The Future of Optical IP Networking

Should IP Be the Brains Behind Optical Networking Brawn?

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Executive Summary

Should IP be the brains behind the optical brawn for carriers' IP networks? More specifically, should technicians continue to engineer and manage optical trunks for such networks, or should they hand the keys of automation over to IP? As intriguing as the question is, the answer might actually be "Yes."

IP's Changing Market Trends

Carriers' IP networks teeter at the apex of two fast-moving market trends that have finally crossed paths. The first key trend is that IP traffic has not only surpassed voice but seems destined to consume it under its increasingly broad umbrella of services. Second, more carriers are finding themselves squeezed between the mushrooming costs of building larger IP networks and their inability to charge premium prices for best-effort services. The implication is that the tighter the market embraces IP as its preferred communications medium, the bigger and smarter carriers' IP networks will have to become.

Key Issues Faced by Carriers Today

The growth of IP services has placed carriers squarely between two powerful forces: ballooning network costs and the slow growth of IP revenues. Traditional network architectures provide very efficient networks for carriers that primarily support voice applications. However, for carriers that also support a substantial mix of IP traffic, traditional networks contribute heavy performance, protection, and scaling costs that are disproportionately high versus associated revenues from best-effort IP services.

While it may be possible for alternative network architectures to ease some of the costs associated with IP traffic, carriers also have the option of increasing their margins by offering enhanced services. In fact, customers have demonstrated increasing need and willingness to pay for premium traffic prioritization and QoS capabilities across IP networks.

Possible IP/Optical Solutions for Carriers

Today, three innovative new approaches, each at a different stage of development, vie for the attention of carriers seeking to build a better IP network. MSPPs (Multiservice Provisioning Platforms) initially set the tone by integrating the aggregation and transport functions from separate network elements used in traditional networks into a single box. This solution was designed to fit a very specialized role in metro networks for delivering multiple types of traffic, including IP, to a centralized set of traffic processing switches and routers.

In contrast, multiplatform interworking solutions are designed to create standards-based communication and provisioning links between IP routers and optical switch networks. Without a doubt, this solution is designed to appeal to carriers that tend to opt for the security of standards-based solutions from the industry's best-of-breed equipment vendors.

Finally, unified IP/optical networking solutions are designed to consolidate the strengths of both IP routing and optical switching into a single network element while eliminating duplicative or unnecessary functions. The result could possibly deliver a powerful yet proprietary solution for carriers looking to distinguish their IP services more quickly and sharpen their competitive position in the market overall.

In short, new IP networking solutions are increasingly positioning IP as the controlling intelligence behind the brawn of optical networks and each to a different degree. Not surprisingly, all three solutions described above hold the potential to deliver the ideal IP networking solution for carriers, depending on their individual applications, preferences, and requirements.

Introduction

"In the beginning . . ." the only cost-effective means for a business to send information across the country or around the world was to place it in an envelope, put a stamp on it, and drop it in a mailbox. The US Postal Service was committed to delivering any item entrusted to it—whenever its carriers could get it there. Sometimes it would take weeks, but usually the mail would eventually find its way to its destination.

For many pieces of information, the best-effort model of the Postal Service was good enough to meet customers' associated expectations and requirements. However, the old "time is money" adage held just as true then as it does today. Once a letter was handed off to the Postal Service, a business no longer had control over the timing of its delivery. The unpredictable and unreliable nature of the Postal Service's delivery schedule sometimes cost companies enormous losses in the form of missed opportunities and/or delayed revenues. However, no matter how much a company was willing to pay for certain information to gain priority over other types of mail, even the most critical communications were still thrown into the same best-effort pile as the rest.

FedEx (Federal Express) capitalized on the swelling demand for critical, high-speed communications when it exploded onto the scene in 1973 with express delivery services. Drawn to the promise of fast, guaranteed delivery, customers flocked to FedEx by the thousands ready and willing to pay extraordinary premiums for the new high-end service.

Not surprisingly, today's IP networks seem to reflect much of the Postal Service's old best-effort mindset. Like the Postal Service's frustrated business customers of years past, commercial IP customers are finding it increasingly necessary to locate ways of prioritizing traffic across their growing networks. Their goals range from throttling irrelevant or malicious traffic to adding new applications, such as video or voice, that carry specialized transmission requirements. Essentially, the market is now looking for the "FedEx" of IP networking and is willing to pay handsomely for premium, high-speed delivery.

Today's IP Transport Model:

- IP networks very similar to the US Postal Service's best-effort model of years past
- Variable and unreliable delivery across IP networks persists today
- Efficient delivery of large volumes of information between Point A and Point B but no adjustments for application-specific traffic shaping/conditioning
- Market looking for the "FedEx" of IP networking
- Market needs to throttle irrelevant or malicious IP traffic while pushing critical traffic to the front of the line
- Market also interested in pouring new types of traffic (e.g., voice applications) into IP networks and is apparently willing to pay premiums for such capabilities
- New market and technology trends are forcing carriers to re-think traditional IP networking architectures and business models

Today, the IP networking industry is experiencing seismic shifts on both the market and technology fronts. These changes are redefining almost everything that carriers have assumed in the past, including their relative competitive and profitability positions.

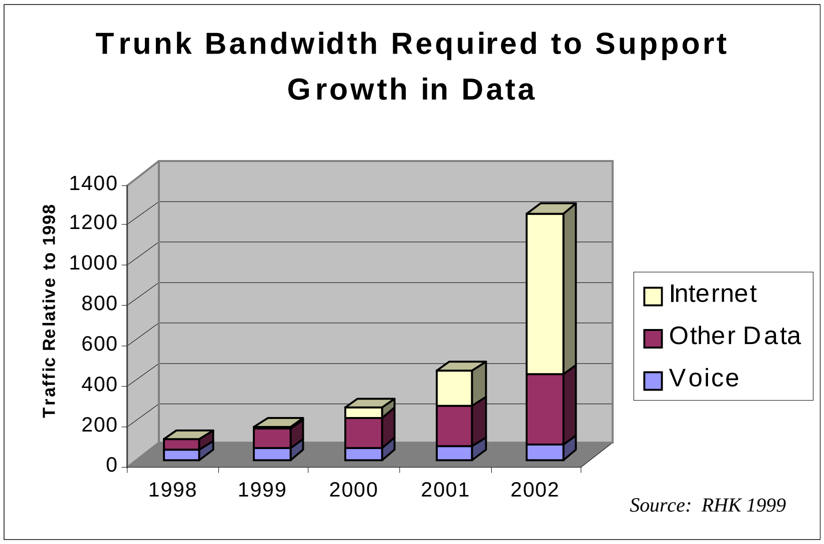
This paper focuses on those pivotal market and technology trends that have already begun to impact carriers' IP networks and also on possible options carriers should consider to hedge against the chance of being swept away by the industry's powerful new dynamics.

Market Trends

Carriers' IP networks teeter at the apex of two fast-moving market trends that have finally crossed paths. The first key trend is that the costs associated with transporting IP traffic across traditional networks are growing faster than the associated revenues for IP services. Second, customers are now seeking enhanced capabilities from IP networks to enable better traffic management in addition to the support of new applications like voice and secure VPNs.

IP's Ballooning Appetite for Bandwidth

IP's seemingly insatiable hunger for bandwidth has finally passed an important milestone, now consuming entire optical wavelengths for use as IP trunks between major network hubs. In fact, not only have carriers' total network volumes of IP traffic now overtaken that of their voice traffic, but voice applications appear well on their way to becoming a small but still important feature among the myriad applications destined for IP networks in the future.



While voice traffic has consistently followed its historical trend of 8 to 12 percent annual growth, the volume of IP traffic continues to double relentlessly every 100 days. Hence, it is not difficult to understand why carriers are now desperately looking toward the promise of next-generation 10 and 40Gbps networks. In fact, RHK predicts that by 2002, IP traffic will represent over 90 percent of the total public network traffic, driven not only by the Internet but by other IP-based data applications as well (RHK, 1999). With these tremendous pressures already stretching the seams of existing IP networks, carriers' IP trunk requirements have ballooned well beyond the capacity of the world's fastest transport technologies. SONET and optical networking solutions are the sole exceptions. As a result, carriers have now stepped into the realm of optical IP networks, consuming entire wavelengths with the addition of each new IP trunk.

In short, the market's unbridled rush towards massive amounts of IP bandwidth has caught many carriers flat-footed. It is quickly becoming apparent that the costs for IP traffic on a traditional voice-optimized network architecture are growing faster than the revenues from such services. This fact is particularly disturbing for carriers watching a growing majority of total customer traffic slide towards the low-margin IP and data portion of their network.

QoS and Customers' Growing Expectations From IP

As the market funnels more and more types of traffic onto IP networks, it has also begun to seek enhanced traffic management and QoS options from service providers. Such capabilities would actually enable carriers to continue capitalizing on the high revenues they derive from QoS-dependent applications. In fact, recent forecasts from IDC predict that IP-based voice services alone will generate revenues of $16.5 billion by 2004 (IDC, 2000).

The crippling impact of Napster traffic on IP networks around the world was a sudden wake-up call for many in the industry. No longer did the baseline capability of IP networks transporting *all* packets with identical priority levels seem a non-issue. This realization occurred when Napster and other file-sharing applications began to consume 40 to 60 percent of some commercial and university IP networks, pushing aside the very applications for which such networks had been built in the first place.

Key IP Market Trends:

Market's Ballooning Appetite for IP Bandwidth

- Data network volumes have already surpassed voice
- IP traffic projected to consume 90 percent of all network bandwidth by 2002
- Voice appears destined to become a small but still important application supported under the broad IP umbrella
- Voice-optimized architectures simply too costly to profitably support traffic volumes that favor data
- Today's IP trunks are rarely built with connections smaller than OC-48
- Massive demand for IP has forced carriers to consume entire optical wavelengths for each new IP trunk added
- The optical IP network isn't coming—it's here

Market's Growing Demand for Enhanced IP Services

- Market trying to pour more types of traffic into IP networks
- Napster led many in market to seek enhanced traffic management capabilities in their IP network
- Increased interest in QoS and prioritization capabilities
- IP-based voice applications alone are expected to generate revenues of $16.5 billion by 2004
- Best-effort US Postal Service model is no longer good enough for IP services
- FedEx-like priority IP service models needed to handle critical communications
- Good news: Exasperation about recent Napster-like problems is increasing customer willingness to pay more for prioritized, FedEx-like services across IP networks

In addition to improved control of Napster-like traffic floods and the creation of enhanced defenses against such things as denial-of-service attacks, customers are also beginning to ask for enhanced capabilities that help them to better utilize and manage their IP networks. For example, customers are increasingly interested in migrating their VPNs away from frame relay and ATM toward IP VPNs and adding real-time applications such as voice across their IP flows.

In conclusion, customers are asking carriers to expand beyond their one-dimensional ability to mimic the US Postal Service's "33-cent-stamp" model for the delivery of best-effort IP services. Customers are now suggesting that carriers look toward the "FedEx" model for a bit of inspiration regarding traffic prioritization and end-to-end quality control across IP networks. The good news is that, similar to the FedEx model, customers appear very willing to pay much higher premiums to ensure that certain types of IP traffic are controlled and managed much more carefully than the rest of their day-to-day transmissions.

Implications of Market's New Trends for Carriers

The implication of these two trends for carriers is clear: The tighter the market embraces IP as its preferred communications medium, the bigger and smarter carriers' IP networks will have to become.

Carriers are increasingly finding themselves squeezed between the mushrooming costs of building larger IP networks and their inability to charge premium prices for best-effort services. In short, the costs for traditional IP networks are growing faster than their associated revenues, which does not bode well for any service provider carrying substantial amounts of IP traffic. Not surprisingly, this has intensified carriers' interest in exploring new, high-margin QoS-enabled IP services to help counter the rising costs of their IP network infrastructures and faltering returns on network investments.

Fortunately for carriers, the market is also learning that it needs enhanced IP services to support its ever more complex network requirements. Therefore, both customers and carriers alike are quickly realizing that today's one-size-fits-all, best-effort IP networks are no longer enough. The good news for carriers, though, is that enhanced IP services (e.g., traffic conditioning, prioritization, and QoS) have become much more than just a simple market curiosity or technical marvel. As the market's interest in (and in some cases, desperation for) enhanced IP services grows, its willingness to pay for such services appears to have grown as well.

Key Issues Faced by Carriers Today

Today's network technologies and architectures have been primarily designed and optimized for voice applications, and they can be extremely inefficient for data. Such architectures made perfect sense when 90 percent of the market's bandwidth requirements centered on voice applications. However, with today's market requirements now reversing against market conditions from just ten years ago, some carriers have been forced to reexamine the appropriateness of this traditional model for their particular traffic mix.

High Cost and Complexity of Current IP Networks

When IP traffic first emerged, carriers simply accommodated the traffic by transporting it across their existing infrastructures, which for decades had been optimized around traditional voice applications. The inertia of such early decisions has since placed some carriers into a situation where well over half of their traffic is now running across a network that was never optimized to support it.

For carriers that still focus *primarily* on voice applications and services, such traditional networks are widely viewed as the best available solution. However, for those carriers supporting a heavy mix of IP applications, traditional architectures can introduce costly functions to IP networks that are either duplicative or obsolete at each layer described below:

- **IP:** IP routers process and route individual IP packets.

- **ATM:** ATM switches are used to aggregate and easily scale virtual IP trunks up to 622Mbps (OC-12) in size for transport across the SONET network. ATM's QoS capabilities are also one of the few tools available to carriers for the support of enhanced IP services.

- **SONET:** SONET terminals and ADMs (Add/Drop Multiplexers) aggregate multiple OC-n trunks from either the ATM switch or IP router in addition to providing the standards-based framing and protection switching needed to carry the traffic across the optical network.

- **DWDM/Optics:** The optical network (i.e., DWDM, optical transponders, and fiber infrastructure) aggregates multiple SONET signals via DWDM onto a single fiber and provides a high-capacity communications path for signals to traverse.

Combined, these four technologies can provide a fairly reliable and efficient means of transporting traffic comprised principally of voice in parallel with other traffic types such as IP. However, for carriers whose IP trunks and traffic volumes have grown to the point that they exceed OC-12 levels, many of the traffic framing, aggregation, and management functions described above have simply become costly, and unnecessary, bells and whistles.

First, four overlay networks must be planned, purchased, and managed. This includes not only the network elements but also duplicate NMS (network management systems), testing equipment, etc., needed to provision, transport, monitor, and manage the associated traffic. Second, traffic engineering under traditional IP architectures is enormously labor-intensive, requiring extraordinarily complex algorithms and long lead times to provision and install new trunks.

Poor Network Utilization and Performance

Regardless of their particular mix of voice and IP traffic, all carriers supporting IP applications face similar problems. These problems typically center around the guesswork related to IP traffic congestion and associated network overbuilds.

Given the best-effort nature of IP traffic, carriers generally try to address performance and congestion issues by simply using network overbuilds to accommodate the inevitable traffic spikes inherent to IP. Unfortunately, even with the most sophisticated traffic modeling tools, IP traffic spikes are extremely difficult to predict with any degree of accuracy. Therefore, network overbuilds for such traffic leave many carriers sitting with varying combinations of empty pipes and poor utilization.

A second key performance requirement for carriers supporting IP traffic is the need for duplicate (or tandem) hardware and related cross-connects. This is due in part to the fact that IP routers were never really designed with carrier-class reliability and redundancy in mind. Hence, many vendors have only recently begun making this a priority in the design of IP networking equipment.

Finally, the traditional SONET ring configurations usually leveraged by APS functions also represent SONET's number-one source of inefficiency: *SONET's 1+1 protection and the associated requirement for 100 percent network overbuilds.*

In the end, it is possible for carriers to find themselves with underutilized IP networks (in terms of network bandwidth and hardware) when using network overbuild strategies to help counter excessive congestion during IP's inevitable traffic spikes. To make matters worse, the inefficiencies associated with such poor utilization levels essentially double under SONET's traditional 1+1 protection requirements. Even with the high costs and inefficiencies that some carriers chose to endure, traditional IP networks still only yield best-effort performance for customers.

Scaling Inefficiencies

Traditional SONET terminals and ADMs provide hierarchical bandwidth scaling up to trunk speeds of 2.5Gbps (OC-48). However, the SONET systems, which are typically deployed in the ring architectures described above to provide network protection, can present scaling problems of their own. Specifically, these systems do not enable carriers to scale trunks to large numbers because of the inherent limits on the number of nodes supported per ring and the resulting networking complexities in increasing ring bandwidth.

ATM was originally layered over SONET links primarily to allow flexible bandwidth partitioning for a large number of virtual trunks. However, the scalability of ATM's virtual trunking can come at a high cost in networking efficiency for carriers with substantial amounts of IP traffic. First, once IP trunk sizes reach beyond ATM's sweet-spot cap of OC-12, ATM's aggregation function for subsequent SONET transport is no longer relevant. Second, some critics of ATM have long expressed concern over what they describe as ATM's cell tax, which they claim can consume up to 25 percent of available bandwidth when transporting IP services. Conversely, other carriers see such overhead as a worthwhile price to pay for ATM's enhanced service and management capabilities. However, for carriers that feel that their raw IP bandwidth requirements have outstripped the benefits of ATM, their frustrations with ATM's overhead costs are only amplified each time they attempt to scale traditional IP architectures.

Need for Retaining and Capturing High-Margin Services

One of carriers' own recurring frustrations about IP networks is their inability to support anything but a one-size-fits-all service offering. There has been little to no flexibility for carriers to differentiate or enhance their IP service offering from that of other major IP carriers. As discussed earlier, the result of this functional shortcoming for IP has been its rapid transformation in the market from an enhanced to a commodity service.

Commodity services by their very nature are low margin. As a result, carriers are watching more and more of their customers transfer high-margin applications (e.g., voice, VPNs, network security, and filtering, among others) from traditional networks to IP networks. Hence, the implication is clear: Unless a carrier's IP network is equipped to handle existing customers' shifting or emerging high-margin requirements, customers will likely seek out a carrier that can.

Summary of Carriers' Key IP Networking Issues

The growth of IP services has placed carriers squarely between two powerful forces: ballooning network costs and the slow growth of IP revenues.

Traditional network architectures provide very efficient networks for carriers that primarily support voice applications. However, for carriers that also support a substantial mix of IP traffic, traditional networks contribute heavy performance, protection, and scaling costs that are disproportionately high relative to associated revenues from best-effort IP services.

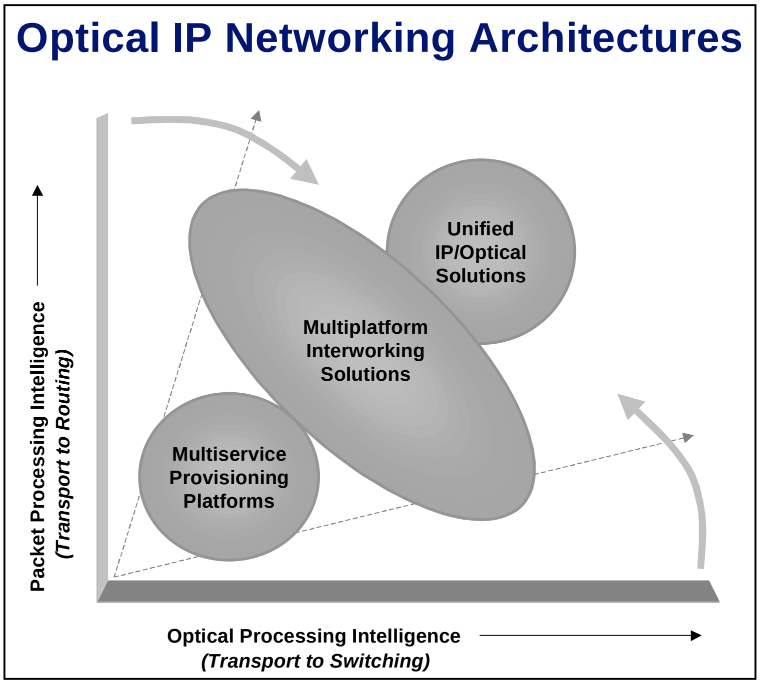
While it may be possible for alternative network architectures to ease some of the costs associated with IP traffic, carriers also have the option of increasing their margins by offering enhanced services. In fact, customers appear to have a growing need and willingness to pay for premium traffic prioritization and QoS capabilities across IP networks.

What Are the Options for Carriers?

With the IP market demanding more bandwidth and increasingly sophisticated services, something will likely have to give. For many carriers supporting ballooning amounts of data traffic, the inherent inefficiencies of traditional IP networks will become even more amplified as they struggle to keep pace with demand.

Fortunately, several viable solutions have emerged for carriers to consider as they work to address these very issues. The following diagram illustrates the different roles three of the more notable new solutions are attempting to fill relative to carriers' transport and processing requirements. These solutions range from those already being sold today to others that hold intriguing yet unproven promises for the future.

All of these solutions will be discussed in further detail, but it is helpful to see on which traditional network function(s) each of the three solutions focuses. Subsequent sections of this paper will highlight these differences more clearly.



Interestingly, all three solutions reflect common trends. The first trend is the gravitational effect that continues to pull IP and optics closer and closer together. In fact, as new technologies emerge, the IP processing and optical processing axes seem to be folding toward the middle as each becomes more dependent on the strengths of the other. The second key trend shared by all three solutions is the push for more intelligent bandwidth and the delivery of more granular control of the network for both carriers and their customers.

While each solution attempts to address a very specific set of carrier requirements, each of the three has its own set of benefits and concerns. However, all are probably worthy of further examination by carriers supporting substantial volumes of IP traffic, as they all seem to hold potential for delivering substantial advantages over traditional IP networks.

Optical MSPPs

MSPP Concept

Various solutions based upon optical MSPPs (Multiservice Provisioning Platforms) were among the first to address the changing winds of the market. New equipment vendors emerged to offer MSPP-based solutions designed to make SONET more data-aware inside optical metro networks.

Optical MSPP solutions aggregate all forms of traffic, including IP, from multiple types of traditional customer interfaces (e.g., TDM, frame/ATM, Ethernet, etc.) and transport it across efficient high-speed optical trunks. Separate routers are still needed to actually process IP packets, but MSPPs boost efficiencies considerably by eliminating the use of traditional channelization of TDM for data and by funneling traffic directly into optical paths. In short, the aggregation and trunking functionality traditionally managed through an overlay of ATM, SONET, and optical networks are now all tightly integrated inside a single MSPP box.

Benefits of MSPP Solutions

The benefits of MSPP solutions for many metro IP carriers supporting substantial volumes of data traffic include the following:

- Improved cost savings and network efficiencies via the integration of traditional four-layer solutions into a single box (requires the purchasing, installation, and management of only two networks to support IP services rather than four).
- Support of multiple service types across the same optical backbone.

- Fit fairly easily with carriers' existing architectures and organizational structures.
- Based on many stable, mature technologies.

Quite simply, MSPPs have been positioned as efficient and cost-effective traffic funnels that aggregate and transport data traffic from multiple types of customer interfaces to IP routers. The results include lower equipment costs and more efficient utilization of optical capacity at the metro level for IP networks.

Possible Concerns and Issues Surrounding MSPP Solutions

Some of the concerns and issues surrounding MSPP solutions for IP carriers include the following:

- Still require the purchase of a separate IP router (no IP processing and routing functionality [aggregation and transport only]).
- Not standards-based (MSPP solutions are proprietary, leading to obvious interoperability issues).
- Not optimized specifically for the aggregation and transport of IP traffic.
- Still maintain much of the technical and management complexity associated with provisioning traffic across four separate network layers.

In conclusion, the benefits carriers enjoy with MSPPs by not having to bet exclusively on a single technology force them to inherit some of the key shortcomings of traditional networking architectures as well.

Multiplatform IP and Optical Interworking

Multiplatform IP and Optical Interworking Concept

With MSPPs now targeting the tough economic issues of aggregating multiple interfaces for IP network access, carriers and their vendors are beginning to look toward options for IP packet processing and optics. Specifically, the focus is on the cost-effective creation, management, and support of multiple types of enhanced IP services across both the IP and optical domains. This is not a simple task, but carriers and their vendors are developing a multiplatform IP and optical interworking solution that does not require carriers to reach too far beyond their traditional network components.

While several standards bodies, including ODSI, OIF, IETF, and ITU, are currently working to develop just such solutions, the general concept is still the same. Rather than provisioning separate links across four overlay networks (i.e., IP, ATM, SONET, and DWDM/Optics), the multiplatform solution simply ignores the irrelevant (and costly) functions of ATM and SONET, focusing instead on IP and DWDM. The ultimate objective is to link seamlessly any IP router equipped with enhanced QoS and management functionality (i.e., an IP Service Switch) with the muscle of any stand-alone optical switch.

In the end, multiplatform solutions hope to establish standards for Optical UNIs that will enable routers to communicate with optical cross-connects or switches to request bandwidth for IP trunks.

Benefits of Multiplatform Solutions

The benefits of multiplatform solutions for carriers supporting large volumes of IP traffic across either metro or core networks are expected to include the following:

- Standards-based solution.
- Ability to combine the best-of-breed vendors for both IP routing and optical switching.

- Fit fairly easily with carriers' existing architectures and organizational structures.
- Improved cost savings and network efficiencies over the traditional four-layer solutions (requires the purchasing, installation, and management of only two networks for IP services rather than four).
- Self-provisioning optical trunks across IP networks will be possible, as routers automatically direct the increases or adjustments to existing trunks using the standards-based Optical UNIs.
- Ability to support QoS and other IP traffic conditioning mechanisms.

In general, the promised impact for customers is that carriers should be better equipped not only to deliver IP services more quickly than they have in the past but with much more sophisticated QoS capabilities and enhancements as well.

Possible Concerns and Issues Surrounding Multiplatform Solutions

Carriers should also be aware of some of the concerns and issues surrounding multiplatform solutions:

- Standards not yet complete (at least four competing standards bodies still working to develop and promote their own version of multiplatform standards).
- Possible interoperability issues if more than one standard persists.
- Two distinct network layers must still be purchased, installed, and managed separately (complexities of both networks now integrated rather than removed).
- Duplication of traffic processing functions (although IP layer performs all of the processing required to resolve addressing, topology discovery, routing, and restoration issues for each and every packet, the optical layer will unnecessarily duplicate the same functions).
- No mixing of multiple QoS traffic on same wave (inefficient use of bandwidth).

While multiplatform solutions still face some issues, the biggest hurdle (and eventually its greatest strength) is its dependence on standards. Given the fact that the industry has not yet coalesced around even a single standards body, multiplatform solutions may be farther down the road than many might hope.

Unified IP/Optical Networks

Unified IP/Optical Networks Concept

One of the key objectives of a handful of vendors now working in stealth to develop proprietary unified IP/optical architectures is the elimination of as many complexities and unnecessary functions as possible. Multiplatform solutions have definitely taken a step in the right direction by eliminating both the ATM and SONET aggregation functions. However, unified IP/optical platforms also focus on the elimination of "swivel-chair integration" between IP routing and optical switching by combining the functionality of both into a single network element.

Unified solutions are also designed to blend multiple types of prioritized and QoS-enabled traffic across common optical facilities or waves. This seemingly minor feature should not only trim associated network costs, but without the limitation of "one IP service type per lambda," carriers should be free to create and manage literally thousands of different service variations and IP flows.

In sum, just as televisions and coffeepots automatically regulate the electrical power levels each requires, unified solutions vendors believe the IP service layer should also regulate the optical bandwidth it requires on an as-needed basis. Such vendors and their carrier customers alike believe that unified solutions represent, in essence, where the continued convergence of IP and optics will eventually lead the market. That conclusion remains to be proven, but until that time, unified solutions still offer carriers a unique set of both benefits and concerns.

Benefits of Unified IP/Optical Solutions

For carriers supporting large volumes of IP traffic across either metro or core networks, the benefits of unified IP/optical solutions are expected to include the following:

- Ability to support full IP routing and optical switching within a single box.
- Lower overall cost of ownership under unified platform that combines both IP and optics (not only are initial and subsequent equipment costs expected to be lower but also associated provisioning, scaling, network protection, and management costs as well).
- Self-provisioning optical trunks across IP networks will be possible, as IP automatically directs the increases or adjustments to supporting optical trunks.
- The ability theoretically to control thousands of different traffic flows as well as myriad QoS and IP service types due to all service conditioning and management being handled exclusively by IP (as opposed to one-for-one coordination between the IP and optical layers).
- Multiple QoS and service types supported inside same wave (efficient and intelligent use of common bandwidth).
- Will likely be available before multiplatform solution standards are complete.

In short, unified IP/optical solutions are being designed to provide QoS-enabled IP packets with complete end-to-end visibility and control across light waves. The IP layer would prioritize, condition, and control the end-to-end transport of IP packets across the entire optical domain.

Possible Concerns and Issues Surrounding Unified IP/Optical Solutions

Some of the concerns and issues surrounding unified/IP optical solutions that carriers should also consider include the following:

- Not standards-based (unified solutions are proprietary, leading to obvious interoperability questions).
- Unified solutions will likely *not* be offered by carriers' existing best-of-breed equipment vendors (although some of the larger vendors may later acquire their unified competitors).
- Radical shift away from traditional network architecture models and associated ownership within carriers' own internal organizations (e.g., "IP" versus "Transport" engineering struggles).
- Technology still unproven and very much in its nascent stage of development.

Without a doubt, unified IP/optical solutions have yet to be proven in the real world and should therefore be approached by carriers with appropriate caution. However, the potential is quite compelling, and for carriers whose swelling IP traffic volumes do not give them the luxury of waiting for standards-based solutions, unified solutions may soon be an option to help these carriers sharpen their market competitiveness.

IP Network Alternatives: A Final Comparison

In light of the key market trends and the issues related to carriers' traditional IP networks, a review of the ability of the three new IP networking solutions described above to address these issues is worthwhile. The table below provides a quick summary comparison of the traditional model and these three solutions.

	Traditional	MSPP	Multiplatform	Unified IP/Optical
Proven Technology	High	Medium	Low	Low
Reduced Costs	Low	Medium	Medium	High
Enhanced IP Performance and Reliability	Low	N/A	Medium	High
Scaling	Low	Medium	High	High
Fit with Current Org. Structure	High	Medium	Medium	Low
Standards-Based	High	Medium	TBD	TBD
QoS Support	Low	N/A	Medium	High

Conclusion

For carriers currently absorbing high volumes of IP traffic across their traditional networks, new solutions are emerging that may help them not only realize greater network efficiencies but enhanced service capabilities (and associated revenues) as well. At stake are both their IP and traditional customer bases. Customers using traditional services continue to move more and more of their high-margin traffic from traditional to IP networks. Those carriers able to handle these consolidated IP traffic requirements stand to gain from the market's recent mass exodus towards all-encompassing IP networks.

Today, three innovative new approaches, each at a different stage of development, vie for the attention of carriers seeking to build a better IP network. MSPPs initially set the tone by integrating the aggregation and transport functions from separate network elements used in traditional networks into a single box. This solution was designed to fit a very specialized role in metro networks for delivering multiple types of traffic, including IP, to a centralized set of traffic processing switches and routers.

In contrast, multiplatform interworking solutions are designed to create standards-based communication and provisioning links between IP routers and optical switch networks. Without a doubt, this solution is designed to appeal to carriers that tend to opt for the security of standards-based solutions from the industry's best-of-breed equipment vendors.

Finally, unified IP/optical networking solutions are designed to consolidate the strengths of both IP routing and optical switching into a single network element while eliminating duplicative or unnecessary functions. The result could possibly deliver a powerful yet proprietary solution for carriers that are looking to distinguish their IP services more quickly and sharpen their competitive position in the market overall.

In short, new IP networking solutions are increasingly positioning IP as the controlling intelligence behind the brawn of optical networks and each to a different degree. Not surprisingly, all three solutions described above hold the potential to deliver the ideal IP networking solution for carriers, depending on their individual applications, preferences, and requirements.