A Survey: Generalized Multiprotocol Label Switching Over Optical Networks

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***Abstract*— GMPLS extends MPLS to provide the control for devices in any of following domains: packet, time, wavelength, and fiber. In this way, data from multiple layers are switched over Label Switched Paths (LSPs). The router is equipped with optical-to electrical and electrical-to-optical converters used respectively to terminate and generate optical signals. These interfaces are directly connected to the input and output ports of the optical switch, while the remaining ports accommodate the fibers linking to neighboring nodes. Generalized Multi-Protocol Label Switching (GMPLS) is being developed by the IETF as the industry standard for transport network control planes. In this paper, we tried to analyze the future research in GMPLS networks.**

***Keywords*—MPLS, GMPLS, QOS, OPTICAL NETWORKS, LSP**

I. INTRODUCTION

Multi-Protocol Label Switching (MPLS) was developed as a packet-based technology and is rapidly becoming key for use in core networks, including converged data and voice networks. MPLS does not replace IP routing, but works alongside existing and future routing technologies to provide very high-speed data forwarding between Label-Switched Routers (LSRs) together with reservation of bandwidth for traffic flows with differing Quality of Service (QOS) requirements. [2]

Generalized Multiprotocol Label Switching (GMPLS), the emerging paradigm for the design of control planes for OXCs, aims to address and solve all the challenges mentioned previously, trying to automatically and dynamically configure any kind of network element. It was proposed shortly after *Multiprotocol Label Switching* (MPLS) to extend its packet control plane to encompass time division (for example, for SONET/SDH), wavelength (for optical lambdas) and spatial switching (for example, for incoming port or fiber to outgoing port or fiber). Nongeneralized MPLS overlays a packet-switched IP network to facilitate traffic engineering and allow resources to be reserved and routes predetermined. It provides virtual links or tunnels through the network to connect nodes that lie at the edge of the network. For packets injected into the ingress of an established tunnel, normal IP routing procedures are suspended; instead the packets are label-switched so that they automatically follow the tunnel to its egress. [3]

GMPLS Interfaces: GMPLS encompasses control plane signalling for multiple interface types. The diversity of controlling not only switched packets and cells but also TDM network traffic and optical network components makes GMPLS flexible enough to position itself in the direct migration path from electronic to all-optical network switching [3]. The five main interface types supported by GMPLS are as:

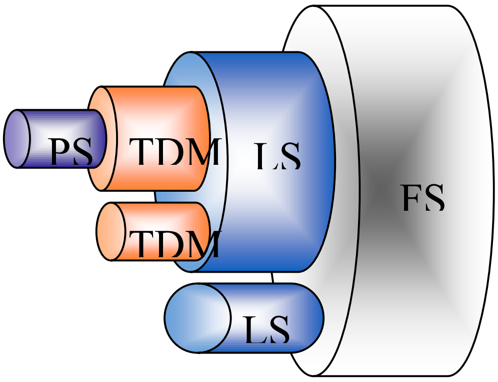

Figure 1: Optical fiber Mechanism

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A. Packet Switching Capable (PSC)—These interfaces recognize packet boundaries and can forward packets based on the IP header or a standard MPLS "shim" header.

B. Layer 2 Switch-Capable (L2SC)—These interfaces recognize frame and cell headers and can forward data based on the content of the frame or cell header (for example, an ATM LSR that forwards data based on its Virtual Path Identifier/Virtual Circuit Identifier (VPI/VCI) value, or Ethernet bridges that forward the data based on the MAC header).

C. Time-Division Multiplexing-Capable (TDMC)—These interfaces forward the data based on the time slot in a repeating cycle (for example, SDH cross-connect or ADM, interfaces implementing the Digital Wrapper G.709, and Plesichronous Digital Hierarchy [PDH] interfaces).

D. Lambda Switch-Capable (LSC)—these interfaces are for wavelength-based MPLS control of optical devices and wavelength switching devices, such as optical ADMs (OADMs) and OXCs, operating at the granularity of the single wavelength or group of wavelengths (waveband). These interfaces forward the optical signal from an incoming optical wavelength to an outgoing optical wavelength. Traffic is forwarded based upon wavelength or waveband.

E. Fiber-Switch-Capable (FSC)—these interfaces forward the signal from one or more incoming fibers to one or more outgoing fibers for spatial control of interface selection, automated patch panels, and physical fiber switching systems. Traffic is forwarded based on port, fiber or interface.

II. LITERATURE SURVEY

Hiroaki Harai, *et. al.* [5], treated a performance optimization problem in all-optical networks. They studied blocking performance of the optical network and proposed a heuristic algorithm to minimize an overall blocking probability by properly allocating a limited number of nodes with wavelength conversion capability. Kalyani Bogineni *et. al.* [6], introduced a performance modeling technique based on a semi-markov analytical model, which eliminated many of the unrealistic assumptions of past approaches to analytical modelling. The performance of the protocol was analysed using this analytical model and discrete-event simulation. The performance is evaluated in terms of network throughput, packet delay and control. Jennifer M. Yates *et. al.* [7], examined the blocking performance of networks in which connections may be blocked due to either insufficient capacity or due to limitations in the transmission network. Analytical expressions and network simulations were used to examine blocking in networks, in which the quality of the received signal may be so poor that the connection is effectively blocked. Brett Schein *et. al.* [8], developed a system model to approximate the blocking probability for both the fixed and reconfigurable systems. They also characterized the gain in traffic capacity that is configurable wavelength division multiplexed network offering over a fixed topology network where lightpath connections are fixed and cannot be changed. Suixiang Gao *et. al.* [9], minimized the overall system blocking probability by studying the problem of placing a given number of converters in a general topology WDM network. The contributions of this work were: (1) formulation of success probability in a network as a polynomial function of the locations of converters; (2) proposal of an optimized model of the converter placement problem as the minimization of a polynomial function of 0–1 variables under a linear constraint so that standard optimization tool scan be employed to solve the problem and (3) design of a search algorithm that can efficiently find the optimal solution to the converter placement problem. Wanjiun Liao *et. al.* [10], proposed a service differentiation scheme called Pre-emptive Wavelength Reservation Protocol (PWRP) to provide proportional quality of service for Optical-Burst-Switched (OBS) networks. In the context of service differentiation, traffic was divided into different service classes based on traffic characteristics. A service differentiation scheme then provides different degrees of resource assurance to different classes of traffic in proportion to their service classes. An analytical model was derived and simulations were conducted to evaluate the performance. The results showed that the approach performed better than existing mechanisms in terms of lower blocking probability and higher resource utilization. Xi Yang *et. al.* [11], measured the network performance in terms of blocking probability, resource utilization and running times under different resource allocation and routing schemes. They addressed the placement of regenerators based on static schemes allowing for only a limited number of regenerators at fixed locations. They further proposed a dynamic resource allocation and dynamic routing scheme to operate translucent networks. This scheme was realized through dynamic ally sharing regeneration resources, including transmitters, receivers, electronic interfaces between regeneration and access functions under a multi-domain hierarchical translucent network model. An intra-domain routing algorithm, which took into consideration optical-layer constraints as well as dynamic allocation of regeneration resources was developed to address the problem of translucent dynamic routing in a single routing domain. Chuan-Ching Sue [12], reduced the blocking probability by presenting a wavelength-routing scheme with spare reconfiguration to construct dependable all-optical wavelength-division-multiplexing networks. They developed a Spare Reconfiguration mechanism with Wavelength Reassignment (SR_WR) and Path Reassignment (SR_PR) to make the spare dynamic. The proposed wavelength routing with SR proceeds in three stages and has polynomial time complexity. Extensive simulation experiments were conducted on the NSFnet and the K5 fully connected network to investigate the performance of the proposed wavelength routing with SR. Hai Le Vu *et. al.* [13], computed and derived the scalable approximations for blocking probability. They have also provided new loss models for Hybrid Optical Switch (HOS) combining optical circuit switching and optical burst switching. Exact blocking probabilities were computed when no priority was given to either circuits or bursts. The sensitivity of the analytical results to burst length and circuit holding-time distributions was quantified by simulation. It was demonstrated that how the proposed approximations can be used for multiplexing-gain evaluation of a hybrid switch. Dongsoo S. Kim *et. al.* [14], introduced a split routing algorithm and its blocking probability to enhance the routability of the high fan-out requests. They studied three-stage Clos switching networks for multicast communications in terms of blocking probabilities on a random traffic model. Even though the lack of multicast capability in the input-stage switches requires a prohibitively large number of middle switches to provide compatible requests with non-blocking paths. They also proposed a probabilistic model which gave an observation that the blocking probability decreases drastically and then approaches zero as the number of middle switches is far less than the theoretical bound. They also corroborate the analytical model by performing network simulations based on a random request generator and a random routing strategy. Suresh Subramaniam *et. al.* [15], minimized the call-blocking probability by considering the problem of optimal placement of a given number of wavelength converters on a path. Using a simple performance model, they first proved that uniform spacing of converters is optimal for the end-to-end performance when link loads are uniform and independent; then they showed that significant gains are achievable with optimal placement compared to random placement. Ling Li *et. al.* [16], studied blocking probability and presented two dynamic routing algorithms based on path and neighborhood link congestion in all-optical networks. In such networks, a connection request encounters higher blocking probability than in circuit-switched networks because of the wavelength-continuity constraint. They have considered Fixed-Paths Least-Congestion (FPLC) routing in which the shortest path may not be preferred to use. Then they developed a new routing method; dynamic routing using neighborhood information. It was shown by analysis and simulation methods that FPLC routing with the first-fit wavelength-assignment method performs better than the alternate routing method in mesh-torus networks (regular topology) and in the NSFnet T1 backbone network (irregular topology). Gaoxi Xiao *et. al.* [17], studied blocking probability and proposed a set of algorithms for allocating Fixed Wavelength Conversion (FWC) in all-optical networks. They adopted the simulation-based optimization approach in which utilization statistics of FWC‟s were collected from computer simulations and then optimization was performed to allocate the FWC‟s. Extensive computer simulations were conducted on regular and irregular networks under both the uniform and non-uniform traffic.

III. GAPS

There are few gaps which we have encountered in the literature survey. There is very little work on probability of multiple failure events considering network topologies. There is a need of optimization of performance in GMPLS Networks with finite and infinite number of sources. The behavior of Restoration signaling algorithms required analysis for failures of networks. Very few analytical models have been proposed in literature for performance optimization of GMPLS Networks. There is a need of such analytical models for the betterment of performance in GMPLS Networks.

IV. ANALYSIS

We compared the Call Holding Probability with Call Blocking Probability for the same Call Holding Time with reference to work done by Mandeep Kaur *et. al.* [18]. We tabularized Call Blocking Probability and Call Holding Probability for different Call Arrival Rate and Call Holding Time in TABLE III.

TABLE I

COMPARISON OF CALL BLOCKING PROBABILITY AND CALL HOLDING PROBABILITY

Call Arrival Rate	**Call Blocking Probability**			**Call Holding Probability**
	For Call Holding Time 5 µs	**For Call Holding Time 10 µs**	**For Call Holding Time 15 µs**	**For Call Holding Time 5 µs**
10	10^{-18}	10^{-23}	10^{-28}	10^{-16}
20	10^{-23}	10^{-28}	10^{-30}	10^{-22}
30	10^{-28}	10^{-32}	10^{-35}	10^{-24}
40	10^{-32}	10^{-34}	10^{-38}	10^{-28}
50	10^{-35}	10^{-38}	10^{-40}	10^{-30}

From TABLE III, we found that Call Holding Probability is more for same call holding time as compared to Call Blocking Probability. Moreover, Call Holding Probability and Call Blocking Probability are very small.

V. CONCLUSIONS

Based on the shortcomings and research gaps identified in the literature survey, there is a huge scope to work in the field of Generalized Multiprotocol Label Switching Networks. Some new analytical model can be proposed for the performance optimization of GMPLS networks which depends upon different parameters like number of channels, number of sources, traffic intensity etc.

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