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Publication:	in Proc. OSA/IEEE Optical Fiber Communications/SPIE National Fiber Optic Engineers Conference (OFC/NFOEC 2005)
Vol.:	-
No.:	-
pp.:	-
Date:	Anaheim (USA). March 6-11, 2005

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NetCat: cross-plane approach for dynamic, distributed service provisioning in a GMPLS enabled optical testbed

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OCIS codes: (060.4250) Networks

1. Introduction

Dynamic service provisioning is expected to be a key feature of next-generation optical networks. The increasing use of wavelength multiplexing (WDM) infrastructures due to Internet traffic is expected to play a crucial role in the flexible, low-cost networking needed for the inherent dynamism of future data services. While the main evolution of current infrastructures is optical intelligence (automated functions in the network), principally through distributed approaches such as the Generalized Multi-Protocol Label Switching (GMPLS) framework, services, mainly based on the Internet Protocol (IP), are also evolving from centralized to distributed. In this work, we group traditional telecommunications services with centralized control (i.e. network operator) as 'centralized services', whereas 'distributed services' are those user-defined or managed, such as Grids or customer-empowered applications [1].

On the other hand, since future optical networks will not be deployed from scratch, they are likely to be series of physically linked but not necessarily 'connected' islands. Each of these islands can be an area (domain), operating independently of other areas within an Autonomous System (AS), or an AS itself. Note that each island will be based primarily upon its own network, and that such a network will most likely be IP, since networks based on IP principals are the industry standard when referring to computer networks. In this context, an architecture is required to allow these 'unconnected' islands to interoperate with one another in a cohesive and useful fashion. While much effort is being placed on the definition of network interfaces (I-NNI, ENNI) at control plane level [2] as part of research in optical intelligence, management interoperability is emerging as a crucial research field for the success of future IP/WDM networks. As in the past, optical networks using well designed management architecture(s) will allow areas and ASes to exchange information, perform remote tasks and provide a greater level of functionality.

In this paper we propose an integrated management solution for providing end-to-end IP connectivity services, either managed by operators or users, in a dynamic, distributed manner. The remainder of the paper is organized as follows. Section 1 describes the framework and the cross-plane approach of the work. Section 2 deals with the rationale behind the NetCat project, focusing on the design and experimental test of cross-plane management. Section 3 contains preliminary results assessing the suitability of the approach. Finally, we draw conclusions.

1. Cross-plane approach for dynamic, distributed service provisioning

This work is in the context of future connectivity services, whose provisioning is expected to be dynamic and real-time, and may be triggered (at least in part) directly by users. Such services may have different granularities, but we focus on wavelength services (optical channels) due to economic reasons in the deployment of our testbed. We focus on an optical network constituting an AS with several areas ('islands'). Within this AS, it is sensible to think that not all the areas and/or users may be GMPLS enabled, or even control plane enabled. On the other hand, WDM technology is present in many transport networks; we consider that our AS adopts the logical evolution of this, that is, Dense WDM (DWDM). Under these assumptions, our objectives are: i) to design an integrated management solution for providing end-to-end IP connectivity services derived from Service Level Agreements (SLA), ii) to avoid centralized paradigms in the management architecture, iii) to provide smooth integration strategies with current networks, and iv) to offer service provisioning to non-GMPLS devices/networks.

In this paper we focus on objectives i) to iii). As for smooth integration, we approach centralized and distributed service jointly, because optical networks, mainly owned by operators and therefore designed for centralized services, are to become the efficient infrastructure needed for supporting emerging distributed applications, which will involve distributed services, totally or partially. Concerning objective i), we understand service provisioning as a cross-plane process based on two pillars, as depicted in Figure 1. The first pillar is the joint approach of centralized

and distributed services, whose main difference will be their profile (triggering more or less complex connection acceptance procedures). The second pillar is the distribution of elements and information concerning management across the network. This distribution (objective iii), which we describe in previous work [3, 4, 5], arises from the modeling of service provisioning as a set of in-out dialogues from an incoming request at an ingress to its acceptance by the egress, encompassing reservation and subsequent allocation of resources by automated functions.

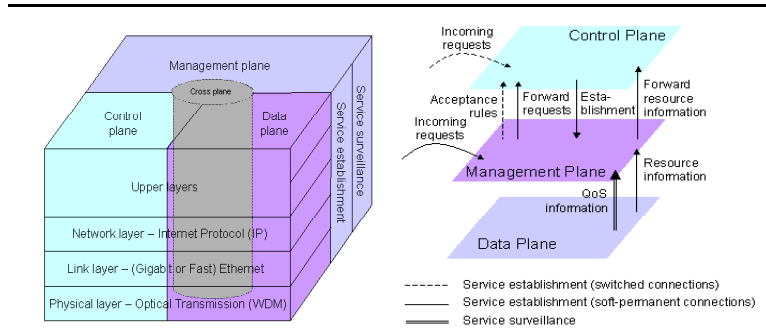


Fig. 1. Cross-plane approach for service provisioning: a) optical planes, layers and functions, and b) in-out dialogues

In this paper we focus on the first pillar, whose rationale follows. We use the control plane as intelligence for providing dynamic soft-permanent (SPC) [2] provisioning. Centralized services are known by the management plane (profile ‘registered users’ in Figure 2), whereas distributed services may encompass unregistered users, which means that acceptance of connection requests is no longer immediate, since users may be unknown to the optical network. Note that in this context service surveillance (SLA guarantee) is also difficult because of the need to support different optical qualities between source-destination pairs that may change their profile dynamically [2]. We describe such surveillance in [5]. In control plane enabled areas, the management plane is responsible for providing it with rules on how to treat incoming requests from services. This is achieved with two strategies: a) management information decentralization combining control plane information flow with simple agents spread across the management plane, and b) Distributed Optical Managers (DOM) gathering user and network information. Strategy a) is described in [3], whereas a simplified view of strategy b) is illustrated in Figure 2 for the case of the NetCat project (GMPLS enabled). It can be generalized to any control plane enabled network. In non control plane enabled areas, the management plane deals with the whole provisioning process, similarly as it is done today.

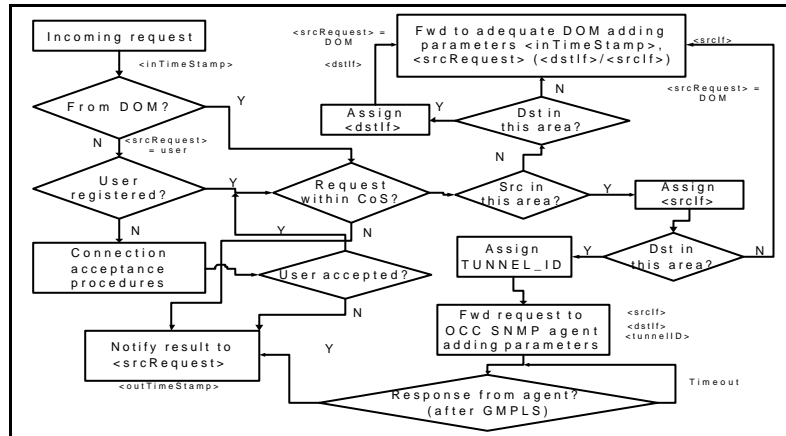


Fig. 2. Dynamic, distributed SPC provisioning in NetCat through cross-plane mechanisms

2. The NetCat project

The rationale behind the project “*Intelligent optical Network for advanced networks in Catalonia*” (NetCat) is to design and test a regional optical ring with DWDM technology and a GMPLS control plane to allow realtime, dynamic configuration of optical channels between multiple clients (concept of Automatically Switched Optical Network, ASON [2]) capable of managing lightpaths. In other words, NetCat models an IP over reconfigurable WDM regional network based on the ASON/GMPLS concepts and on distributed management.

For testing the pillars and strategies of the cross-plane approach outlined in the previous Section, we use an experimental testbed (ADRENALINE, <http://www.cttc.es/adrenaline/>). This testbed is a three-area AS based on an ASON/GMPLS network constituted by a metropolitan DWDM ring with three dynamically reconfigurable OADM's and a GMPLS-based control plane. Due to the flexible architecture of the testbed, combining fiber and emulated links, the number of nodes (Optical Connection Controllers, OCC) and the topology of the control plane can be easily modified, with up to nine nodes. In NetCat, the ADRENALINE testbed is configured as a nine node ring, emulating a possible future network for Catalonia, which is a region of Spain, as depicted in Figure 3a.

Each OCC is composed of a GMPLS entity, containing RSVP-TE and OSPF-TE daemons for signaling and routing, respectively, and a Simple Network Management Protocol (SNMP) based agent for communicating with other management entities, namely Distributed Optical Managers (DOM) and all agents located in active elements, as described in [3, 5]. Exchange of signaling, routing and management messages is done through the use of a single IP control channel implemented with full duplex Fast Ethernet links. Each optical node has four client interfaces, which are allocated to users either a priori or dynamically by the DOMs (in case of SPCs) and the GMPLS entities (switched connections [2]). A user may be physically connected to the network through one or more interfaces, and he/she may request bandwidth with bounded setup delay depending on Class of Service (CoS). Inter-area communication is achieved via eXtensible Markup Language (XML) whereas communication with the control plane is done via OCC agents with SNMP and an internal Application Programming Interface with the GMPLS engine.

4. Preliminary experimental results

In our tests, we assume bidirectional SPC requests of Premium class from both registered and unregistered users. Connection requests, which arrive to the DOMs via an Internet server (DOM-G in Figure 3a) [4], are served on a FIFO basis, all having the same class. Traffic distribution among nodes is uniform. Figure 3b plots setup/release delays within an area (no switching time considered) for the case of Poisson inter-arrival and exponential holding times, including XML parsing. All requests are intra-area and sent to the right DOMs to avoid request forwarding between managers and to minimize connection acceptance procedures (illustrated in Figure 2). Figure 3c illustrates the components (in msec) of end-to-end provisioning for the case of user access with ADSL 256 kbps.

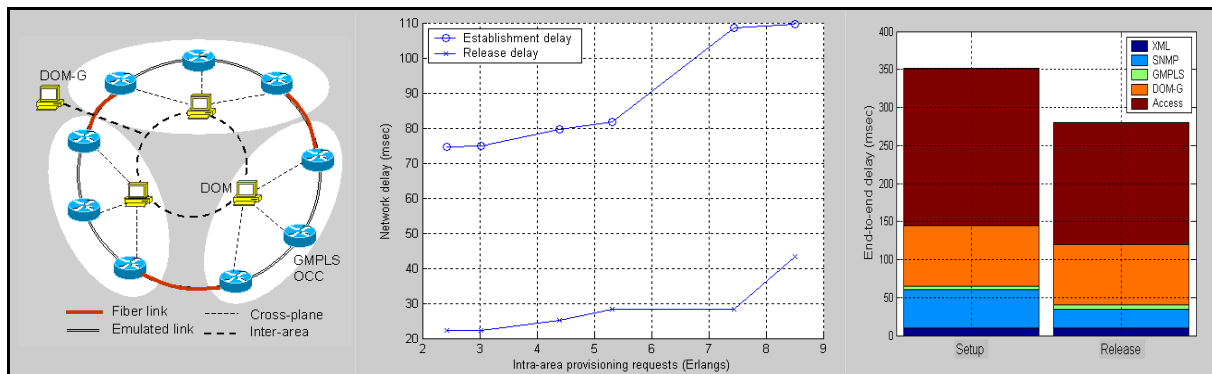


Fig. 3. a) ADRENALINE testbed configuration for NetCat, b) intra-area provisioning and c) end-to-end delay for SPCs

Conclusions

The main evolution of current optical networking infrastructures is intelligence, principally through distributed approaches such as GMPLS. Novel distributed, IP-based services are arising. In an effort for management integration in such a context, we obtain ms-order bandwidth on demand provisioning through a cross-plane approach in the management plane, which interacts with automated functions (control) and resources (transport).

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