AN EXPERIMENTAL GMPLS-BASED WAVELENGTH RESERVATION PROTOCOL FOR FLOODING GLOBAL WAVELENGTH INFORMATION IN UNI-RING-BASED MAN

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Abstract: The accelerating growth of Internet traffic, together with its bursty traffic pattern is specially motivating the research on not only high-bandwidth but also dynamic metropolitan networks based upon recent advances in optical networking technologies such as R-OADM and OXC. The dynamism of the wavelength-routed networks can be achieved by means of a distributed control plane (i.e signalling for wavelength reservation and routing for dissemination of topology and optical resource state), which can be based in GMPLS. The objective of this paper is to propose a GMPLS-based signalling protocol which allows to have a global wavelength resource information without any routing protocol when provisioning bidirectional connections in uni-ring-based MAN. Performance evaluation has been carried in a GMPLS test-bed composed of Linux routers named ADRENALINE.

1. INTRODUCTION

The existing metropolitan area networks (MANs), primarily made up of TDM technology, are not optimized for tomorrow's demands. Built to reliably and efficiently transport voice traffic, the TDM metro network is quickly reaching its capability to grow with the fast-changing data-centric world. The accelerating growth of Internet traffic, together with its bursty traffic pattern is motivating the research on not only high-bandwidth metro networks but also dynamic metro networks based upon recent advances in optical networking technologies such as *Wavelength Division Multiplexing* (WDM), reconfigurable *Optical Add Drop Multiplexers* (OADMs) and *Optical Cross Connects* (OXCs), capable of providing reconfigurable high-bandwidth end-to-end optical connections. The automation of the future optical MAN is achieved by means of a distributed optical-control plane (i.e, routing and signalling), which can be based in the Generalized Multiprotocol Label Switching (GMPLS), an extension to MPLS for fiber, wavelength, waveband and TDM switching..

Under distributed control each node makes its decisions based on the network state information (topology and wavelength resources) it maintains, which can be either local o global. In GMPLS-based networks, enhancement to IP interior gateway protocols (e.g. extended OSPF-TE or IS-IS) can be used to flood (periodically or threshold-based) network state information so that each node in the network can have a global knowledge of the network state, using link-state advertisement (LSA) update messages. The need to broadcast update messages may result in significant control overhead, and furthermore, it is possible for a node to have outdated information, and make incorrect routing decision based on this information. For the case in which a node only knows the status of its immediate links (local information), collisions are likely to occur if attempts to establish lightpaths for two contemporary connection requests are initiated over a particular link from both directions simultaneously, specially when no wavelength converters are available and a lightpath must be establish using the same wavelength on all the links along the path (wavelength-continuity constraint). So efficient distributed wavelength reservation protocols are needed for dynamic WDM networks with rapidly changing wavelength availability.

The objective of this paper is to propose an enhancement to GMPLS which allows to have a global wavelength resource information using a fixed routing scheme without LSA update messages, based on a GMPLS-based distributed control scheme for bidirectional lightpath establishment in unidirectional-ring-based MAN named Salmon Reservation Protocol (SRP), proposed by the authors in [1]. Performance evaluation, in terms of blocking probability and average lightpath set-up time, has been carried in ADRENALNE test-bed composed of Linux-based routers acting as GMPLS optical connection controllers (OCCs).

The remainder of this paper is organized as follows. In section 2 we describe GMPLS-based distributed Lightpath establishment schemes. In section 3 we present the SRP proposal. Section 4 describes the enhancement to the GMPLS signalling protocol in order to flood the wavelength state information throughout the whole network. An overview ADRENALINE testbed is described in section 5. Finally section 6 presents the experimental performance and section 7 concludes the paper.

2. GMPLS-BASED DISTRIBUTED LIGHTPATH ESTABLISHMENT SCHEMES

In order to set up a lightpath, a signalling protocol is required to exchange control information among nodes and to reserve resources along the path, such as GMPLS extensions to RSVP-TE and CR-LDP. In this paper we will only consider RSVP-TE. Likewise we concentrate on wavelength reservation schemes with wavelength continuity-constraint. GMPLS-based reservation protocols are categorized based on whether the resources are on a hop-by-hop basis along the forward path (*Forward Reservation Protocol*, FRP), or reserved on a hop-by-hop basis along the reverse path (*Backward Reservation Protocol,* BRP) [2,3].

In GMPLS, the signalling phase consists of a generalized label request, sent in a RSVP Path message, traversing hop-by-hop from the source node to the destination, followed by a generalized label assignment, sent in a RSVP Resv message, traversing in the opposite direction back to the source. When a new connection request arrives to the source node, it initiates a RSVP Path Message containing a Generalized Label Request Object. Then a strict path to the destination is determined, recorded on an Explicit Route Object (ERO). In this work we assume fixed routing scheme, that is, a fix route is specified between each source-destination pair. In order to guarantee the wavelength-continuity constraint when no global information about optical resources is available, a Label Set object is included in the Path message at the source node. The Label Set Object allows an upstream node to restrict the set of labels that a downstream node can choose, ensuring that a downstream node will assign a label that is acceptable to an upstream node. The source node includes a Label Set Object specifying the available wavelengths on its outgoing fiber link. If a Forward Reservation scheme is used, all the wavelengths specified in the Label Set are locked at each hop in the path, over-reserving temporally the resources. In contrast a backward reservation scheme does not reserve the wavelengths of the Label Set, it just collects the usage information of wavelengths in the path. Each intermediate node updates the received Label Set removing currently unavailable wavelengths. If no wavelength of the Label set is available, the request is blocked and the reserved wavelengths (only for FRP) on the partially established path are immediately released. If the Path message reaches the destination node, one label is selected based on a wavelength assignment algorithm such as the First-Fit or Random, and initiates a Resv message including the Generalized Label Object with the selected wavelength that will be configured at each hop toward the source node. For FRP, in addition, the temporally reserved wavelengths will be set free at each hop.

Using the GMPLS signalling extensions it could be possible to integrate forward reservation and backward reservation into one process. This is accomplished through the Suggested Label Object. This object is used to provide a downstream node with the upstream node's label preference. This permits the upstream node to start reserving and configuring its hardware with the proposed label. Therefore combining a Label Set Object based on a Backward Reservation Scheme, and a Suggested Label Object (based on a Forward Reservation Scheme), it could be possible to do a Forward Reservation based on a single label (conservative), and if it fails, the Backward Reservation would continue the connection request. In [5] it is shown that the combination of BRP & FRP excels both FRP and BRP working separately, but this study is not GMPLS-based. Therefore we will work with this reservation scheme assuming that is the best one according this study.

3. SALMON RESERVATION PROTOCOL (SRP)

Salmon Reservation Protocol (SRP) is a GMPLS-based distributed control scheme for bidirectional lightpath establishment in unidirectional-ring-based metropolitan networks supporting both Soft Permanent Connections (SPC) and Switched Connections (SC) in multi-domain environments, proposed by the authors in [1]. In the basic GMPLS architecture [4], bidirectional optical connections are established using a single set of Path and Resv messages, but this mechanism does not work in unidirectional rings, since one fiber is dedicated as working fiber and the other is dedicated as protection fiber. Working and protection fiber operate is opposite directions: the working ring operates on the clockwise direction on the protection ring and the protection rig on the counter clockwise direction.

When a new end-to-end SC or SPC request crossing multiple domains arrives to the unidirectional ring (figure1), the source node separates the request connection into two RSVP connection segments between the input/source node and the output/destination node located in the same ring. Both connection segments in the ring are associated using the "Session Name" attribute of the Session Attribute object. The input/source node inserts in the Session Name filed a unique value to allow unique identification of both RSVP connection segments at the output/destination node. Therefore the input/source node initiates two RSVP Path messages identified by its Session Object, containing a Generalized Label Object, a Label Set Object (based on a Backward reservation scheme), a Suggested Label Object (based on a Forward Reservation scheme), an Explicit Route Object (ERO) to determine a strict path to the destination node, and other relevant objects. The first RSVP Path message requests the downstream wavelength, therefore the ERO specifies an strict path to the destination in the same direction of the ring transmission, whereas the second Path message request the upstream wavelength. In this case the ERO specifies a strict path to the output/destination in the opposite direction of the ring transmission. Moreover the second Path message includes an Upstream Label Object (UL) in order to indicate that the wavelength resources are requested in the opposite direction of the optical transmission. Then Both RSVP Path message are sent along their respective explicit routes to the destination. When one of the two Path messages reaches the destination/output node, it waits until the associated Path message also reaches the destination, checking the Session Attribute. Once both Path messages have reached the destination/output node, it is checked whether the destination of the requested connection is out of the Ring. In the first case, the node will generate a single Path message to the next node and the request connection will continue its journey. In the second case, two RSVP Resv messages, one for each connection segment will be generated.

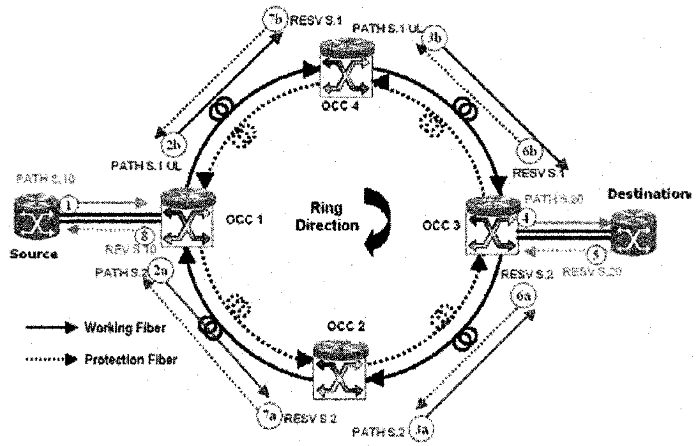

Figure 1. SRP. Bidirectional Lightpath establishment in uni-ring-based MAN

4. AN EFFICIENT GMPLS-BASED WAVELENGTH RESERVATION PROTOCOL FOR MAN

The main drawback of combining FRP and BRP as explained above is that the suggested label is chosen by the source node that only have local information. In this case the wavelength of the Suggested Label is chosen randomly from the label set. So there is no guarantee that the label suggested by the source node be available along every link in the path.

In order to solve this drawback we propose a simple enhancement to the GMPLS signalling protocol that can be used to flood global wavelength state information when bidirectional connections are requested over unidirectional-based WDM rings. In our proposal each node in the ring has a global wavelength resources table, indicating which wavelengths are available in all the links of the ring. The first time the algorithm is used, all the wavelengths of the table are set as free. Then the source node that initiates the connection request inserts in both RSVP connection segments a Record Route Object in order to record all the hops in both routes. The Suggested Label is chosen by the first node according its global wavelength resource table. It must accomplish the wavelength continuity constraint, so only those wavelengths that are available at each link form the source node to the destination node are suitable. From the valid wavelengths, one of them is chosen randomly and is used by the Suggested Label Object. Once both RSVP connection segments (upstream and downstream) arrive to the destination node, two RSVP Resv messages are generated according the above section. In the proposed reservation scheme, each RSVP Resv message includes, apart from the previously specified objects, three GMPLS-based extensions, which are the complete Record Route Object (RRO) and the Generalized Label Object (GLO) of the complementary connection segment, and the full Record Route Object of the own connection segment. So the final result is a RSVP Resv Message containing a GLO and a complete RRO from the own connection request, and GLO and complete RRO from the complementary connection request (from now they are referred as Complementary GLO and RRO). Then each node when receives the Resv message must update its global wavelength resource table, reserving the wavelength specified by the Generalized Label in all the links specified by its own RRO, and the same applies for the Complementary GLO and RRO. The final Result is that each node is able to update its own global wavelength resources table every time receives a RSVP Resv message of an incoming connection request.

5. ADRENALINE TESTBED

ADRENALINE testbed is based on an experimental ASON/GMPLS control plane composed by 9 distributed GMPLS-based Optical Connection Controllers (OCC), allowing the establishment of real-time, dynamic, end-to-end optical connections. Each OCC has been implemented on a Linux-based router with a Pentium IV 2,6 GHz processor. OCCs are interconnected by fast Ethernet point-to-point links, using both simulated and real links. The real links are bidirectional optical fiber links with a distance of 35Km each (control channels are carried on 1310nm). The simulated links are based on an additional PC with a network emulation package that allow to emulate the link delay between two OCCs. The network topology is based on a unidirectional-based ring, using 3 real optical fiber link and 6 simulated links that emulates a delay of also 35Km. Note that the circumference of the ring is about 300km, suitable for a metro core network.

6. EXPERIMENTAL PERFORMANCE EVALUATION

In this section, we investigate the performance of the proposed GMPLS-based reservation protocol for unidirectional-based metro networks over the control plane of the experimental testbed, comparing when the Suggested Label is chosen from local (named SRP Local) or global (named SRP Global) wavelength resource information. Firstly, we describe the main assumptions adopted and then we present the results and discussions. All the lightpath requests have been assumed as bidirectional connections. Lightpath requests arrive according to a Poisson process, and the lightpath holding time is exponentially modeled with a mean of 100 ms. To avoid having almost zero size lightpath holding time (holding time inferior to setup delay), we have added a small fixed time of 10ms to the lightpath holding time (*offset time*). The traffic is uniformly distributed among all node pairs (typical behaviour in metro core rings). Each data point is obtained over a simulation of 100.000 connection requests. Each link supports 8 wavelengths. The time to configure an OADM node is 10ms.

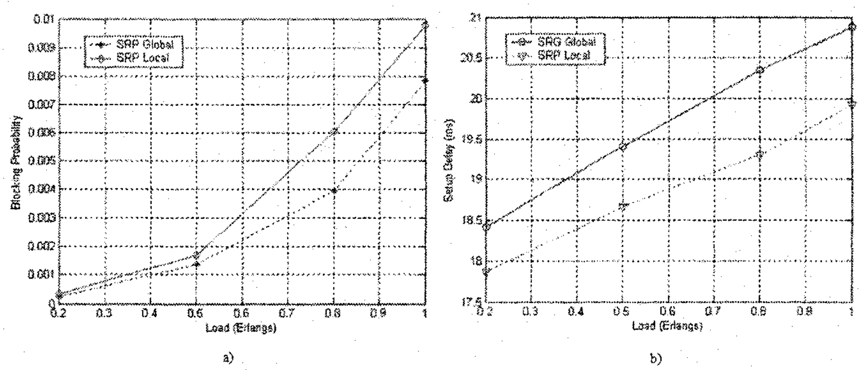

Figure 2. Figure 2. a) Blocking Probability. b) Set-up delay

Load is measured in Erlangs, which can be calculated by multiplying the connection arrival rate with the average connection holding time. To study the network's behaviour under different loads, the arrival rate of connection requests is varied as a parameter. Figure 2.a) plots the obtained blocking probability vs. load for global and local SRP. Global SRP always exhibits an upgraded behaviour respect to the local WRP approach, for high loads. For example the blocking reduction of the global SRP is about 34 percent compared to the local SRP when the total offered load is fixed at 0,8Er. For low loads there are very few differences, since almost all the resources are free and therefore the probability of failure when selecting a wavelength based on local knowledge is low. Figure 2.b) shows the setup delay vs. load. Obviously, Local SRP presents lower delays than SRP, reducing the setup delay up to 8%. As shown, the connection setup delay increases as load increases due to the fact that each OCC has to support more RSVP sessions, causing the increase of the queuing delay at each OCC.

7. CONCLUSIONS

This paper presents a GMPLS-based wavelength reservation scheme that allow to have a global wavelength resource information using a fixed routing scheme without LSA update messages, based on a GMPLS-based distributed control scheme for bidirectional lightpath establishment in unidirectional-ring-based MAN named SRP. Using the GMPLS signalling extensions it could be possible to integrate FRP and BRP into one process, through the Suggested Label (based on FRP) and the Label Set (based on BRP) objects. The Suggested Label is chosen by the first node randomly based on local information. This integration reports an upgraded behaviour than BRP, but it can be improved if the label is chosen based on global information by the proposed wavelength reservation scheme, showing a reduction of the blocking probability up to 34%.

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