I

Optical packet switching

Chapter 2

Optical packet switching: an overview

2.1 Introduction

In the following chapter we describe the common concepts that underlying any OPS proposals both in wide and metropolitan scenario (section 2.2). Afterwards, we separate the environments, describing first the state-of-the-art of OPS solutions for metro networks (section 2.4) and then for core networks (section 2.5).

2.2 Main concepts

The implementation of packet switching techniques in the optical domain is a research topic that has been investigated all over the last decade [62] [105]. Several research projects demonstrate the feasibility of the OPS technology and significant progress in terms of component availability and integration has been recently achieved [33].

The target is building transparent optical network equipments capable to carry data-centric traffic at huge bit-rates. Since electronic-based devices may result too slow to perform the required ultra-fast switching operation, the basic idea is to exploit the bandwidth made available by optical components while reducing the electro-optical conversions as much as possible and achieving better interfacing with WDM transmission systems. An example of OPS network with mesh topology is shown in Figure 1.4. Legacy packet-oriented networks (e.g. based on IP, ATM or Gigabit Ethernet) are "clients" of the OPS domain and supply heterogeneous datagrams/cells/frames to it through the ingress *edge systems*, which are responsible for building optical packets. In particular, each edge node has to collect incoming data and arrange them into optical packets, according to the specific format adopted by the network. While performing this operation, it may be required to aggregate small incoming data units or segment long ones in order to fit them properly into the optical container. The edge node is also in charge for creating a packet header and adding control information to it, needed to accomplish a correct path inside the OPS network. Once a packet has entered the OPS domain, it is transparently switched by the nodes

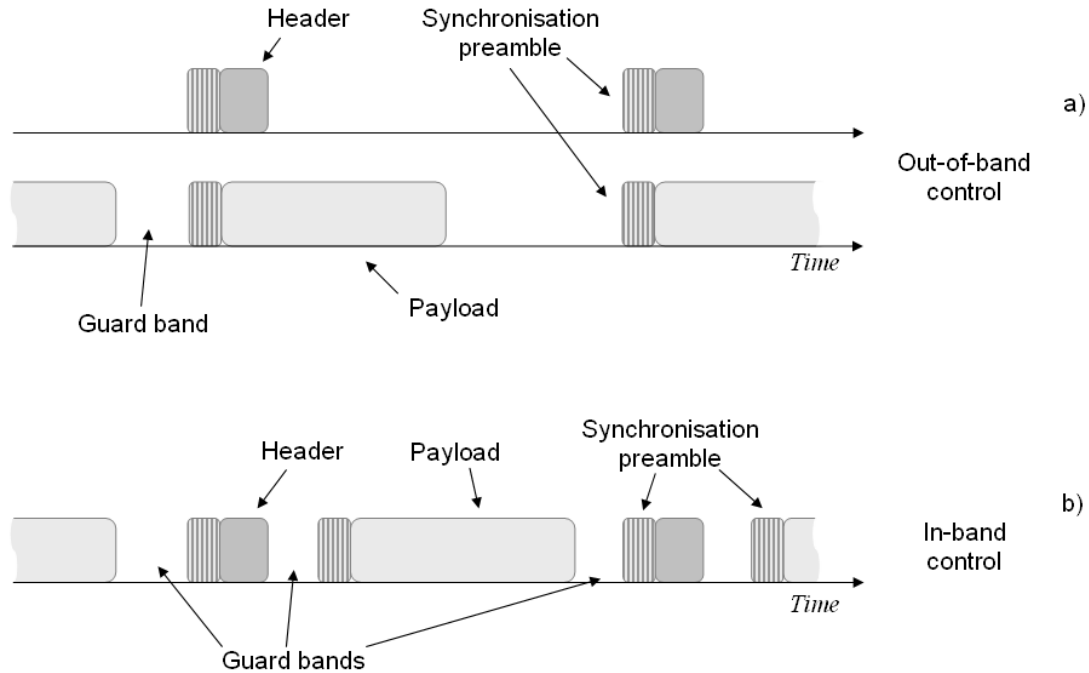


Figure 2.1: An example of optical packet formats. a) out-of-band control channel, b) in-band control channel

according to a statistical multiplexing techniques. As soon as the packet has reached the proper egress edge node, its data content is translated back to the original format and delivered to the destination legacy network. Here some reassembling operations may be needed.

2.3 Packet formats and network operations

One of the key issues in OPS is the format of optical packets, that should be carefully chosen taking into account the limits of the optical technology on one side and traffic characteristics as well as transparency requirements on the other. The optical packets are typically composed by header and payload. The header contents are used to control the routing/switching decisions of the optical packet. Different techniques to attach the header to a packet can be used:

- out-of-band control, where the headers are transmitted on a separate wavelength, i.e., the control channel (e.g., [9]);
- in-band control, i.e., serial transmission of header and payload on the same wavelength (e.g., [50]); in this case, header and packet can be transmitted using orthogonal modulation formats to increase the channel utilisation (e.g., [69]).

Figure 2.1 show an example of the different optical packet formats: a) refers to the case of out-of-band control while b) to the in-band transmission case.

The figure shows that a suitable idle time intervals, called *guard bands* have to be introduced between header and payload and between contiguous packets accounting for switching times of the constituent opto-electronic devices as well as payload position jitter [50]. In addition, *synchronization preambles* are placed in front of each header and payload, allowing the receivers to correctly lock on the optical signal.

The out-of-band control transmission is generally used when packets and headers travel together on the same route and have a locked timing relationship. This is especially a viable approach in metro networks where simple ring or star topologies are adopted, as the synchronization between the control and data channels is reasonably easy to maintain. On the other hand, it results complex when applied in a core network which generally consists of a meshed topology.

The next step in the definition of the optical packet format concerns the choice of the size of the entities to be switched as well as the network operation techniques to be adopted. The following alternatives have been proposed in literature, we use Figure 2.2 to compare them supposing that two client packets entering in the OPS domain and the in-band control transmission is used for any alternatives:

- **Fixed length packets and synchronous node operation**, FLP-SO [50] (see Figure 2.2b). The time scale is partitioned into time-slots of fixed duration and switching and transmission functions are performed only at given instances, i.e. at the beginning of each slot. Each payload has a fixed size and is inserted in a time-slot; a header is added into each slot and resulting fixed-length packets are switched independently one-another. Here, some padding to fill-up the last slot may be necessary.
- **Variable length packets and synchronous node operation**, VLP-SO [17] (see Figure 2.2c). In this case the datagram transmission time is larger than the slot size, and a single header is inserted in the first slot while the payload spans over several time-slots, which are switched altogether as a single "train of slots". Some padding operation to fill-up the last slot may be required.
- **Fixed length packets and asynchronous operation**, FLP-AO [55] (see Figure 2.2d). Incoming datagrams are put into one or more optical packets of a given size, which may be received, switched and transmitted at any time. Insertion of some padding to fill-up the optical payload may be necessary. This case has little interest and will not be considered in the following discussions.
- **Variable length packets and asynchronous node operation**, VLP-AO [99] (see Figure 2.2e). Incoming datagrams are put into the optical payloads "as they are" and each packet may be received, switched and transmitted at any time.

From the performance point of view, using fixed length packets with synchronous operation is the better choice. Unfortunately, this case is not very well tailored by Internet traffic. Indeed, the IP packets are variable length datagrams and must be fitted into fixed length containers. This may cause severe inefficiencies while at the same time the synchronous operation implies that the input interface of the switches

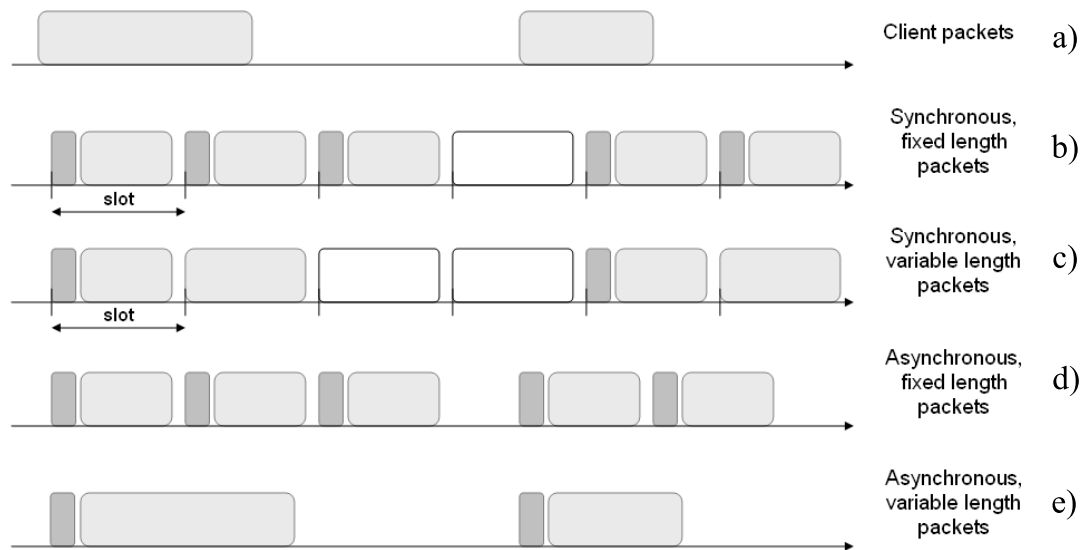


Figure 2.2: Data incoming from client layers (a) can be placed in different optical packet formats: synchronous, fixed-length packets (b); asynchronous, fixed-length packets (c); synchronous, variable-length packets (d); asynchronous, variable-length packets (e).

needs to delineate and align the packets arriving from the different input ports. This operation is not trivial and is one of the most arduous, complex and cost tasks [99] for the OPS networks. Thereby, the asynchronous networks generally have lower cost, higher flexibility, robustness and offer better interworking skill with network protocols; on the contrary they have lower overall throughput than synchronous networks, because of the increased contention probability.

For these reasons, current investigations mainly consider the asynchronous, variable length case for the wide networks where generally the available bandwidth is not the principal design constraint. At the same time, asynchronous, variable length case well suits with the in-band header transmission; hence we can assume a scenario with full flexibility where packets and corresponding headers travel together across a meshed network using any available route with whatever wavelength from source to destination node.

On the contrary, the synchronous, fixed-length case is the preferred solution for the metro networks where limiting the cost per transmitted bit is generally the main goal to achieve [30]. At the same time, the utilisation of the wavelengths can be further improved using the out-of-band header transmission, i.e., putting the control information on an additional wavelength. In this case we can assume a scenario where packets travel on the data wavelengths while the corresponding headers all together on a single control wavelength; a locked time between packets and headers permits to recognize the correct relationships; while a regular topology fixes the route from the source and destination nodes and does not affect this correspondences [43].

2.4 Metro area network context

Whereas core and access networks are currently experiencing huge innovations, the metro networks are mostly SONET/SDH over WDM rings that carry the increasing amount of data traffic very inefficiently. This results in the so-called *metro-gap*. The gap creates a clear network bottleneck preventing the client benefits. Therefore researchers world-wide make big efforts to investigate new packet-based technologies (e.g., Resilience Packet Ring [93] [95]). They natural fit with the now ubiquitous IP traffic, and appear to be the best choices for overtaking the metro-gap in a cost-effective manner.

In the current networking context, a MAN must meet the following requirements [64] [74]:

- *Flexibility*. Capability of handling different granularities of bandwidth and to support a wide range of protocols. Techniques for dynamic allocation of capacity, needed in order to exploit more efficiently the limited network's resources.
- *Cost-effectiveness*. The appropriate network topology and protocols must be identified. Compared to the current technology, CAPEX and OPEX must be reduced by a considerable amount.
- *Upgradeability*. Ability to incorporate new technologies in an easy and non-disruptive manner must be present.
- *Scalability*. Ability to add network devices in an easy and non-disruptive way.
- *Efficiency*. High throughputs and short delays should be provided.
- *Fairness*. Starvation of nodes through a regulation of the bandwidth usage must be avoided.
- *Multicasting*. Efficient support to applications such as videoconferences or distributed games implies efficient multicast support.
- *Quality of Service*. Rapid provisioning capabilities and service guarantees to mission-critical data and delay-sensitive applications must be supported. The interaction between metro MAC protocols, and core and access network protocols must be taken into proper account in order to ensure an end-to-end QoS to customers.
- *Bandwidth management*. In order to control the amount of high priority traffic injected in the MAN and avoid congestion situations.
- *Reliability*. The network elements must offer a high degree of reliability. This mandates that critical sub-systems are fully protected and capable of in-service upgrades. Network recovery strategies must cover and work around network failures and ensure continuing availability of crucial services.

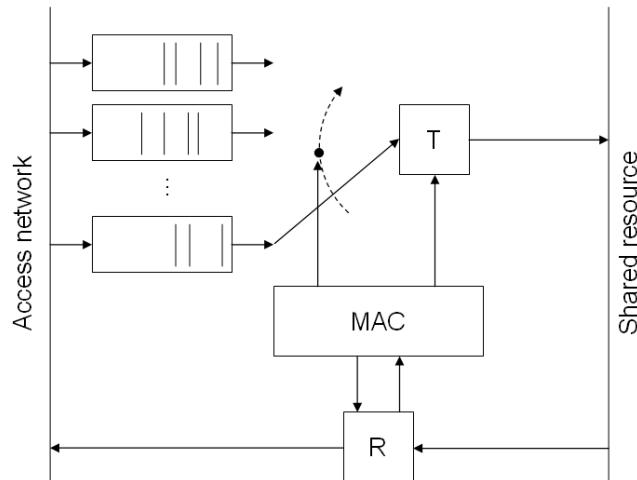


Figure 2.3: Schematic example of an OPS node for metro networks

OPS solutions appear to be a good candidate for future metro architectures to cope with these requirements. Besides the fact that it is a packet-based technology, it also avoids any electronic bottleneck conversion, and cuts the cost through a simplification of the structure. At the same time, the use of WDM channels allows to reaching high network capacity and the flexibility of the statistical multiplexing provides very high resource utilisation.

Since in WDM networks multiple channels are created by transmitting and receiving data on parallel wavelengths, two types of data collisions can occur: (i) transmission collision takes place when two or more nodes send data on the same wavelength channel simultaneously; and (ii) receiver contention takes place when a number of packets (in different wavelengths) must be received at the same time by a given node which has not enough receivers. Therefore, the nodes of the OPS-based metro networks generally use electronic buffer to store the packets coming from access networks accessing the shared wavelength channels by deploying a Medium Access Control (MAC) protocol which aims at either avoiding collisions and contentions or mitigating their impact on the network performance. Once a packet is transmitted, it runs the entire source-destination path without experiencing any additional delay (i.e., buffer-less path). Figure 2.3 shows a schematic example of the structure of an OPS node. It consists of a MAC chip which is in charge of selects from the set of electrical buffers the packets to be sent to the shared resource. To decide when and at which wavelength send the packet, the MAC can also listen the shared resource to identify a free space. At the same time, the MAC listen the shared resource to recognize the packets to be received by its node. It is therefore clear that all these processes strongly depend on several aspects of the metro network which include: network topology, node architectures, MAC protocols, and QoS strategies.

For what regards the physical topology, it can usually be a star [79], a linear bus [73], or a ring [94] as shown in Figure 2.4 for the case of WDM metro network. From a performance perspective, all topologies are currently equally attractive. To increase

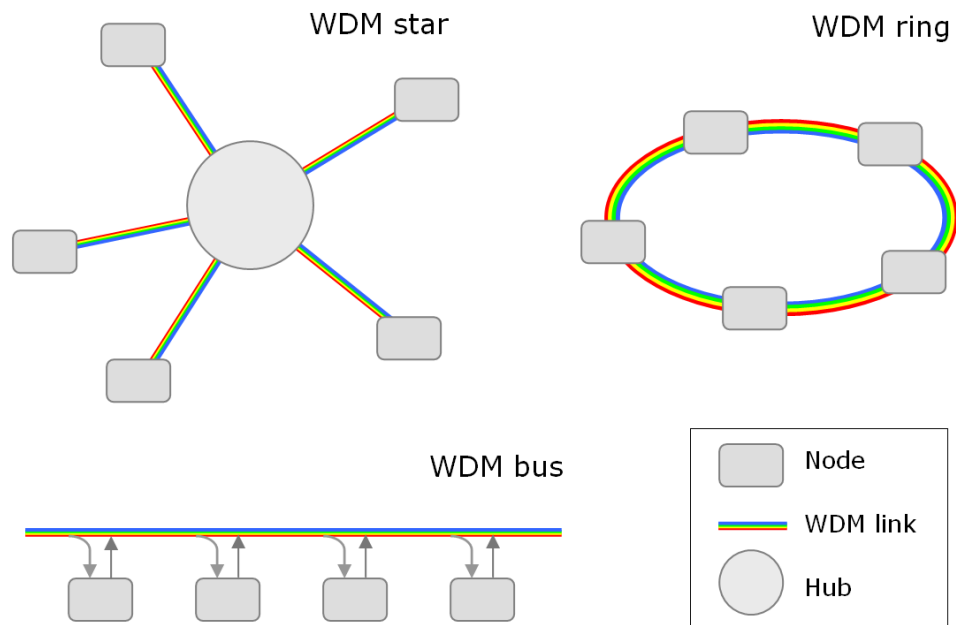


Figure 2.4: Example of physical topologies for metro networks

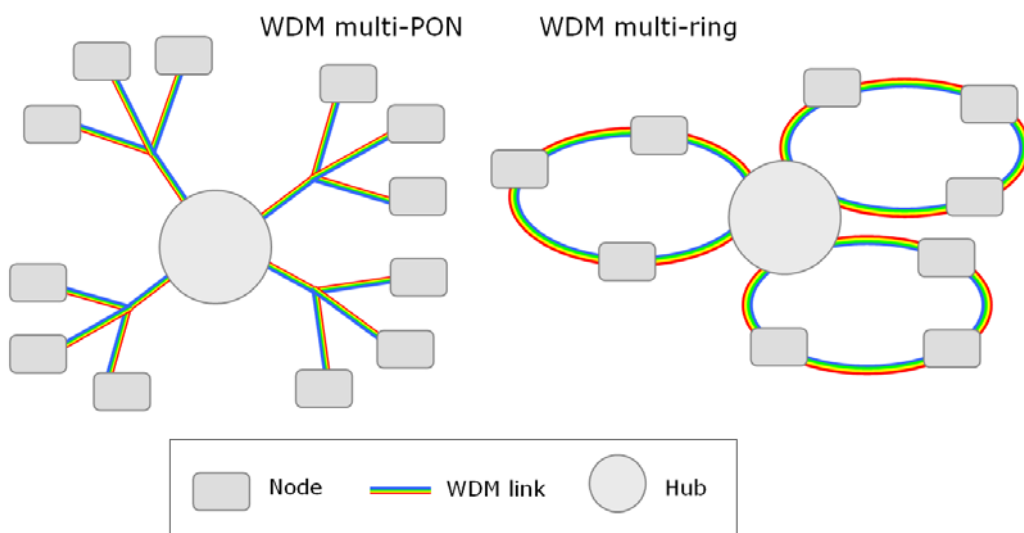


Figure 2.5: Example of composite physical topologies for metro networks

the number of nodes and/or the overall network throughput, it is possible to create composite topologies [9][25][46] as in Figure 2.5. In this case several small networks such as Passive Optical Networks (PONs) or rings can be connected through a central node forming multi-PON or multi-ring topology. In such topologies, the central node is usually referred as *Hub*.

For what regards the node architecture, the use of WDM systems opens up a wealth of possibility mainly related with the transmitters and receivers devices:

- Fixed Transmitter(s) and Fixed Receiver(s) (FT-FR);
- Tunable Transmitter(s) and Fixed Receiver(s) (TT-FR);
- Fixed Transmitter(s) and Tunable Receiver(s) (FT-TR);
- Tunable Transmitter(s) and Tunable Receiver(s) (TT-TR).

Fixed transceivers, which can only access some predetermined channels, are ready available in the market, but considerations often restrict the installation of a large number of such transceivers at each node. For TT-FR and FT-TR structures, no channel collisions will occur and simple MAC protocols can be employed, but the maximum number of nodes will be limited by the number of available channels. Systems based on the TT-TR structure are probably the most flexible in accommodating a scalable user population, but they also have to deal with the channel-switching time overhead of the transceiver [79].

In addition to the source and destination nodes, the star and composite topologies have a central node (i.e., the Hub). In this case, the Hub can be based on different architectures:

- Passive Star Coupler (PSC) [34] [66]. It is an N -input, N -output device with the property that the power from each input is divided equally among all the outputs. This implies that each transmitted packet is broadcasted at the Hub to all receivers which may simplify the design of the MAC protocol but presents poor performance due to the high redundancy and high transmission collision probabilities at the output ports of the Hub. Hence, it is a suitable solution only for low to medium network loads.
- Arrayed Waveguide Grating (AWG) [6] [82]. It is an N -input, N -output device which provides static space routing dependent on the input (port, wavelength)-tuple and offers frequency periodicity. Unlike the PSC the AWG allows for spatial wavelength reuse, i.e., each wavelength can be applied at all AWG input ports simultaneously without resulting in transmission collisions at the AWG output ports [74]. The design of the MAC protocol may result more complex and some feedback information about channels usage must be sent to the transmitter nodes to avoid both transmission collision and receiver contention.
- Semiconductor Optical Amplifier (SOA)-based switch [36] [43]. It is an N -input, N -output device which provides full connectivity between any input and

output ports. In this case, the configuration of the switch must be regulated by a Switch Control Logic (SCL) which is in charge of assigning output resources according to the incoming packets. The design of the MAC protocol may be easier than the previous case, but the switch needs advanced optical devices.

A large number of MAC protocols for metro WDM networks have been proposed and investigated in the literature. Many of those MAC protocols make use of well known *random access schemes* such as ALOHA and CSMA (Carrier Sense Multiple Access) or *controlled access schemes* such as token ring and FDDI and adopt them to the high-speed multichannel WDM environment. The interested reader can refer to [102] [79] [80] for an extensive survey on media access techniques.

At the same time, very few works have been developed to provide QoS in metro WDM networks [75] [49]. This is in contrast with the well defined schemes adopted in electrical metro network such as FDDI and DQDB [97] and in new electrical solution RPR [96]. Without lose of generality, we can classify the different type of QoS provided by the standardized metro network within one of the following classes:

- Isochronous. It refers to precesses that ensure that data flow continuously and at a steady rate in closing timing.
- Synchronous. It refers to data that have real-time constraints, implying that they need to be delivered in a certain time with a maximum delay. Synchronous data usually have reserved bandwidth.
- Asynchronous. It refers to data that can be sent at the leisure of the node. Asynchronous data can only use the leftover bandwidth. The asynchronous service may include more than one sub-service with different priority among them [97].

2.4.1 Examples of OPS-based metro network prototypes

In this section, we briefly describe three OPS-based metro networks currently under development in different research/university centers. These examples demonstrate the world-wide interest and the viability of such solutions.

AWG-STAR (Figure 2.6) is an NTT solution based on an AWG based star metro WDM network which interconnect n nodes [82]. Each node has 2 fixed-tuned transmitters and n fixed-tuned receivers. Each node transmits data packets on the same $1.55 \mu m$ wavelength and the corresponding header on the same $1.3 \mu m$ wavelength. To enable communication between any arbitrary pair of nodes, wavelength have to be converter at the central AWG. A WDM coupler routes the header to the optical header analyzer which determines the target wavelength on which the packet has to be transmitted to reach the destination node. The data packet is amplified and forwarded to the wavelength converter which consists of multiple light source each operating at different wavelength.

HORNET (Figure 2.7), which stands for Hybrid Opto-Electronic Ring NETWORK, is a WDM time-slotted ring developed at the Stanford University [94]. HORNET has

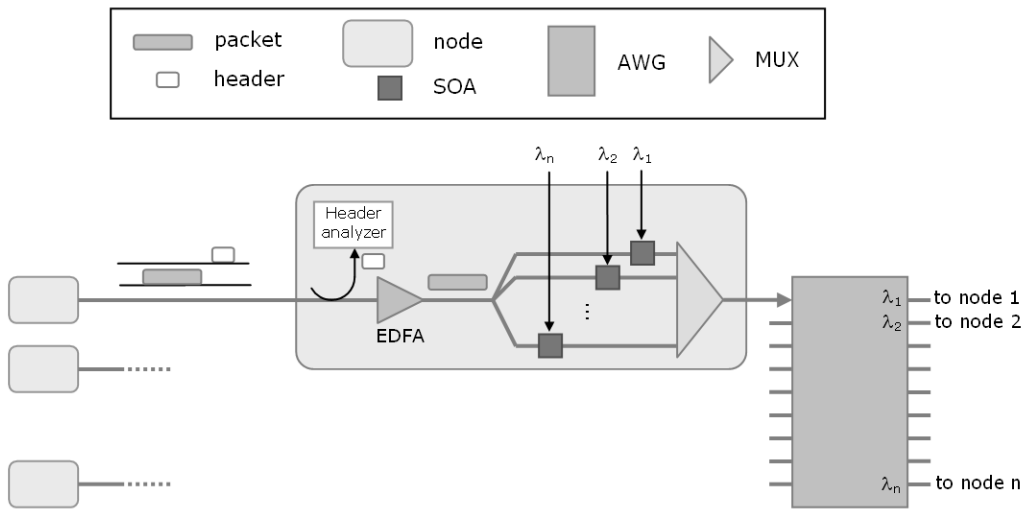


Figure 2.6: Structure of the AWG-STAR metro network

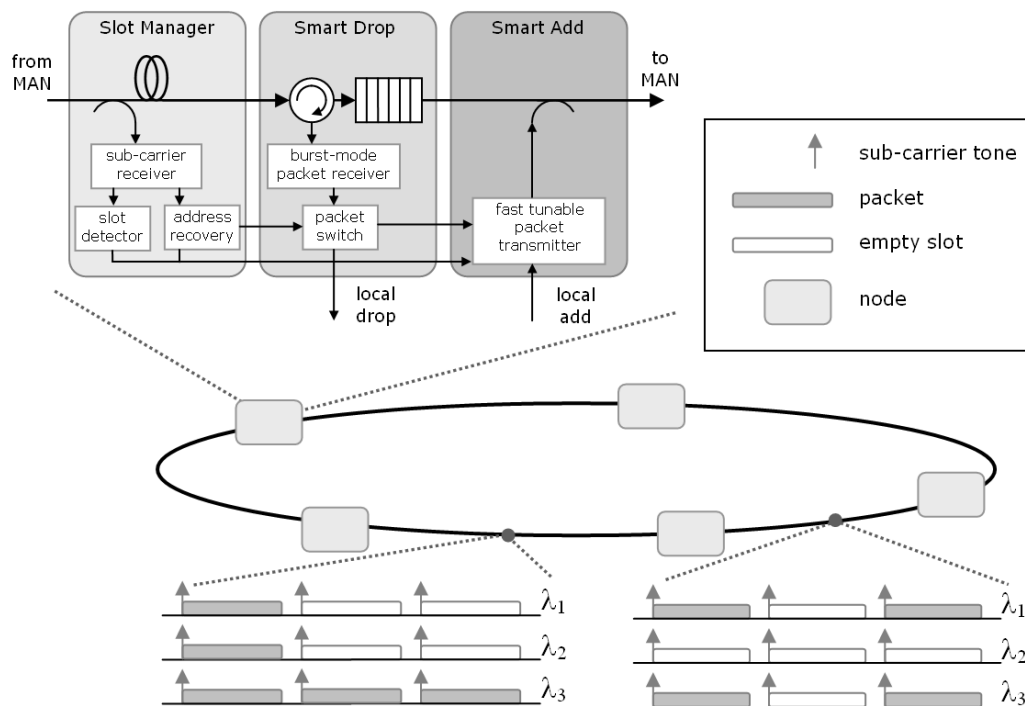


Figure 2.7: Structure of the HORNET metro network

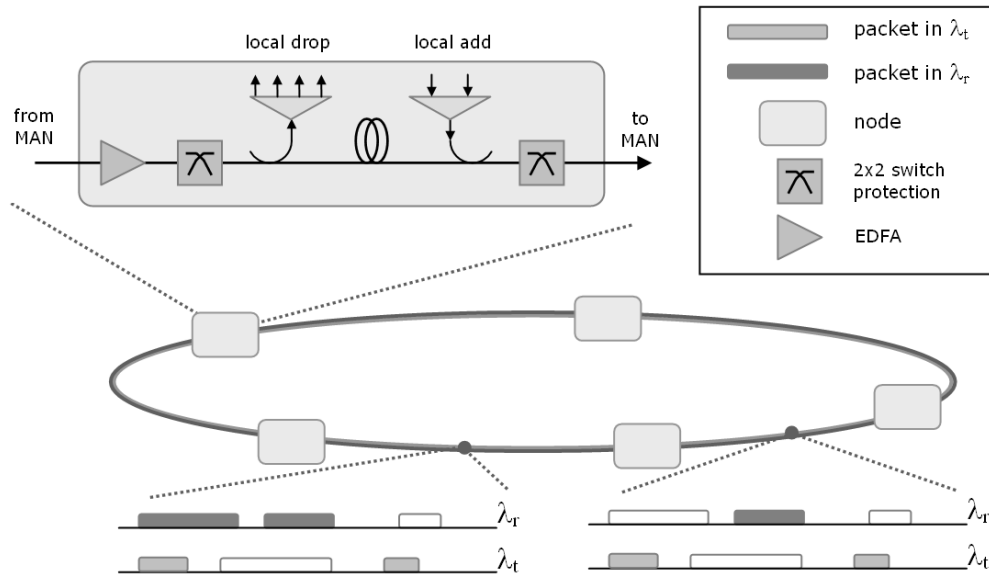


Figure 2.8: Structure of the DBORN metro network

a tunable transmitter, fixed receiver design (TT-FR), and the nodes use a CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) MAC protocol to govern access to the wavelengths (see [94] for more details on the access protocol). HORNET can use either slotted or variable-length packets- a characteristic which can provide flexibility. It can be based on two counter-rotating rings to offer cut-fibre protection, nevertheless, a failure will result in halving the available bandwidth. Multicast can be provided via node-by-node re-transmission, but no protocol is included and evaluated to handle multicast traffic and incoming traffic at the nodes. Neither QoS strategies nor fairness mechanisms are implemented. No performance evaluations to assess the merits of such architecture are available.

DBORN (Figure 2.8), which stands for Dual Bus Optical Ring Network, is based on a unidirectional fibre ring organized around a Hub developed at Alcatel Research and Innovation [73]. This architecture uses a spectral separation of upstream and downstream flows from/toward the Hub, forming a dual logical bus structure. Nodes dynamically read data on the downstream bus and write on the upstream bus, while the Hub interconnects the buses through a wavelength conversion. The spectral separation avoids the use of erasing functionality at the nodes increasing the nodal cascadability. A simple collision avoidance MAC is implemented through power detection utilizing a photodiode and a fixed-length delay line. The network can support any client packets and makes it easy to add/ remove nodes to/from the network. Some cost studies have shown the benefits of this architecture [73]. A performance evaluation is not available; neither QoS strategies nor fairness mechanisms have been implemented. The current protection mechanism is based on duplicating the network components.

2.5 Wide area network context

As stated in previous sections, the key topics in wide networks are the contention resolution algorithms and the node architectures designs. In this section we give a short overview of the current proposals.

2.5.1 Node architectures

The general architecture of a OPS node is presented in Figure 2.9, showing the main functional blocks:

- *Input interface* used to demultiplex the wavelengths on incoming fibers, to synchronize packets, to tap some optical power, packet header information extraction, and packet header removal.
- *Optical switching* used to perform the packet switching in optical domain solving the possible contentions. This block can be formed by different sub-blocks:
 - *Optical space switch* is a non-blocking space switching matrix used to physically interconnect the input and output ports;
 - *Optical buffer* used to solve contentions in the time domain;
 - *Wavelength converters* used to solve contentions in the wavelength domain.
- *Output interface* used to regenerate the optical signals, insert the packet header, and to multiplex wavelengths back to the fiber.
- *Switch control logic* used to perform header processing and rewriting, routing table lookup, as well as to set-up the optical devices to proper arrange the optical switching.

Several proposals for an OPS node architecture can be found in literature [104]. We can categorise them in two fundamental ways:

- There can be a single stage or multiple stages;
- The contentions can be solved either using a feed-forward or feedback configuration.

Single-stage architectures are generally easier to implement but may require complex scheduling algorithm to solve packet contentions. To increase the buffering capacity, the multi-stage architecture cascades many small switches, forming a larger switch with a greater buffer depth. Figure 2.10 depict a schematic example of the single stage and multi-stage node architecture.

In a feed-forward configuration (see Figure 2.11a), when packets enter in a stage, the possible contentions are solved once and then the packets are sent to the next stage or to the output; this implies that the packets travel along a constant number

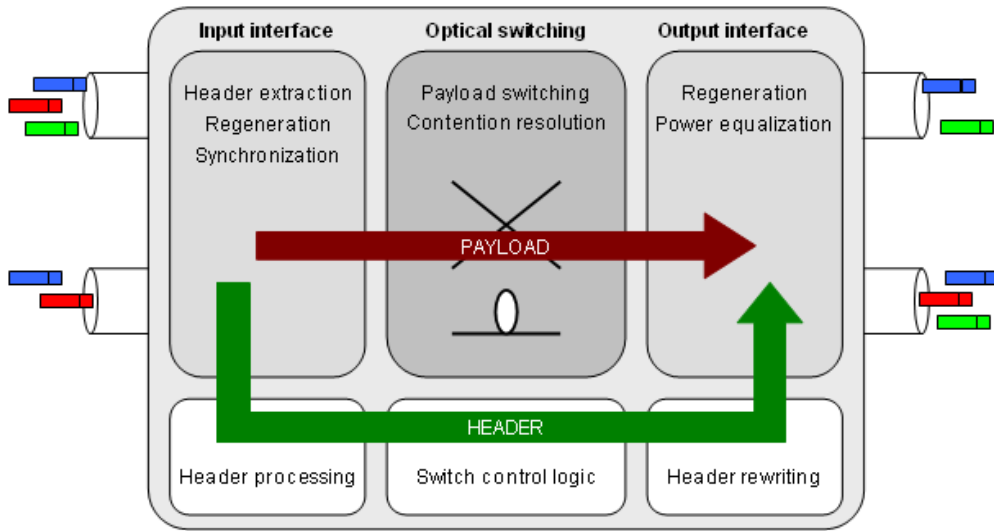


Figure 2.9: A generic OPS node architecture

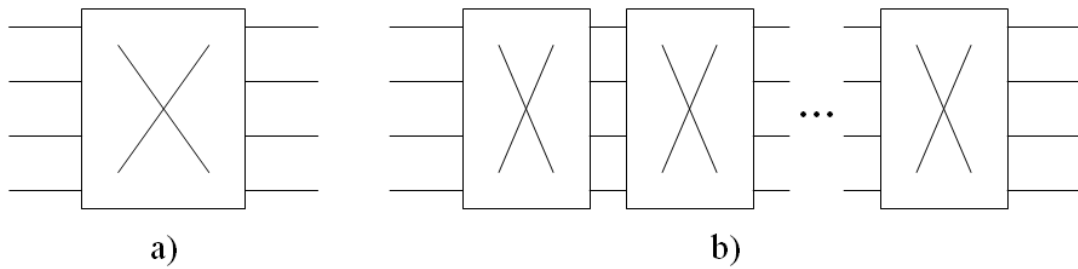


Figure 2.10: Schematic example of the a) single-stage and b) multi-stage node architecture

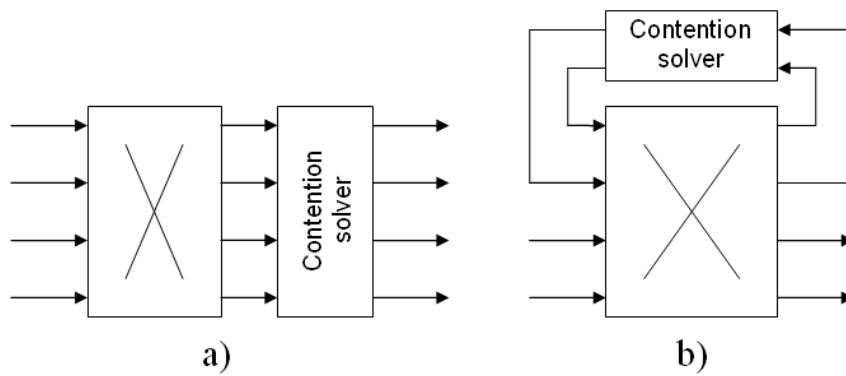


Figure 2.11: Schematic example of the a) feed-forward and b) feedback node architecture

Table 2.1: Example of node architectures

	Single stage	Multi-stage
Feed-forward	OASIS [60]	SLOB [59], WASPNET [61]
Feedback	SMOP [60], DAVID [43]	

of stage. In a feedback configuration (see Figure 2.11b), the packets can back to the input of the same stage in order to solve again the contention if the previous one was not sufficient; this implying that the delay generally differs between packets.

In table 2.1 we indicate some example of node architectures proposed in literature according to the classification described above.

Since this thesis is not focussed on architecture for optical packet switching we do not enter into specific technological aspects but deal with the contention resolution problem, which is a mandatory task for whatever architecture.

2.5.2 Techniques for contention resolution

Since OPS is based on statistical multiplexing, packet contentions may arise at each node. Indeed, when a packet enters a node and, according to its header, must be forwarded to a given output fiber and wavelength, it may happen that the requested resource is unavailable because occupied by another packet. Therefore, a contention resolution policy must be applied to reduce the packet loss probability and make the statistical multiplexing more efficient. Contention resolution techniques typically adopted by OPS networks exploit space, time and wavelength domains.

Space domain

Deflection routing is ideally suited to switches that have little buffer space. When there is a conflict between two packets, one will be routed to the correct output port, and the other to any other available output port. In this way, little or no buffer is needed. However, deflection packet may end up following a longer path to its destination. As a result, the end-to-end delay for a packet may be unacceptably high. Also, packets will have to be reordered at the destination since they are likely to arrive out of sequence.

Time domain

The implementation of optical buffering is the major problem. Optical RAM does not exist and in order to implement optical buffering, resort must be made to optical fibre delay-line (FDL) [48]. The alternative, of course, is to convert the optical packet to the electrical domain and store it electronically. This is not an acceptable solution, since electronic devices cannot keep up with the speeds of optical networks. Other solution is to use a hybrid approach; where both electronic and optical buffers are used in cooperation [76]. This solution relaxes the O/E/O bottleneck but introduce

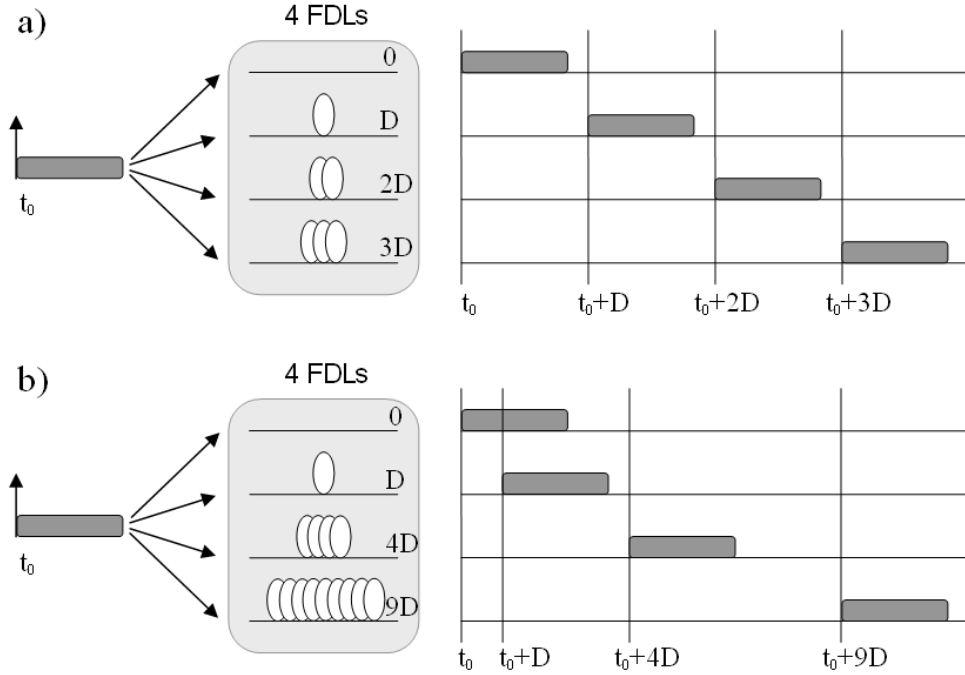


Figure 2.12: Buffer configurations with 4 FDLs, a) Degenerate $k_j = j - 1$, $\mathbf{Q}_4 = \{0, D, 2D, 3D\}$, b) Non-degenerate $k_j = (j - 1)^2$, $\mathbf{Q}_4 = \{0, D, 4D, 9D\}$

more problems than benefits since both very high speed electronic devices and FDLs are required.

Therefore, in general an optical buffer is made by a pool of B FDL with different lengths providing delays which are multiple of a basic delay unit D , also known as *buffer granularity*. The set of possible delays are denoted by \mathbf{Q}_B and the delay provided by the j -th delay line is $D_j = k_j D$ with $j \in \{1, 2, \dots, B\}$. A measure of the buffer capacity is given by the *maximum available delay* $D_M = \max_{j \in \{1, 2, \dots, B\}} \{k_j D\}$.

Two examples of optical buffers are shown in Figure 2.12. The first configuration (Figure 2.12a) assumes $k_j = j - 1$ and corresponds to delays which are consecutive multiples of the delay unit D : the first fibre does not introduce any delay, the second one provides a delay equal to D , the third to $2D$ and so on until the B -th fibre which offers the maximum available delay $D_M = (B - 1)D$. Therefore, $\mathbf{Q}_B = \{0, D, 2D, \dots, (B - 1)D\}$. This uniform delay distribution is the simplest case and can be considered a sort of reference. Such configuration has usually referred as *degenerate* buffer. Another possible configuration is the *non-degenerate* buffer where non-uniform delays are used and k_j can assume any value. Figure 2.12b shows an example of a non-degenerate buffer where $k_j = (j - 1)^2$, and therefore $\mathbf{Q}_B = \{0, D, 4D, \dots, (B - 1)^2 D\}$.

It is clear that D is a key parameter in the buffer design, and it must be accurately chosen. It strongly depends on the format of the optical packets and on the network operation. In the case of FLP-SO and VLP-SO, the value of optimal D is related with the length of the packets. In the case of VLP-AO, the value of optimal D depends

on the average length of the packets and on the contention resolution algorithms as demonstrate for example in [17].

Finally, as buffering tool, FDLs are bulky and not scalable. Compared to electronic buffers and their role in current packet networks, FDLs can only offer limited buffering capabilities (few tens of possible delays at maximum [45]).

Wavelength domain

In WDM, several wavelengths run on a fibre link that connects two optical switches. This can be exploited to minimize the contention probability as follows. Let us assume that two packets are destined to go out of the same output port at the same time. Then they can be still transmitted out, but on two different wavelengths. So then, wavelength converters are used to change the wavelength of the packets in contention in such a way that multiple packets can be sent simultaneously to the same output port. As a result, wavelength conversion is the most effective contention resolution, not incurring additional latency while maintaining the shortest path or minimum hop distance. This method may have some potential in minimizing contention, particularly since the number of wavelengths that can be coupled together onto a single fibre continues to increase.

The recent works on the contention resolution algorithms and QoS mechanisms are discussed in Chapters 7 and 9, respectively.

2.5.3 Example of OPS-based backbone network prototypes

In this section, we briefly describe two OPS-based backbone networks developed in different research/university centers. These examples demonstrate the world-wide interest and the viability of such solutions.

WASPNET [61] is a packet-based optical WDM transport network proposing a node design based on wavelength router devices (Figure 2.13). The network operation is synchronous and the packets are fixed-length. All the inputs are wavelength demultiplexed to a number of parallel planes, one for each wavelength channel, each plane containing an optical packet switch. A combiner merges the wavelength channels from all planes, allowing dynamic wavelength allocation at each plane. The AWG in each plane routes packets to the space switch, which then switched each of them to the correct output port at the correct wavelength via the final stage of wavelength conversion. The contended packets are routed to the recirculating loops for buffering, while the straight-through packets are routed to switch outputs. Contention resolution is implemented assuming a FIFO algorithm and ensures that no more than one packet may exit from each combination of FDLs, a demultiplexer and a multiplexer; otherwise, it will be router to other alternative AWG outputs or, if necessary, to longer-delay lines.

DAVID [43] proposes a broadcast-and-select architecture, which ensures nonblocking performance using SOA technology, as illustrated in Figure 2.14. A shared recirculating FDL buffer is used to help solving contention, where exploitation of the wavelength domain does not suffice. The switch operates synchronously and both

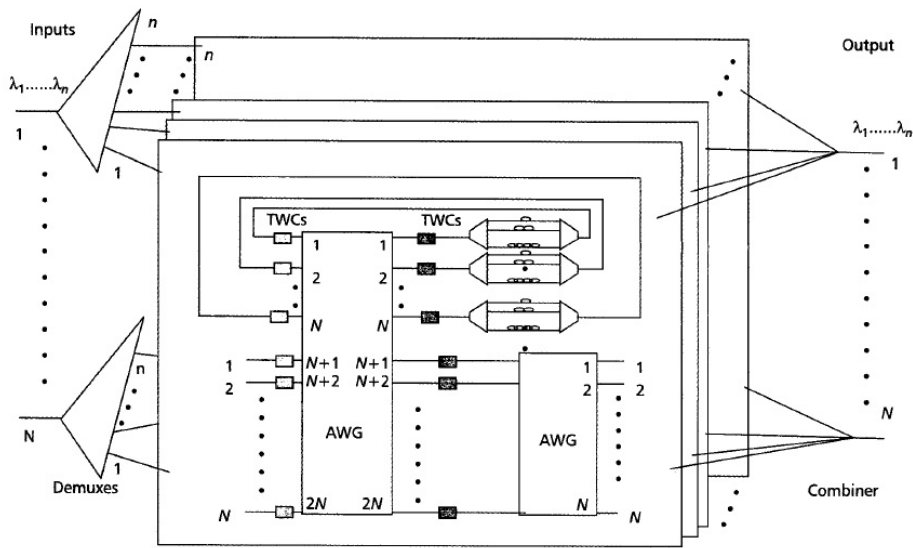


Figure 2.13: Structure of the WASPNET switch node

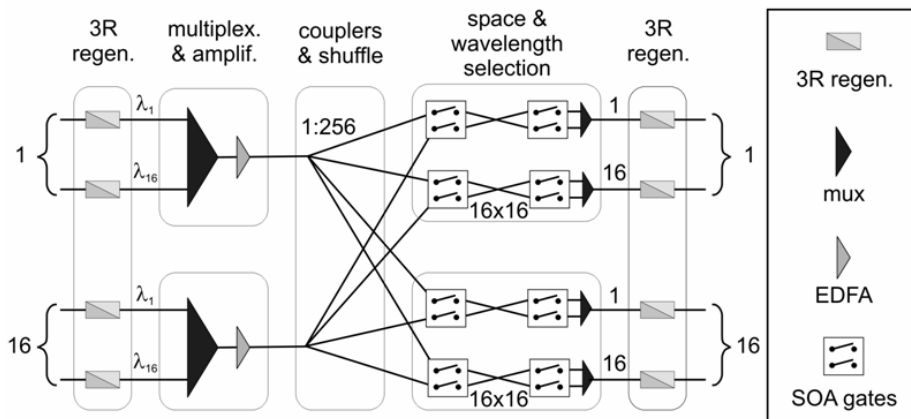


Figure 2.14: Structure of the DAVID switch node

FLP and VLP packet formats alternatives are studied. For the former, a simple first-fit algorithm is proposed and applied to two different buffer structures. For the latter, several algorithms are suggested showing that the optimization of the usage of the FDL must be the main aim to reach acceptable performance.

