Scheduling of GMPLS Path Services Using Switched and Fixed Paths

Abdella Battou
Mid-Atlantic Crossroads, 8400 Baltimore Ave, College Park, MD, 20740,USA
E-mail:abattou@maxgigapop.net
Payam Torab
Broadcom Corporation, 5300 California Avenue, Irvine, CA 92617, USA
Phone: +1-949-926-6840, Fax: +1-949-926-7793, E-mail:ptorab@broadcom.com
David H. Walters
Lambda OpticalSystems, Herndon, VA, 20170, USA
E-mail:dwalters@lopsys.com

Abstract: This paper describes distributed scheduling technology based on schedule-aware network elements using switched path LSPs whose physical path may vary during service. This technology provides more reliable, more efficient service to better meet user needs.

OCIS codes: (060.0060) Fiber optics and optical communications; (060.4256) Networks, network optimization

1. System Concept

The distributed scheduling technology is based on the protocol framework provided by the standard IETF GMPLS protocol suite using RSVP-TE signaling [1,2], OSPF-TE routing [3], and the related Path Computation Architecture [4], introducing the Path Computational Element (PCE). The scope of this work applies to all GMPLS/PCE switching technologies, but the primary focus is on packet and lambda switching capable technologies.

Figure 1 depicts a representative scenario where the user submits a request for scheduled service that includes a desired service start time, T_S, and desired service duration, T_D (in addition to the standard GMPLS service parameters) to the Network Management System (NMS). Then the NMS requests a path from the PCE via the Path Computation Client (PCC). In response the PCE returns the service schedule consisting of the service path, assigned service start time, ts, and assigned service duration, td, to the NMS. The NMS forwards the service schedule to the ingress Network Element (NE) allowing the NEs to become "schedule aware" and to take responsibility for service resource reservation, activation, and release without any intervention from the NMS.

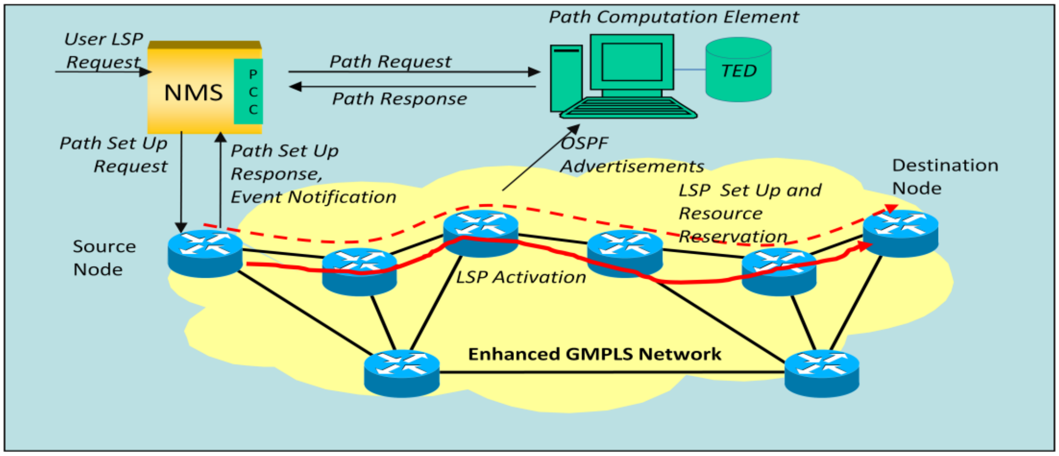

Figure 1: Representative System Concept

Upon receipt of the service schedule, the NEs reserve the resources necessary for the scheduled Label Switched Path (LSP) as indicated by the dashed line in the figure, e.g., cross-connects will be reserved for the period (ts, ts+td) in optical networks. At time ts, the ingress network element initiates the activation of the LSP as indicated by the solid line in the figure, e.g., cross-connects will be reset in optical networks. At time ts.+.td, the ingress network element initiates release of the LSP. All of these actions are performed without any intervention of the NMS so that if a network failure occurred preventing the NMS from communicating with the NEs, the user service will still be activated.

The ingress NE provides the NMS with event notifications as resources are reserved, activated, and released. Also, the PCE receives OSPF advertisements from the NEs so that it may track loading on the TE links.

Having the schedules stored in the control plane provides major advantages for activation and recovery. Since there are no messages between the control plane and the management plane at the time of activation with this approach, delays will be reduced and failure points eliminated during activation. Therefore, the activation may be done faster and more robustly. When a network element is in a recovery mode, it will be able to retrieve the resource schedule from its neighbor using advanced GMPLS protocols similar to a graceful restart [2], but recovery details are future work.

As described in [5], the support of scheduled services requires the introduction of new protocol objects into OSPF-TE, RSVP-TE and the PCE Protocol (PCEP). OSPF-TE requires a timed interface descriptor object into OSPF-TE to advertise the dependent availability TE link resources. RSVP-TE and PCEP requires objects to support desired schedules, acceptable, and assigned schedules. Also, RSVP requires objects to support the activation of schedules.

2. Problem Formulation

The scheduling of GMPLS services may be formulated in terms of a multi-parameter network optimization problem. Specifically, this problem may be stated as given desired start time,Ts, desired duration, Td, Network Element endpoints (i,j), in addition to the standard GMPLS QoS parameters, minimize the function $\emptyset$ (ts, td) to determine the optimal start time, ts*, duration, td*, and LSP path (Pij*):

$$\emptyset(t_s, t_d) = \alpha|T_s - t_s| + \beta|T_d - t_d| + \frac{\gamma}{v_{ij}}\frac{}{t_d}\int_{ts}^{ts+td} c\,(P_{ij})(t)dt$$

Where α = start time weight β = duration weight γ = path length weight to control the optimization process,
vij = normalizing constant,
Pij is the path between nodes i and j,
c(Pii(t)(t) is the cost of path Pij(t) defined as the sum of the cost functions for all the links on the path.

It is assumed that the link cost functions are non-negative, but may change over time. In the studies discussed in Section 3, the link costs are assumed to be constant, i.e., at any given point in time, a link cost equals either a fixed finite value or infinite to denote link unavailability.

Consider the hypothetical example depicted in Figure 2. The path Pij may be a Fixed Path (FP) where the physical path is unchanged during the service duration as depicted in Figure 2a or may be a Switched Path (SP) where the physical path changes during the service duration as depicted in Figure 2b. The Switched Path solution always has the shortest path distance between NEs i,j, denoted aij*(t), while the Fixed Path may not. For example, in Figure 2a, the physical path of 4 links is unchanged throughout the service due to link availability for the FP. However, in Figure 2b, two path segments are used for SP. The 4 link path is used for the time period [ts*, ts* + td*/2) while the 3 link path is used for the time period [ts* + td*/2, ts* + td*) because the shorter path was not available during the former time period.

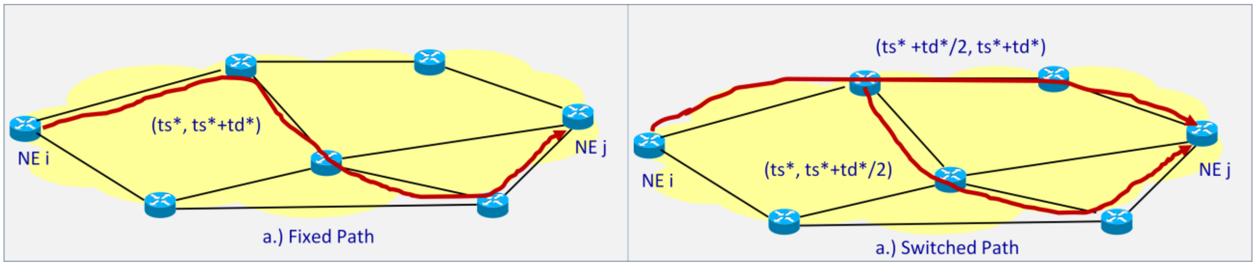

Figure 2: Comparison of Scheduled LSP Using Fixed and Switched Path Solutions (Unidirectional LSP)

Since SP allows the physical path to change during service, it may use the shortest available path at all times so c(Pii(t))(t) = aij*(t), shortest path cost between i and j at time t. This allows for the more efficient use of network resources at the expense of more complex control plane actions.

The disadvantages of the SP solution are the short disruption in service in switching path segments and the additional Control Plane complexity to implement the individual shortest path segments comprising the service. Each SP segment is set up as a separate LSP and standard Make Before Break Signaling [1], is used to switchover from one LSP to the another at breakpoints. As discussed in [5], some gridlock situations may occur in circuit switched networks preventing a smooth make before break switchover. Therefore, SP solutions may be most appropriate for packet networks.

3. Tradeoffs/Conclusions

The performance of the multi-dimensional scheduling optimization problem may be characterized in terms of blocking of service requests, service duration variation from desired value, service duration weighted by data rate service duration, variation from desired value start time, average, path length, and network link utilization. As described in [5], we have developed the theoretical foundation to characterize optimal solutions and formulated algorithms to generate them.

Using these algorithms, we have also carried out a performance study to quantify the improvement of SP solutions over FP solutions and have found that SP uniformly reduces blocking, reduces path length, improves network utilization, and more closely matches the actual start time to the desired start time [5].

Table 1 summarizes some typical results for a 15 node GMPLS packet switched network with weights $\alpha = 0.3$, $\beta = 0.6$ and $\gamma = 0.1$; start time windows = 10 and 100; mean desired duration of 25 with minimum duration of 10 and maximum duration of 25 uniformly distributed; and 1000 service requests with Poisson arrival distribution. While the actual durations for SP are slightly less than the FP durations (1%) and the durations weighted by data rate for SP are greater, both SP and FP provided very close to 90-91% of the mean desired duration (25) in all cases, i.e., not much difference. Additional details are provided in [5].

Table 1: Packet Network Performance

	Service Attempts	No. of Success	Average Duration	Weighted Duration	Path Length	Network Util	Start Time Var.
Switched-Wind.100	1000	954	22.32	120.17	2.71	5.33	14.98
Fixed-Wind.100	1000	927	22.55	119.61	3.03	5.79	18.53
% Improvement		3%	-1%	0%	-12%	-9%	-24%
Switched-Wind.10	1000	815	22.63	114.73	2.61	4.39	1.65
Fixed-Wind.10	1000	780	22.83	113.50	2.92	4.64	1.87
% Improvement		4%	-1%	1%	-12%	-6%	-13%

The frequency of segment switchovers is a potential concern for SP solutions. However, it was found that this does not appear to be a major issue. For example for start time window size of 10, the effect was minimal. Although nearly 50% of the LSPs used multiple segments (389/815 = 47.7%), there were only1.84 segments (paths) per service. Thus, there were only relatively few switchovers required.

Another concern is the relative CPU processing times for FP and SP service scheduling. The CPU time per service for an expanded window (100) and the smaller window (10) for FP were compared with SP using peak loading samples 801to 950. These results (generated using a 1.5 GHz processor, 1024 KB cache, and 512 MB RAM) show that the processing time for SP routing grows less quickly than the processing time for FP routing as the window size increases. For example, FP increased by a factor of 2 while SP increased by a factor of 1.5. Specifically, with the window size of 100, the SP processing times are 20% greater, (73 ms vs. 60 ms) while with the window size at 10 the SP processing is 60% greater (48 ms vs. 30 ms). Thus, SP appears to be more scalable as the window size grows, but requires more study.

The support of the United States Department of Energy under SBIR Grant No. DE-FG02-06ER84515 is gratefully acknowledged. The work of Xilin Guo in implementing the algorithms is also gratefully acknowledged.

5. References

[1.] D. Awduche et al., "RSVP-TE: Extensions to RSVP for LSP Tunnels," RFC 3209, December 2001.

[2.] L. Berger et al., "Generalized Multi-Protocol Label Switching (GMPLS) Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions," RFC 3473, January 2003.

[3.] K. Kompella et.al., Routing Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", RFC 4202, October 2005

[4.] A Farrel, J.P. Vasseur, and G. Ash, "A Path Computation Element (PCE)," RFC 4655, August 2006.

[5.] "Dynamic Path Scheduling through Extensions to Generalized Multiprotocol Label Switching (GMPLS)," Phase II for the US Department of Energy SBIR Grant Number DE-FG02-06ER84515, August 2009.