Reconfigurable optical and wireless mesh networks

This paper elaborates on the emerging area of reconfigurable optical and wireless mesh architectures from the standpoint of carrier and users’ needs and technology evolution. It first examines the limitations of legacy optical and wireless networks, then looks at some emerging technologies, provides the drivers for these specific implementations and gives an insight understanding on their functionality and capabilities for providing next generation applications. It examines the role and realisation of reconfiguration in optical and wireless networks from the standpoint of user needs and requirements where the user is a network operator or the end user.

Reconfigurable and mesh architectures are capable adapting, reactively or proactively, to the environment requirements and conditions, by means of self-configuration.

Introduction

Recently there has been an increasing demand for bandwidth demanding applications, which has led to the development of new technologies which will provide networks that can carry very large amounts of capacities, which, in turn, can lead to offering services to customers at lower costs. The emergence of new broadband applications such as Video on Demand (VoD), IPTV, VoIP and Peer to Peer (PtP) services has led to large demand on traffic placed on the network and a high degree of management effort on the operator side. These services will drive consumer capacity requirements up to 100 Mbps. In such situations where the traffic load changes very quickly an operator also needs to respond equally quickly by having established reconfigurable and flexible architectures. Otherwise it will be faced with a high management overhead of setting-up and tearing-down already established connections that cannot cost effectively support these high capacity levels. Users require use of new services that run at high speeds but this must be managed efficiently by operators. They are willing to subscribe to new services, which lead to higher average revenue per user to the operator, but it must be managed efficiently with low capital and minimum operational expenditure. This drives investment of operators into reconfigurable optical network systems and wireless architectures that will both enable this network progression and high-speed service provision.

Present architectures

Present architectures are mainly using Wavelength Division Multiplexed (WDM) networks, which are based on fixed optical add/drop multiplexers (OADMs) in which the number of wavelengths in the network and their allocation to users is fixed and predetermined. This hardwired configuration uses simple fixed optical filters and low cost subsystems as is shown in Figure 1.

Figure 1. DWDM Optical architecture consisting of fixed nodes

This imposes a significant limitation on the operators in the management of their optical networks especially in moving subscribers between services and provisioning new ones into the network. The lack of flexibility and slow service provisioning are the main drawbacks of building the dynamically provisioned network of the future. When traffic requirements change, additional operational expenditure is required by means of having manual intervention and network reoptimisation that causes loss of revenue. Similarly, in the wireless world the infrastructures have a fixed functionality since they are either used for transporting traffic between back-hauling nodes or for providing access to fixed places at predetermined configured user profiles. Such a wireless infrastructure is shown in Figure 2. In this architecture the frequency allocation for the traffic routing from one node to another and the user’s profile in terms of traffic requirements and service provisioning is fixed and predeter-
mined. Where a new user requires service provisioning, manual intervention is required for the management of traffic requirements.

### Overview of reconfigurable & mesh architectures

Reconfigurable and mesh architectures are capable adapting, reactively or proactively, to the environment requirements and conditions, by means of self-configuration. Reconfigurable networks are adaptable from network layer 3 up to the application layer 7 of the OSI standard reference model.

Reconfigurability provides technological solutions that enable the network elements and the user’s terminals to dynamically select and adapt to the most appropriate conditions and parameters in order to fulfill the user’s expectations and needs for services at the expected bit rate and QoS means.

The benefit to the user will be reflected in cost reduction to the operator and finally to the end user since the reconfigurable network requires less operational costs by efficiently handling the user traffic and requested services.

### Reconfigurable optical and mesh wireless architectures

A reconfigurable optical architecture is shown in Figure 3. It’s main architecture is based on reconfigurable optical add/drop multiplexers (ROADMs) that provide the means to dynamically manage and monitor users incoming or outgoing from the network. Briefly, the ROADM system has the ability to add/drop or redirect any wavelength at any port via an input coupler, thus enabling service providers to remotely perform wavelength insertion, termination or switching at any site or adding a new optical path for servicing new customers without re-engineering the network or interrupting the existing services. The services are carried by wavelengths and it can be seen that a typical 40 Gbps traffic that can be carried in a fibre, it leads to a large number of services carried by different wavelengths that can easily dropped or added through reconfigurable architectures in the network.

The mesh wireless architectures, as shown in Figure 4, do provide the means for dynamically managing local traffic so that if a link is overloaded with traffic, then some of the extra traffic is carried to another link. Also in case that a link fails its service traffic, all traffic is carried by another route. This is done dynamically without manual intervention.

### Main drivers for Reconfigurable Optical and Wireless Mesh Architectures

The main services that are currently used are broadband data and VoIP, something that can be satisfied by 1 Mbps in an average household. This trend will steadily shift to higher values as video traffic requirements increase due to IPTV, High Definition TV (HDTV) and Video on Demand (VoD) usages that all can reach values close to 20 Mbps per household. VoD allows users to purchase video content whenever they desire and as such, provides a unique video stream between the user and the video source. These video services will grow fast in the next years, pushing large streams of data across the network. These streams will be more difficult to predict and plan to what values they can reach than broadband data traffic. Video data will most likely be pushed to the edge of the network to be closer to media servers across the network.

In the access domain the infrastructure needs to be in mesh mode to be able to support dynamically changes of traffic. The delivery of these high-speed services with QoS will require from telcos turning investments into ROADM and mesh technologies. Therefore, the main drivers for offering reconfigurable and mesh architectures will be the high bit rates required by video services.
Transformation of operator’s network technologies

The deployment of new services by telecom operators has increased the demand for a highly scalable, reconfigurable and dynamically service provisioning network infrastructure. The original fixed infrastructures are not going to satisfy the needs for dynamically changing high bit rates of traffic that are to be carried by the networks. The new video services such as VoD, HDTV and IPTV, which push large amounts of traffic over networks, have introduced scepticism among operators resulting in the reassessment of their fixed DWDM and wireless equipment in favour of a new set of reconfigurable optical add/drop multiplexers and wireless mesh architectures. The benefits of the above technologies lead to:
• a competitive advantage over the competition that does not implement such technologies
• easy adaptation of networks in new traffic models and schemes
• automated planning and management of complex networks

Transformation of services

The reconfigurable optical and wireless mesh architectures favour the emergence and implementation of high bit rate services by assuring resiliency, continuity, always availability and extensibility. Services can be switched on remotely without requiring any manual intervention and network resources can be dynamically allocated according to traffic demand. The above architectures are able to support high capacities required by the triple play services and therefore both users and operators will benefit by their installation and operation. These technologies result in:
• the reduction of time for new services to enter the market
• new services can be provisioned in hours rather than days
• the addition/removal of a service without disturbing the operation of a live network.

Transformation of users’ lives

Implementation of reconfigurability and mesh paradigms in the network architectures are the enablers that provide:
• seamless experience to users in selecting a network (wireless or wired) in a dynamic and robust manner,
• improved service provision and adaptability so that the user will be able to subscribe to new high bit rate services,
• possible reduction in the cost of using new high bit rate services.

Conclusions

The ROADMs enable operators to remotely insert, terminate and reroute services across the network and adapt dynamically to changes in the traffic requirements. These systems fully satisfy this requirement by offering a higher level of flexibility and efficiency with significant reduction in operational expenditures and seamless service introduction. The wireless mesh architectures provide dynamic support of various services over different links. These can maintain and optimise network traffic to maximise customer satisfaction.

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Glossary

HDTV: High Definition TV
IPTV: Internet Protocol Television
OSI: Open Systems Interconnection
PtP: Peer to Peer
QoS: Quality of Service
ROADM: Reconfigurable Optical Add Drop Multiplexer
VoD: Video on Demand
VoIP: Voice over Internet Protocol
WDM: Wavelength Division Multiplexer
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