GMPLS IN OPTICAL NETWORKS

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ABSTRACT: The significance of **G**eneralized **M**ulti**P**rotocol **L**abel **S**witching (**GMPLS**) has been demonstrated by its significant adoption in optical networks. In recent years GMPLS has become the most globalized solution, which operates, and is implemented in core networks. This new technology was developed to support the Internet by providing many additional services for applications using the **I**nternet **P**rotocol (**IP**). The focus of this paper is on the issues and constraints that have arisen in the process of applying GMPLS in optical networks such as **R**outing and **W**avelength **A**ssignment (**RWA**). These two are a concatenated issue. One affects the other. The blocking probability in finding a route is potentially high without the wavelength conversion capability. This paper will also demonstrate how to find the least significant blocking probability in a route using the existing proposed RWA algorithm. We demonstrate that using the generalised probability of blocking, and applying this blocking probability into RWA. We can appropriate the path with the least significant blocking propensity. The reduction in routing problem, will greatly smooth the wavelength assignment issues. The investigation is conducted by reviewing the current literature. This paper also contains a reflective analysis on the issues in the application of GMPLS in optical networks. This report highlights some of the technical challenges that GMPLS is encountering, while in the implementation phase. Finally, a set of recommendations will also be suggested.

INTRODUCTION

The growing adoption of optical networks has dramatically increased in recent years. A network system often requires more powerful network devices to provide an advanced network, and sophisticated applications to cope with a multi-service platform. The ability to cater for different traffic requirements with a real-time service capability such as for voice and video with acceptable **Q**uality **o**f **S**ervice (**QoS**) is the key for survival amongst service providers. All these have led to the evolution of an advanced protocol – GMPLS. Particularly in recent years, GMPLS has become a widely-used solution.

GMPLS is an advanced protocol which is essential for managing a diverse and complex network, because service deployment and service provisioning are manual, lengthy and costly processes. GMPLS has caused technical challenges in its deployment in optical networks. These challenges can be generalized into two areas: label assignment and wavelength conversion capability. In regard to wavelength conversion, which is correlated to routing problems. The inability of the optical switch to perform wavelength conversion has yielded a routing problem. The incompatibility of optical devices has violated the algorithms of path determination. It results in a high blocking factor call along the path and high latency; these would eventually prejudice the performance of optical networks. If the routing problems could be minimized, this would help to ward off at least part of the problems.

With regard to labels in optical networks, a real challenge for the transition from MPLS to GMPLS in optical networks is making the **L**abel **S**witch **R**outer (**LSR**s) at either end of a link agree on a label value to mutually identify the traffic flow. The representation of label value is resolved by using a signalling protocol to control the traffic between LSRs so that both LSRs agree on the value to use. However, the scope of this paper is to discuss the RWA problem, not label assignment. Also, use of GMPLS and **L**ink **M**anagement **P**rotocol (**LMP**) in optical networks has precipitated interoperability. In practice, GMPLS is sufficiently evolved to both meet a network provider's standards and provide hardware level interoperability, however, resources that need to be managed in optical networks are expected to be much larger in scope than in a packet-based network which in turn is making it harder to ensure path establishment.

RELATED WORK

Multi**P**rotocol **L**abel **S**witching (**MPLS**) has become popular amongst service providers by providing advanced services such as bandwidth-based guaranteed serviced (by QoS), priority-based bandwidth allocation (by differentiated service for a specific user applications and data flow). The function of MPLS in a network is used to forward data packets based on their label value. MPLS overlays an IP network to facilitate traffic engineering and allow resources to be reserved and routes pre-determined. It also merges layer 2 technologies and supplements IP so that traffic can be marked with a label.

GMPLS further extends the features of MPLS by operating at extremely high-speed rates in optical networks. In addition it enhances path establishment and set-up operations. The inheritance from MPLS gives it the credibility to be able to survive against competitive service providers. Different types of traffic switched among different domains, for instances, packet, cell by label, time by time slot in repeating cycle, wavelength by lambda, physical space by fiber. All these flow into optical network and GMPLS is used for the associated switching and control components. One significant strength of GMPLS over MPLS is the multi-Gigabit transmitting speed. Figure 1 shows different switching domain and its layered architecture.

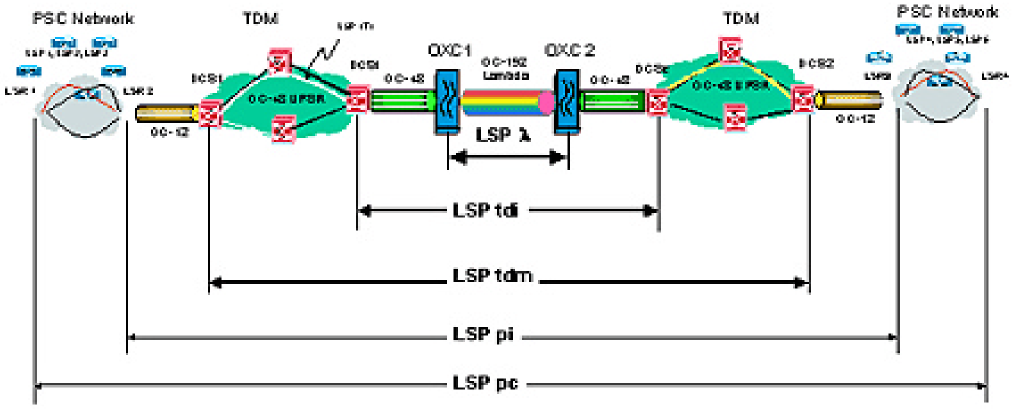

Figure 1. Switching domains and traffic types.

Problem:

The focal of this paper will be on RWA issues. Within an optical domain, the majority of optical devices such as **O**ptical **C**ross **C**onnect (**OXC**) devices were not primarily designed to cope with switching and converting wavelengths between devices. To define a route, literally it would involve converting the light to and from electrical signal at each hop along the path, thus the rate of blocking during path determination becomes potentially high without conversion capability. It makes path establishment more difficult to achieve from end-to-end. Later in section 4, we show that the blocking probability can be formulized into an equation. Applying this equation in conjunction with the RWA algorithm. We can generate the path with the least blocking probability. Thus we can make a dramatic improvement in path establishment. Second a related problem is how do we represent labels in optical networks? In GMPLS, the premise is that the generalized label could be anything that is sufficient to identify a traffic flow. It is very difficult to configure a large system in a sophisticated application environment, amongst dissimilar network types, such as in **T**ime **D**ivision **M**ultiplexing (**TDM**), wavelength, or those based on space (physical ports). This is one of the major constraints in adopting GMPLS. There are a few approaches to this issue, however, it is beyond the scope of this paper to extensively discuss this issue.

Other GMPLS issues have been identified and must also be taken into consideration:

- Bandwidth allocation. The allocation of bandwidth in each **L**abel **S**witch **P**ath (**LSP**) is done in a discrete unit. This is unlike IP-based networks, where bandwidth may vary from 10Mbps to 100Mbps. However, this is not the case in optical networks, the bandwidth is fixed. It would not make sense to allocate an entire 622Mbps line for just a 10Mbps flow.

- Scalability. In the long term, the network must be able to grow and expand without major alteration of the network infrastructure. In other words, the ability to accommodate the network changes is a key issue in design. Particularly for resources involved in TDM or optical networks, which are greater than IP-based networks. How to manage a large scalable network in optical networking becomes a real challenge.

- Configuration. Configuration in an optical network may be a time-consuming, complex and costly process involving link bundling, which contains thousands of LSPs. Configuration and network maintenance need to be done very precisely, otherwise it will have a huge impact on network performance. Optical switches are relatively slow to program. The time taken to establish an LSP could be double than the conventional MPLS, and this causes considerable latency in LSP set-ups. Cumulative delays become an issue.

- Network reliability, network recovery, network detection, network protection. These are the main recovery issues that need to be considered. GMPLS must be able to inherently have the ability to perform network recovery efficiently, to ensure reliability. It also needs to address the traffic engineering requirement using QoS.

INVESTIGATION

The following describes search tools and methodology.

- Literature searches over the topic “Optical Networks” using Internet databases.
- Also conducted a library search, for example, library catalogues, books in print, journal articles.
- Also looked into local newspapers particularly in the information technology pages and E-Business sub-section.
- Finally, bibliographic databases which contain full-text articles and research papers where also consulted.

I have conducted my literature search using on-line technology such as the Internet. Different sources of information from different type of publications. For instance, white papers, **I**nstitute of **E**lectrical and **E**lectronics **E**ngineers (**IEEE**) papers, on-line journals, on-line databases, and technical reports. I looked into other synonymous documents and did comparisons. Also I have conducted a various searches in libraries such books, journals articles, video, local newspapers. This provide more refined searches over a variety of sources.

RESULTS AND ANALYSIS

The problems described in section 2 are concatenated. One affects the others. The inability of wavelength conversion introduces a blocking probability between the links, this yields a path routing problem. The following work has illustrated the blocking probability in finding a route during path establishment. We make these assumptions in the following projection:

- All the switching devices in different domain have the same capability of function regardless of the hardware-level agreement. For instance, here we assume they all have similar platform capability such as multi-transport capability, consistent data transfer rate. They all can process similar tasks.

- Here we also assume the IP routing protocol is OSPF, which is divided into areas (domains). The routing algorithm we use is a shortest path routing algorithm that guarantees to find a shortest path between the source and destination.

The blocking probability can be defined as below:

Let $P_b(li)$ be the probability of blocking. Let li is the non-utilized wavelength within a link. Single-round probability of blocking is $\frac{k^2}{l\mathrm{i}^2}$ = 1 for links are greater than two with probability $\frac{li-1}{l\mathrm{i}}$. Table 1 shows the acronym of variables.

li	Number of non-utilized wavelength
k	Links
P_b	Blocking probability
Akj	Number of fibers for which wavelength is utilized
Mk	Number of the fibers within the link
p	Path
j	Wavelength pair

Table 1. Table of Variable

The blocking probability illustrated in above can be minimized by this **R**outing and **W**avelength **A**ssignment (RWA) algorithm. In combining the wavelength discontinuity constraint and routing problem, these problems can be formulated into the following notation:

Let U_k = $\sum_{j=k}^{k} P_b$, Since with the probability $\frac{li-1}{li}$ and P_b are $\frac{k^2}{li^2}$ = 1 where *Akj* is the number of fibers for which wavelength is utilized, subtracted by *Mk* the number of fibers within the link, we get (*Mk* - *Akj*) which is the available fiber which vacate for use. We redefine (*Mk* - *Akj*) by $?_n$, $?_{n-1}$ …. Number of non-utilized wavelength. Thus the least loaded path *p* and wavelength *j* pair (*p,j)* with the most least significant of blocking probability P_b will be chosen for that link connection.

Reflective analysis on other GMPLS major issues and recommended solutions:

Label in Optical Networks. In MPLS, the basic requirement in identifying a traffic flow is mutually using an agreed label. It must be a label value (up to 32 bits) that can be encapsulated into a MPLS "shim" header as the packet travels on the link ca be used, as long as both LSRs agree on the label value regardless of the traffic engineering of the network. However, in GMPLS, the premise idea is that the generalized label could be anything that is sufficient to identify a traffic flow.

In addressing the representation of a label value in optical networks, GMPLS previously had introduced a new generation of label distribution "generalized label distribution". This new format of label is capable of supporting different formats of data. Labels could represent several formats of data such as a single wavelength, a single fiber, a single timeslot. It also applicable to MPLS. In general, this is very different from the nature of MPLS labels where the labels are simple arbitrary numbers, whilst in optical networks, labels are directly related to the network resources.

The following sections outline how the generalized label is being utilized in different switching components. The representation of label format could be summarized as follows.

- Whole Fiber Labels

  The number of the selected fiber or port number of the fiber could be used as the label value. In this case, instead of agreeing on the frequency of wavelength to use, LSRs may choose to allocate which (whole) fiber to transport the flow. LSRs simply need to agree on which particular fiber to use within the bundle.

- Wavelength labels

  In this case, the representation of label value is the wavelength itself. As the bandwidth is subdivided into different frequency of wavelength, LSRs can choose which wavelength to agree to transport the flow.

- Timeslot labels

The bandwidth is subdivided into time slots by time division multiplexing, the LSR must agree with the time to use the resource for traffic flow. For example, if a label denotes a single **S**ynchronous **O**ptical **NET**work (**SONET**) VT-6 timeslot, the available bandwidth is the bandwidth of a VT-6 timeslot.

5. CONCLUSION

Routing and wavelength conversion continues to be a challenging problem. We defined the metric of blocking probability and formulated it into equation with a single round probability (k^2/ $?_i^2$) = 1 and applied this into the existing RWA algorithm. Section 4 shows the results. Here our work is using this probability function applied in RWA to get the least loaded path and wavelength with the least significant propensity of blocking probability. Hence we are providing a more optimal route for switching. If we can eliminate the incidence of blocking during routing, we could then argue that wavelength conversion is further efficient, because it provides a physical path between different domains. Beyond routing, the next level is multi-layer switching, data is being switched between path and competing for fiber/ bandwidth availability, which is another issue for discussion.

The success of GMPLS provides a solution that enhances IP by its remarkably advanced features particularly the improvement in data transfer rate. GMPLS can be well classified, managed and policed across different types of networks. For service provisioning of end-to-end engineered traffic paths, due to the constraints of wavelength conversion, it experiences routing and label assignment issues. Although extension protocols such as **C**onstraint-based **R**outing – **L**abel **D**istribution **P**rotocol (**CR-LDP**) and **R**esource re**S**er**V**ation **P**rotocol – **T**raffic **E**ngineering (**RSVP-TE**) have already been proposed to enhance the wavelength conversion amongst multi-platform environment.

Meanwhile, there are certainly several unresolved issues needing attention and these issues are discussed in section 2 together with the suggested solutions are also outlined in section 4. However the provisioning of these solutions into viable optical networks remains an open question.

6. GLOSSARY

CR-LDP	Constraint-Based Routing – Label Distribution Protocol
DWDM	Dense Wavelength Division Multiplexing
GMPLS	Generalized Multiprotocol Label Switching
IETF	International Engineering Task Force
IP	Internet Protocol
LMP	Link Management Protocol
LSP	Label-Switched Path
LSR	Label-Switched Router
MPLS	Multiprotocol Label Switching
OSPF	Open Shortest Path First
OXC	Optical Cross-Connect System
QoS	Quality of Service
RSVP-TE	Resource Reservation Protocol – Traffic Engineering
RWA	Routing and Wavelength Assignment
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing

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