November 14, 2002

# G-MPLS: Streamlining Networks Back to Profitability


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## Executive Summary

G-MPLS (Generalized Multi-protocol Label Switching) is a new technology based on a framework of standards that enables the interworking of and communications between the transport and data layers. It extends the data layer routing capabilities to the optical network. Ultimately, G-MPLS can enable different network layers (i.e., the transport and data networks) to act as one homogeneous network. G-MPLS plays a crucial role in network simplification and optimization.

G-MPLS's introduction comes timely given the pressure on service providers to improve profit levels. With G-MPLS, service providers can achieve cost saving benefits from its cross-layer traffic engineering, integrated restoration and protections, and rapid service provisioning capabilities. Additionally, service providers can speed up the time to revenues and introduce new and differentiated services. Some new services they can offer include bandwidth-on-demand, bandwidth brokering, tiered services, and optical VPNs.

Discussions with equipment vendors and service providers reveal the anticipated impact of G-MPLS on cost and revenues, as shown below:

- Multi-Layer Traffic Engineering – 10 to 20 percent capex savings and up to 50 percent opex savings
- Integrated Protection and Restoration – 15 to 30 percent capex savings and 10 to 40 percent opex savings
- Rapid Service Provisioning –10 to 70 percent opex savings
- Increased Data Service Revenues – up to 10 percent

With the availability of G-MPLS-enabled equipment in the market today, service providers can now deploy the technology and realize these benefits quickly.

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# 1 G-MPLS: Streamlining Networks Back to Profitability Introduction

With so much emphasis on survivability and building a profitable business, service providers have to quickly implement cost-cutting and cost-stabilizing measures, particularly with slower than expected or even declining revenues. The typical service provider network today consists of multiple service- or protocol-specific devices and independently operated network layers.

As result of the current slowdown in revenues, most service providers have projects underway to reduce capital and operations expenses through optimization of their networks. Some have started to integrate and consolidate functions and services within specific equipment, while other operators are considering collapsing network layers together, and eliminating an entire network layer.

In addition to significant equipment cost savings, this process also results in tremendous operations costs savings as the networks become simpler to maintain and manage.

However, many of these benefits cannot be realized as long as much of the interaction between the different network layers, such as the optical network and the data network, is done manually today. The good news is that G-MPLS enables service providers to further streamline their networks and realize maximum savings through automated communications and interworking between different network layers.

Although the standards are still evolving, some equipment vendors have already implemented G-MPLS in their platforms and others plan to support it in future releases. Service providers are also expecting G-MPLS to dramatically change the way optical networks operate. TeleChoice interviewed a number of service providers regarding their expectations of G-MPLS. Interviewees included representatives from the marketing, engineering, and operations groups. The service providers that participated in the interview process fall into three categories:

- Nationwide CLEC with Metro Presence
- Global Network Provider
- Wholesale Service Provider

This white paper discusses the results of those interviews and the service providers' expectations of the technology's benefits from a qualitative and quantitative perspective. Some quantifiable benefits obtained from leading hardware vendors are also included.

# 2 What is G-MPLS?

The Internet Engineering Task Force (IETF) and Optical Internetworking Forum (OIF) are busily developing the G-MPLS standards to ensure interoperability between different network layers. Today, the transport layer (optical) and the data layer (typically Layer 2 and/or IP) are typically disparate networks acting independently from one another. G-MPLS is a framework of standards with a common signaling protocol that enables the

interworking of and communications between the transport and data layers. It extends the data layer routing capabilities to the optical network. Ultimately, G-MPLS can enable the transport and data networks to act as one homogeneous network.

G-MPLS is an extension of MPLS, a packet and cell switching technology designed to improve the efficiency of data networks. While MPLS covers packet switching technology, G-MPLS extends this to circuit-oriented optical switching technologies such as time division multiplexing (TDM) and dense wave division multiplexing (DWDM). Using label swapping with MPLS as a comparison, G-MPLS extends that notion to timeslots and wavelengths.

Using G-MPLS does not require a service provider to discard all current networking equipment and buy new equipment from a single vendor for both the data and transport networks, as currently deployed platforms can be extended with GMPLS or GMPLS-like features. Additionally, service providers don't need to wait for the final G-MPLS standard to start reaping the benefits of G-MPLS, as many aspects of optical interworking can already be activated on currently deployed platforms. Equipment vendors will provide upgrades and new releases to conform to the approved standards. Refer to the Appendix for possible implementation options in a multi-vendor environment.

# 3 Benefits of G-MPLS

G-MPLS offers a number of benefits. Some of the top benefits from which the service providers expect the most positive financial impact are in the following areas:

- Cross-Layer Traffic Engineering
- Integrated Restoration and Protection
- Rapid Service Provisioning
- Increased Revenue Per Customer

This white paper first covers each of these top four benefits in detail, followed by a quantitative analysis of these benefits.

## 3.1 Cross-Layer Traffic Engineering

IP routers forward traffic based on the shortest path available through the network. However, simply routing over the shortest path doesn't always result in the best performing and the most optimized network. Shortest path routing can result in underutilized links and highly congested links. MPLS, with its traffic engineering capabilities, helps address some of these problems in that it also takes into consideration the utilization of the pre-defined logical optical paths connecting the routers. But what happens when there's severe congestion on all available paths due to unexpected spikes in traffic volumes and/or link failures? The network then delays or discards the traffic, resulting in poor network performance. To avoid this situation, service providers need to pre-provision excess capacity and links throughout the network.

By using a centralized traffic engineering tool and employing advanced algorithms, G-MPLS allows the automatic reconfiguration and optimization of the logical optical paths

between the routers based on the actual traffic patterns and volumes and taking the physical network and interconnecting topology as a given. Figures 1.a and 1.b below depict how G-MPLS might change the topology of an IP network to reflect the actual traffic patterns. Such an optimization could be performed daily or weekly.

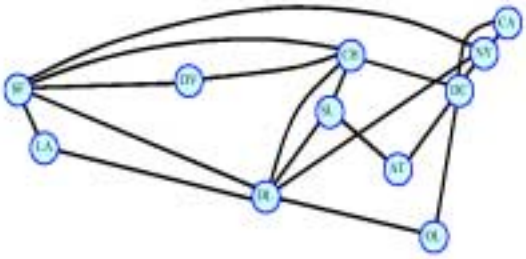

Figure 1.a. Original IP Topology

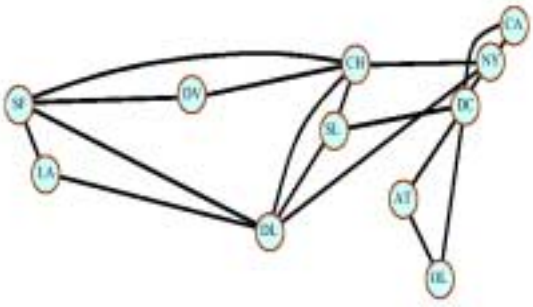

Figure 1.b. Reconfigured IP Topology

*(Source: "Network control and management for the next generation Internet," Telcordia 2001)*

A more optimized IP network and the automated reconfiguration capabilities result in cost savings in the following areas:

- **Traffic Engineering Manpower.** G-MPLS can minimize or eliminate the need for network designers to manually design/reconfigure the IP network topology. In today's environment, this manual and tedious process imposes tremendous stress on network designers as they rely heavily on traffic pattern and volume estimates to design the optimal solution. They face even greater challenges when they need to very quickly react and reconfigure the network. Manual and rushed reconfigurations also increase the probability of human error that can further exacerbate the situation. With G-MPLS, a wholesale carrier expects a 20 to 30 percent cost savings with just the increases in human efficiency. A big CLEC with metro rings in major cities throughout the United States would like to achieve 50 percent savings in its traffic engineering opex costs.

- **Bandwidth.** With G-MPLS, service providers do not necessarily need to design for peak traffic volumes or overprovision the network in anticipation of traffic spikes such as those associated with unexpected events. Cross-layer traffic engineering can improve bandwidth utilization. It prevents stranded bandwidth (unused capacity) and underutilized links. One service provider feels that G-MPLS can increase utilization of a half-utilized link, for example, to 65 percent. Therefore, the expected improvement on utilization is approximately 30 percent.

- **Router Ports.** Similarly, G-MPLS can reduce the number of router ports required. In some parts of the network, the service provider may be able to deploy a smaller router initially or delay the upgrade to a larger router. Or the current inventory of routers and router ports can potentially support more connections, more traffic, and more customers.

Simply put, as networks grow and become more complex, as traffic volumes increase, and as traffic patterns become more unpredictable and dynamic, the traditional, manual

traffic engineering methods can quickly snowball into a big nightmare. G-MPLS provides the intelligence and automation required to overcome the service providers' traffic engineering challenges effectively.

## 3.2 Integrated Protection and Restoration

Service providers require a high level of network availability to support the reliability requirements of end user applications and meet service SLAs. To achieve the highest levels of network availability, networks have to implement network recovery techniques at both the data and the transport layers. These restoration schemes are designed to protect the network from all types of failures including cable cuts, router card failures, power outages, etc.

G-MPLS enables a more dynamic multi-layer recovery technique. In addition to recovering from optical failures, the optical layer also helps with recovery from router failures. The optical network reconfigures and even reoptimizes the logical IP topology during a router failure.

One wholesale service provider can envision a 20 to 30 percent savings in both capex and opex as a result of the network restoration and protection capabilities of G-MPLS. This service provider believes that G-MPLS savings are big enough to be desirable and it "might give [them] margin in the future." Some of the areas where service providers can achieve cost savings with G-MPLS's restoration and protection capabilities are as follows:

- **Restoration Plan / Design Management.** Some service providers have made the move from protected SDH rings to meshed networks to significantly reduce cost. A ring topology requires dimensioning of all section to the maximum point-to-point traffic in the ring, and protection capacity equal to the working capacity. In contrast, a network of meshed point-to-point SONET/SDH links can optimize both the active and spare bandwidth on each section, thereby significantly reducing the total equipment cost. This is illustrated in Figures 2.a and 2.b.

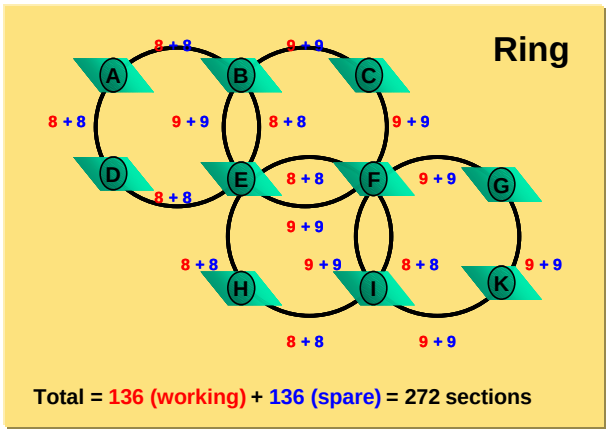


Figure 2.a. Ring Topology

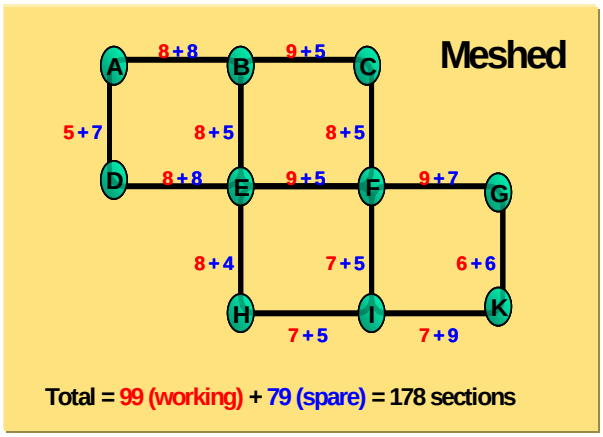


Figure 2.b. Meshed Topology

To take advantage of such a meshed topology, G-MPLS works with the intelligence and the automation built into the optical devices. For the most part, the meshed optical network operates like a router-based network in how it transports and restores traffic. When restoring around optical failures, the inherent intelligence of meshed networks gives the network more restoration options. Coupled with G-MPLS, the restoration options can achieve a more flexible and more dynamic restoration configuration with meshed networks.

This more intelligent optical network simplifies the restoration planning process and saves time in managing the restoration designs.

- **Restoration Time and Manpower.** If failures in the data network can now be restored at the optical layer, restoration can occur more quickly for several reasons. The optical layer typically operates at a higher speed and restoration happens at a much coarser level (i.e., can switch a much larger amount of traffic all at once). It also minimizes or eliminates disruption to the data network. In the case of a router-based network, if the optical network can mask the link failure, the routers do not need to update routing tables and re-converge.
- **Spare Capacity.** As discussed previously, service providers have to reserve capacity for protection in both the data and transport layers in today's environment. Using G-MPLS, service providers do not need to have huge amounts of spare capacity in the data layer. Instead of providing spare capacity in the IP layer to recover from IP router failures (or changes in traffic patterns), the optical network reconfigures the logical IP topology during such failure conditions. However, spare capacity still has to be foreseen to deal with lower layer failures such as cable cuts or optical cross-connect failures. Enough capacity is also needed in the optical layer to support the reconfiguration of the logical IP topology and the traffic routed on that topology.
- **Router Ports.** Lastly, capacity savings can result in router port savings, in addition to the router port savings from multi-layer traffic engineering mentioned on page 4. Service providers can alleviate the cost associated with the router ports supporting the spare bandwidth. One of the largest long distance service providers in the US expects to save 20 to 30 percent in capital costs associated with router ports and spare capacity as a result of using G-MPLS in its network.

Restoration/Protection is rapidly becoming a "must have" for service providers. This is a result of the increasing reliance of enterprises on public IP networks for their daily business functions. Many enterprises have also experienced first hand the impact of network downtime on their business. The enterprises' tolerance for downtime continues to diminish, particularly for those that use the network for sales, order entry, and customer management purposes. And some companies have stringent restoration requirements including disaster recovery/business continuity plans. G-MPLS is inherently designed to help service providers address the enterprises' availability requirements, minimizing susceptibility to failures and fixing problems quickly.

## 3.3 Rapid Service Provisioning

Human intervention and the manual mapping of circuits are required to turn up new circuits in today's networking environment, particularly with optical networks. This is a very complex process and often results in errors that service providers must correct to

successfully provision the circuit. These second and sometimes third attempts to bring the circuit up are major cause for delays. Some service providers claim that as much as 95 percent of the provisioning process, particularly in the optical network, is manual. It can take months to turn up a new circuit. This not only delays the start of the revenue cycle, it frustrates customers.

G-MPLS can alleviate some of these provisioning headaches and make the provisioning process much quicker and smoother. G-MPLS allows point-and-click and near-real time provisioning of optical circuits through a management interface. Better yet, it is designed to operate in a multi-vendor, multi-layer, and multi-carrier environment. Thus, service providers can set up the service in minutes or hours using an automated process with little or no human intervention, in cases where a truck roll is not needed.

The following are some areas where the provisioning capabilities of G-MPLS allow significant reductions in operational expenses:

- **Provisioning Time and Manpower.** Many of the provisioning benefits of G-MPLS will translate into opex cost savings in provisioning time and manpower requirements. In fact, one of the service providers that TeleChoice interviewed indicated that it expects to reduce the overall end-to-end provisioning time from an average of 30 days to approximately 15 days (includes logical and physical changes). Another service provider that believes its provisioning process has a lot of built-in inefficiencies wants to see opex cost savings related to provisioning in the 70 to 80 percent range and 20 to 30 percent savings in capex to evaluate the solution. On the other side of the spectrum, another service provider only expects a 10 percent savings in opex. This lower percentage improvement is due to the homegrown provisioning tools and systems that this service provider developed and designed specifically for its environment. Developing and deploying homegrown systems can be rather time-consuming, resource-intensive, and costly. And not many service providers have the luxury to take this approach, especially with today's budget constraints.

  The service providers described different ways that G-MPLS can help them achieve cost savings:

  - **Automated Network Discovery.** With automated network discovery, the network automatically discovers new equipment or changes to existing equipment. Additionally, G-MPLS automates the capacity assessment and path computation process. These capabilities substantially reduce the amount of time it takes service providers to provision services and make network changes. Furthermore, as capacity and/or equipment become available and as customers cancel, disconnect, or change orders, resources can be readily made available to other customers. Without optical signaling, discovering available resources and "actually" making them available is a painful process for most service providers.

    One provider mentioned that it has two separate databases today that contain information on its network topology. The challenge is in keeping these two databases in synch with one another. As the network changes, both of the databases must be updated to account for the changes. G-

MPLS helps ensure the accuracy of the topology records and eliminates the need to reconcile between multiple databases.

- **Automated, End-to-End Provisioning.** G-MPLS is designed to enable multi-vendor, multi-layer provisioning. Therefore, requests for services in the data network that may require connectivity or reconfigurations at the optical layer can happen in a more automated fashion. Also, instead of provisioning on a site-by-site basis, G-MPLS creates a homogenous network where provisioning is performed network-wide. Working with multiple networks but with a standard control plane causes the network to act as one network.

  As an example, a network provisioner can simply identify the end points of an IP VPN and the quality-of-service policies for that customer network (although it may traverse multiple vendor networks and/or layers) in the provisioning system. The data and the optical layers will then determine and setup the network paths and configure the parameters based on the policies specified (i.e., restoration, prioritization, etc.) without the provisioner having to configure the different network elements. This can also eliminate truck rolls and manual reconfigurations by field technicians.

- **Customer Self-Provisioning.** Customers have little control over the provisioning of their services. They still need to contact their sales representative or customer service representative, complete an order form, and submit the order for any new, change, or disconnect orders. This manual order entry process using a middleman coupled with the service provider's manual or semi-automated provisioning process leads to extended provisioning intervals. Self-provisioning plus G-MPLS helps to shorten provisioning times. Customers can place orders and change policies using a web-based interface or customer network management system that is directly tied to the service provider's provisioning system. Self-provisioning not only meets the customers' requests more quickly, it also allows service providers to reallocate sales and customer service resources to focus on other functions such as establishing strategic relationships with executives, cultivating new accounts, resolving billing disputes, administrative changes, etc.

- **Provisioning Tools and Systems.** Service providers can save capital expenses as well. Service providers don't need to invest in multiple provisioning systems, one per platform vendor or network layer. The built-in network discovery and intelligence of the optical network may also eliminate or at least minimize the need for some network design tools and inventory databases. Service providers can also achieve system maintenance and management cost savings with the integrated G-MPLS solution.

- **Training Time and Cost.** A service provider indicated that using G-MPLS would be a cultural shift for the company. The streamlining of the process and the integration of functions will require training and some time for the users to accept and feel comfortable with the technology. Despite this initial investment in G-MPLS training time and cost, the benefits far outweigh the training time and cost required to operate and support multiple provisioning systems, multiple

databases, and manual processes. The solution of having disparate systems for different platforms or layers becomes increasingly painful as the networks become more complex. Unlike the G-MPLS solution, the level of effort remains relatively constant even as the service provider adds more network elements and layers.

In this age of instant gratification, when someone decides they need/want something, they typically want it as soon as possible. And in today's economy, the quicker service providers can bill for the services, the better off they are. These two factors combined propel more effective and automated provisioning to the forefront of service providers' requirements. G-MPLS will simplify and speed up the transition to an automated system, resulting in cost savings. Additionally, rapid service provisioning also has a positive impact on revenues as discussed in the next section.

## 3.4 Increased Revenue Per Customer

The ROI story is not complete with just the opex and capex cost savings opportunities. The rest of the equation consists of revenue-impacting factors. G-MPLS can improve revenues in the following ways:

- **Improve Customer Retention.** Service providers can lower customer turnover rates because G-MPLS can improve the overall network performance and quality.

- **Increase Revenue Using Stricter SLAs.** The services can become more closely aligned to the customers' real requirements for bandwidth, restoration times, dynamic connectivity, traffic treatment, and provisioning times. Premium tariffs can be applied to services with such "tight" Service Level Agreements.

- **Speed Up Time to Revenue.** The self-provisioning and automated provisioning capabilities can shorten the period from the time the customer orders a service to the time the service is turned up, hence allowing the service provider to bill for the service more quickly.

- **Improve Speed of Service Innovation.** Increases in revenues can be achieved from the launch of enhancements to existing services and/or the launch of new and differentiated services. The inherent network intelligence gives service providers the flexibility to support new services/features without making significant incremental investments. The service provider can focus on defining, provisioning, supporting, and managing at the service level and relegate the element and network functions to the intelligent network.

  Some of the potential services/features that service providers envision G-MPLS enabling are as follows:

  - **Bandwidth-on-Demand.** Vertical markets and/or specific applications have occasional and dynamic bandwidth requirements that they want to use and pay for on an as-needed basis. So the customer may, at any time, request a specific level of bandwidth between several sites for a specific period of time.

    The service provider can also setup the service where the network dynamically and automatically increases/decreases bandwidth as traffic volumes/patterns change. If the demand for bandwidth increases

unexpectedly, additional bandwidth can be dynamically provisioned for that connection. This includes overflow bandwidth or bandwidth over the stated contract amount. The triggering parameters may be utilization thresholds, time-of-day, day-of-month, per-application volumes, etc.

Many service providers shy away from offering these types of services today because of the unpredictability of the traffic volumes and patterns and their inability to consistently meet those on-demand and dynamic requirements using today's technology and manual process. The intelligent optical network with G-MPLS's traffic engineering and provisioning capabilities can help service providers overcome these concerns.

- **Redirection Services.** Redirection services allow customers to change the termination point or the destination point of a connection. The redirection can occur during specified timeframes, events, or on demand. It certainly has similarities to bandwidth-on-demand and bandwidth brokering services with the exception that the changes are in the source or destination, not bandwidth levels. However, it would make sense to combine these features for specific applications. From traffic engineering and provisioning perspectives, the considerations are similar in that an A-B connection redirected to A-C is just like disconnecting a connection from A to B and allocating bandwidth (on demand or brokered) between A and C.

- **Tiered Protection/Restoration Services.** With the multi-layer restoration capabilities of G-MPLS, service providers can offer network resilience mapping aligned with the customers' quality-of-service requirements. The service providers have the flexibility to implement the best combination of network resilience schemes to provide the service tiers that the market desires. With prioritization or quality-of-service assignments coupled with protection restoration options, service providers can offer different levels of service with corresponding differences in pricing levels. Most IP services available in the market today do not discourage customers from marking all traffic high priority because the service providers offer one level of service only. G-MPLS allows service providers to more easily create distinct service tiers and justify differences in pricing. So service providers can now get paid more for higher quality and higher availability services that may require more network resources or more frequent access to resources.

- **Optical IP VPNs.** Optical IP VPNs provide any-to-any IP connectivity service over an optical network between multiple locations. The optical IP VPN will transparently reconfigure the local connections and increase/decrease bandwidth as network usage and/or network policy changes. Customers can also achieve a greater level of control over the performance and configuration of the network using self-provisioning features. They can control their own bandwidth, set prioritizations, or change the distribution of bandwidth.

The service providers have just scratched the surface of the potential services they can offer given the capabilities available in data and optical platforms. And in most of these cases, it is just a matter of service packaging and launching the service. No additional equipment, new capabilities, and fancy support systems are required.

### 3.5 Other Benefits

Other G-MPLS benefits the service providers cited are as follows:

- **Overcome the Static Nature of Optical Networking.** G-MPLS will allow dynamic, automated processes and provide a higher level of flexibility in the optical network.
- **Open Standards.** G-MPLS can work across a multi-vendor, multi-layer, and even a multi-carrier implementation. Service providers can more easily connect their networks with another G-MPLS-enabled network of another carrier, although more interoperability tests between different vendors and carriers still needs to happen.
- **Homogeneous Networks.** Multiple optical networks and data networks can be viewed, managed, and maintained as a single network using a single network management system. This eliminates the swivel chair environment in which most service providers operate today.
- **Troubleshooting and Maintenance.** Service providers can more quickly isolate and troubleshoot network problems with the management system automatically correlating alarms and problems between the data and transport networks.

## 4 Financial Impact

Equipment vendors and service providers alike anticipate significant service provider cost savings and increased revenue potential from the deployment of G-MPLS. The table below shows some vendor estimates (based on discussions with carriers and network modeling).

| Area | Capex Savings | Opex Savings | Increase in Data Service Revenues |
|---|---|---|---|
| Cross-Layer Traffic Engineering Savings | 10 to 20 % on | Up to 50 % | |
| Protection/Restoration Savings | 15 to 30 % | 10 to 40 % | |
| Provisioning Savings | | 10 to 70 % | |
| Increase in Revenues Due to Faster Provisioning | | | Up to 5 percent |
| Increase in Revenues Due to Enhanced Service Levels | | | Up to 10 percent |

The service providers that TeleChoice interviewed mentioned expected cost savings roughly in the same range as those mentioned above. One of the service providers can foresee a 50 percent reduction in opex cost from the traffic engineering benefits alone.

Another service provider cited that it expects to gain a 20 percent cost savings just on improved human efficiency for traffic engineering functions. For restoration and protection, the service providers expect a 20 to 30 percent savings in both capex and opex. The service providers expect at least 10 percent operational cost savings and 70 to 80 percent on the high end with G-MPLS's rapid provisioning capabilities

# 5 Conclusions

TeleChoice's discussions with the service providers and with equipment vendors indicate that G-MPLS can significantly improve the profitability of service providers. Service providers can achieve bottomline cost savings as a result of G-MPLS's multi-layer traffic engineering, integrated protection and restoration, and rapid service provisioning capabilities. G-MPLS can also impact the top line through increased revenues due to fast provisioning and launch of new services.

G-MPLS-enabled equipment is available today. Service providers do not need to discard all current networking equipment and buy new equipment from a single vendor for both the data and transport networks. G-MPLS can be activated on currently deployed platforms. Additionally, service providers don't need to wait for the final G-MPLS standard to use G-MPLS. Equipment vendors provide upgrades and new releases to conform to the standards. Therefore, service providers can start implementing G-MPLS today to realize the first savings and revenue increases immediately—a primary goal in today's market.

For more information about G-MPLS and for additional references on G-MPLS, visit the following web sites:

- http://www.oiforum.com
- http://www.lightreading.com/
- http://ietf.org/
- http://www.iec.org/
- http://G-MPLS.org/

# 6 About TeleChoice

TeleChoice assists companies in creating new markets around innovative business models, technologies, products, services, and applications. As the strategic catalyst for the telecom industry, TeleChoice helps start or greatly accelerate the process of crystallizing a business or market strategy, value proposition, or differentiated position. Playing a strategic role, TeleChoice enables clients to launch new businesses, new markets, and new products and services rapidly and successfully.

Supporting service providers and the technology vendors that serve them, TeleChoice focuses on leading-edge public network technologies. Since being founded in 1985, we have been differentiated by our proven ability to transform new technologies into successful products and services. Our portfolio of offerings helps clients conceptualize, launch, market, and capitalize on innovations in networking--faster, more efficiently, more profitably.

# 7 Appendix
# Multi vendor G-MPLS Implementation Strategies

There are two primary G-MPLS implementation methods: the Overlay Model and the Integrated Model. In addition, a third implementation model, the Hybrid Model, can also be utilized.

## Overlay Model

The overlay model provides interworking between the optical and data planes using the Optical User-to-Network Interface (O-UNI) (based on the RSVP-TE protocol).

The Optical Network-to-Network Interface (O-NNI) is used between the optical devices. The optical devices can run an IP protocol such as OSPF (with CSPF) for routing, and RSVP-TE as signaling protocol.

The LMP protocol can be used for neighbor discovery and fault/maintenance management. LMP runs on both O-UNI and O-NNI interfaces.

The data network is still independent of the optical transport network from a routing perspective in this model. The automatic switched transport network (ASTN) provides point-to-point links for the transport of data network traffic. The IP/MPLS routing, topology distribution, and signaling protocols are independent of the routing, topology distribution, and signaling protocols at the optical layer. MPLS may provide a mechanism to bypass routed hops.

## Integrated Model

In the integrated model, a single routing protocol instance runs over both the IP/MPLS and optical domains. The integrated model proposes all data and optical elements in the network follow the IP model and exchange topology information. The IP/MPLS layers act as peers of the transport network. Every connected network element knows the network topology of the complete network. A common interior gateway protocol (IGP) such as OSPF or IS-IS, with appropriate extensions, will be used to distribute topology information.

## Hybrid Model

The hybrid model includes both the overlay and integrated models. Service providers can choose to use the peer model for integrated optical and data networks and exchange full network topology information between the network elements. The overlay model can be used to interface with another carrier's network. The defined peering points and interface protocols can be used to facilitate interworking between service provider networks while protecting sensitive network topology and capacity information.