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Experimental user-oriented architecture for rapid provisioning in IP/WDM networks

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1.- INTRODUCTION

The accelerating growth of data traffic, mainly based on the Internet Protocol (IP), is motivating the research for more efficient, flexible, intelligent optical network architectures. Wavelength Division Multiplexing (WDM) offers efficiency in the use of deployed optical fibers through multiplexing tenths to hundreds of channels per fiber. Therefore, IP over WDM (IP/WDM) is becoming accepted as one of the most promising candidates for next-generation transport optical networks. Generalized Multi-Protocol Label Switching (GMPLS) is also thought to be an integral part of future optical networks, especially as distributed control plane of the Automatic Switched Optical Network (ASON) [1] because it renders networks intelligent. On the other hand, XML is emerging as a de facto standard to exchange information over heterogeneous systems while SNMP has been the industry standard for network management since the last 1980s.

This work presents the design and implementation of an ASON management plane that performs SPC provisioning and incorporates a gateway for user-driven service requests. Its service-oriented architecture is achieved through integrating eXtensible Markup Language (XML) and Simple Network Management Protocol (SNMP) based communication mechanisms in the management plane, and through coordinating these mechanisms with the GMPLS protocols used in the distributed optical control plane. Experimentation results with an ASON/GMPLS testbed, XML based remote requests with SNMP and ASON/GMPLS provisioning processes, assess potential suitability of the overall distributed management approach for service provisioning due to its low delays and high flexibility.

2.- THE FOUR PILLARS OF THE APPROACH

1) User-driven provisioning of wavelength-services.

In circuit-switched optical networks, such as ASON, the service offered is capacity and connectivity in the form of wavelength and/or sub-wavelength channels. Current networks, based on Synchronized Digital Hierarchy (SONET/SDH), offer optical pipeline communications between electrical routers. Such services, known as permanent connections, are provisioned through manual configuration of the switching equipment. This process takes hours to weeks, depending on the service class, due to the amount of semi-manual operations needed. To improve this, the ASON framework offers two novel dynamic services: soft-permanent connections (SPC), triggered by the optical management plane (usually by the administrator through the Network Management System, NMS) and established through the dynamic mechanisms of the control plane, such as those of GMPLS; and switched connections, requested by

the users through the User-to-Network Interface (UNI) and established by the control plane [1].

An example of user-driven provisioning follows. The administrator of a campus network wants to set up a wavelength service to access the Internet. The first step is to log onto the network's service web page. A demo site is available at <http://netcat.cttc.es>. At this stage, the optical network checks the running services for this user (established channels from/to the user), and the services that the user can establish (source and destination clients, service quality, etc.). Then, the user selects the parameters of the service he wants to request by point-and-click, and the server forwards the request to a SOAP gateway, which validates it and sends it to the NMS, named optical manager. After this, a dialogue between the management and control planes of the optical network is established to forward the request to the GMPLS signalling entity of the node to which the user is physically attached. [5] and [8] describe the distributed processing of the optical manager and SNMP based agents, as well as GMPLS signalling mechanisms. When the control plane has established the channel, the response is translated to SNMP, and once the optical manager has validated the response and retrieved all parameters, the gateway packages the response into an XML file in accordance with the scheme defined. Finally, the server retrieves the relevant parameters from the XML response file and displays the result on the web page. It is then that the user is aware that the connection has been established and can start transmitting data.

2) Combination of existing and emerging technologies

User-driven provisioning of an optical service encompasses combining existing and emerging technologies, adapting optical network elements, and making protocols and communication mechanisms cooperate, the goal being that a user, agnostic to network resources and performance, can point and click" a service. Optical networks are usually managed through SNMP managers and agents [2]. Other common communication mechanisms are the Transaction Language One, which is an ASCII-based command language used mainly in switches, cross connects and fiber-optic systems, and the Common Object Request Broker Architecture (CORBA), an object-oriented framework used for inter-domain management communications and in the interface between managers and agents.

Distributed technologies are the most suitable to allow user-driven service provisioning requests, due to the inherent decentralization of triggering the provisioning process if users are to be in control of lightpath establishment and deletion. Some of the most popular technologies for distributed management are CORBA, Java Remote Method Invocation (RMI), Open Distributed Management

Architecture (ODMA) and Distributed Component Object Model (DCOM). Since next-generation optical networks are expected to be heterogeneous, the main disadvantage of these technologies is that both the client and the server must have similar or the same engine and operating system for these technologies to work. Therefore, the above-mentioned approaches do not support true distributed components, that is, client and servers with different operating systems, running on different machines and networks.

Instead, XML based communication mechanisms are a very powerful technology, greatly motivating the idea of distributed computing. Rather than creating or reinventing protocols, XML, which is emerging as a de facto standard to exchange information over heterogeneous systems, runs on top of HyperText Transfer Protocol (HTTP), with or without intermediary layers, such as the Simple Object Access Protocol (SOAP) [3]. HTTP has been, since its birth in the 1990s, a significant step in the evolution of service-oriented architectures. The combination of HTTP and markup languages, such as hyper-text (HTML) or XML allows using the web for information sharing; this has changed the computing model from client-server to browser-application: a "web revolution". This web revolution has resulted in new possibilities for integration and platform independence, and has created a new distributed service model for management [2], which we think is bound to reach optical management. In fact, XML provides information encoding, whereas HTTP provides transport of such information over any IP infrastructure, including IP/WDM networks. Therefore, XML/HTTP may be included as part of the optical management service protocol, together with the management communication and the signalling protocol used in the control plane, which in this work are SNMP and the Resource Reservation Protocol (RSVP) [4], respectively.

The price to pay for any automated system is usually higher implementation complexity. In order to alleviate this, we use SNMP, GMPLS and XML to form a constructive cooperation to deliver optical services (in this work, soft-permanent connections). We have described the role of XML in this cooperation, as well as the elements and communication mechanisms and messages involved in the user-driven service provisioning process. The use of SNMP, focusing on a GMPLS-oriented MIB module is described in [5] and [8]. These references detail as well the complementarity approach used in the dialogue of the management plane (SNMP) and the control plane (GMPLS). In short, such complementarity is based on allocating functions to both planes so that no functionality or data is replicated, and flexible collaboration of the control plane's real-time and management plane's near-real-time mechanisms is achieved. Combining SNMP and GMPLS makes agents "intelligent", in the sense that they are autonomous, cooperative, reactive and proactive. A description of the use of GMPLS, one of the key enablers of automated provisioning in future IP/WDM networks, follows.

When a new optical connection request arrives to a source (ingress) GMPLS based OCC, it creates a new Path State Block (PSB) for this session (identified by the destination node, TUNNEL_ID and LSP_ID) and initiates a Path message with the following objects: Session and Lsp_Tunnel_IPv4_Sender_Template (identification of the Lambda-LSP request), Generalized Label Request (request of Lambda LSP indicating payload), IPv4_IF_ID_RSVP_HOP (node and interface/link for the lambda), SENDER_TSPEC (required bandwidth), and other relevant objects such as Explicit Route (ERO), Label Set (guarantee wavelength continuity) or Upstream Label (bidirectionality). Note that in this work user-driven connections are of SPC nature, since they are triggered in the management plane. Therefore, the last hop of the ERO must specify the destination (egress) node and the destination interface identifier. This information can be provided by a routing protocol, which is responsible for disseminating optical topology and network resources.

3) Implementation of an ASON management plane

In late 2001, the standards organization ITU-T specified the architecture and requirements for the ASON [1] as applicable to hyper transport networks, which is known as G.8080. G.8080 describes the set of control plane components that are used to manipulate transport network resources in order to provide the functionality of setting up, maintaining and releasing optical connections in ASON settings. So, an ASON consists of three different planes: control (optical intelligence), transport and management. The ASON control plane performs call control and connection control functions, so that through signaling, it sets up and releases connections, and may restore a connection in case of a failure. The transport plane provides uni- or bi-directional transfer of user information, from one location to another, and it may also provide transfer of some control and management information. Neither details of the Data Communication Network (DCN), which provides the communication paths to carry signaling and management information, nor of the management plane are given in G.8080.

Generically, the ASON management plane must perform management functions for the transport plane, the control plane and the ASON system as a whole, and must provide coordination between all the ASON planes. In this work, the ASON management plane is composed of a central NMS (called optical manager), which performs as control plane, transport plane and resource manager, a gateway, which is responsible for proxying with remote SPC requests and SNMP agents at each optical node. Note that agents are embedded not only in optical (active) hardware (Optical Add-Drop Multiplexers, OADM, or Optical Cross-Connects, OXC) but also in control plane's Optical Connection Controllers (OCC).

4) Low-complexity data modelling for service provisioning

ITU-T Recommendations of X.700 Series or M.3010 are examples of conceptual (information) modeling of the management plane, including service provisioning. Such modeling is independent of specific implementation, and defines relationships between managed objects. Since control plane and transport plane elements (OCCs and OADM/OXCs, respectively) contain management agents, as well as a Management Information Base [5] and a message communication function, encompassing a management information protocol, the optical manager is able to access the information models of both the control and transport planes. Concerning the management information protocol, we have chosen SNMP [6] because it has been the industry reference for management since the last 1980s; SNMP agents are installed in almost any system to enable remote access to its components, making SNMP a de facto standard for networked hardware management [2].

3- INTRA-AREA EXPERIMENTAL RESULTS

Here we describe preliminary experimental tests performed in an ASON/GMPLS setting (ADRENALINE¹), which operates 8 DWDM channels/fiber at up to 2.5 Gbps, due to economic reasons. Links span 35 km and the topology used is a ring, emulating a metropolitan environment. The testbed's architecture is detailed in [8]. Tests are preliminary because of the following: gateway and optical manager are in the same machine, SOAP is not considered because is not yet fully deployed, and all clients are authorized by the network.

Delays for SPC requests are split in two parts: the optical networking, involving the manager and OCCs (agents and GMPLS daemon), and the Internet side, involving the web server, the gateway and the user site. Since Internet delays are difficult to analyze and depend much on the user access technology (wireless, ADSL, fiber...), we only include orientative user site times (Figure 2). To emulate multiple remote users, we have compiled several XML documents containing setup and teardown requests.

All lightpath requests are bidirectional, Premium class, and served as they appear in the XML files. Traffic distribution among nodes is uniform. Figure 1a depicts the setup and teardown delays obtained for different traffic loads. Figure 1b depicts setup and teardown delays for different user access technologies, namely modem at 9,6 kbps, ADSL at 128 kbps and optical fiber. Apart from these results, some modellings of Internet round-trip time dynamics [9] suggest that our approach could satisfy optical Service Level Agreements (SLA) even for Premium Class, such as the 1 min setup delay proposed in [10] for bandwidth on demand services.

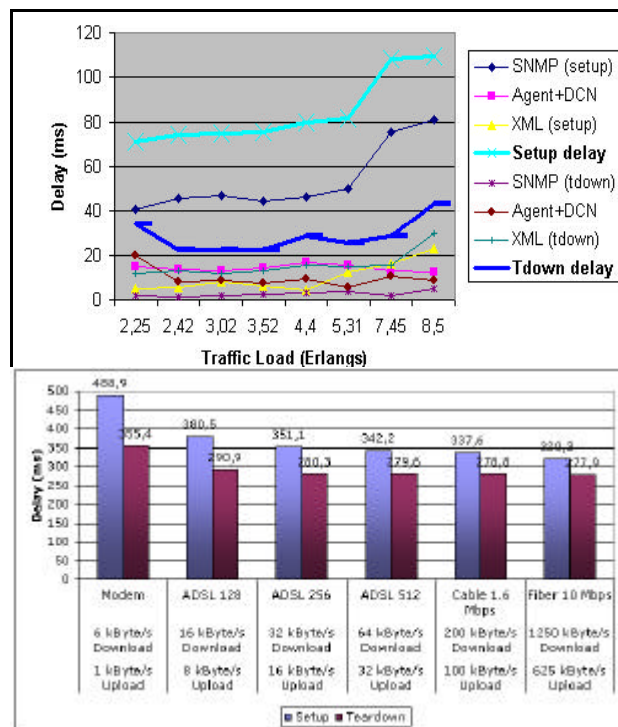


Figure 1. a) Delays vs. connection arrival and b) Delay including user access.

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