Evolving IP and Optical Architectures

Executive Summary

Operators' networks are more reliable than they were in the nascent days of the Internet and have managed to expand despite the proliferation of devices, increasing video content, and unprecedented traffic growth. Global IP traffic is forecasted to grow at a 29 percent CAGR from 2011 to 2016 to reach 1.3 zettabytes, and there will likely be 3.4 billion Internet users downloading 1.2 million video minutes every second.[1] This growth has been extremely disruptive to operators' current architectures and business models.

Hierarchical architectures were built during the last 10 years to aggregate and statistically multiplex at each tier before merging into the core. However, operators are now looking at next-generation networks that can help them collapse the complexity, generate new revenue models, and improve operational efficiencies. ACG Research examines the differences in these architectures, how IP and optical convergence will reduce capital and operational costs, the key benefits of adding multilayer optimization and how that optimization will play a significant role in keeping costs down and improving service velocity and provisioning.

Key Takeaways

- Demand for content, cloud services and video traffic growth are challenging our current network architectures.
- Changing traffic patterns are adding additional challenges that are different from the challenges of just adding devices.
- Combined IP and optics products will flatten the network and decrease OpEx inefficiencies.

Need for a New Architecture

Managing the increasing network challenges with the types of architecture currently in place has actually resulted in more equipment being deployed at the expense of potential efficiency gains. A service-oriented architecture is required to handle those challenges, and this will provide the opportunity to improve operators' profitability. In order to shift to a more service-centric model, the industry needs **to rethink how networks are built**, which requires some innovative technology to lower power, reduce footprint, and increase the flexibility of the network. Figure 1 outlines how a typical architecture looks today. Figure 2 displays a multitude of building blocks that have come to market to build an optimized next-generation service network, which comprises an MPLS based inner-core, an IP-based outer core, and an integrated packet-optical layer with a common OSS.

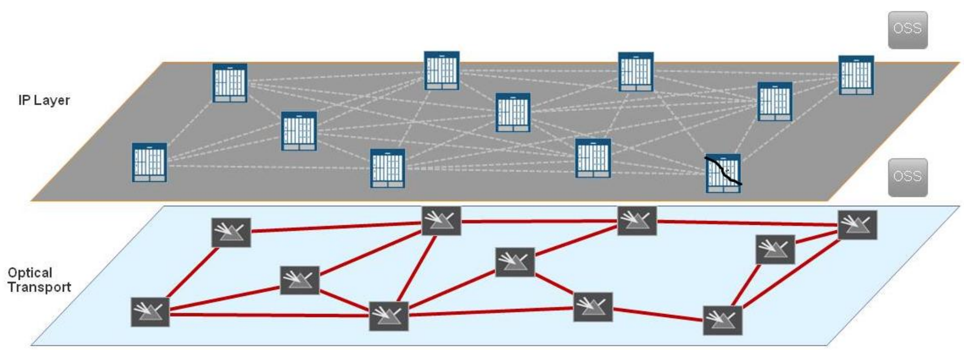

Figure 1. Traditional Network Architecture with Independent Layers

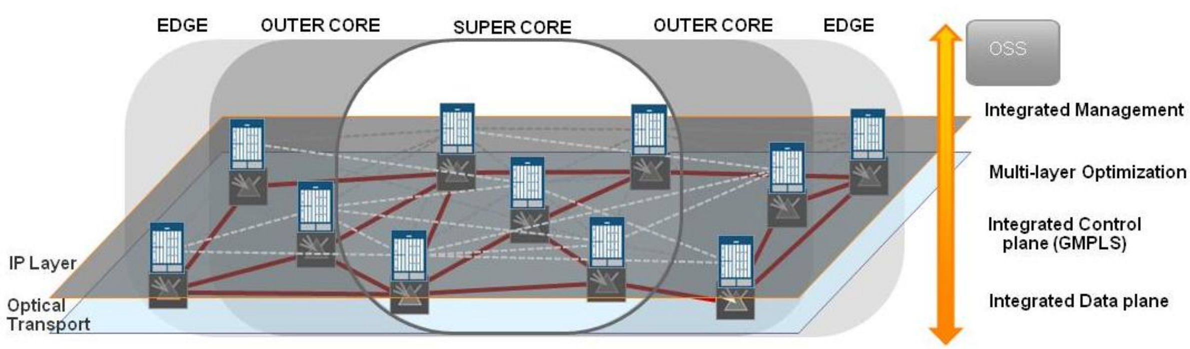

Figure 2. An Integrated Architecture at Multiple Levels

Table 1 outlines how the new service-oriented architecture differs from the traditional architectures:

	Traditional and Hierarchical Architecture	Service Oriented Flat Architecture
Convergence	Topologies with discreet layers	Converged products with interworking layers
Integration	IP and transport layer are separate	IP and transport are integrated
Layers 0–3	Multiple independent control planes	Interoperable control plane
Routers	Core routers	LSRs in the Supercore, core routers at only large peering points
Transport	Fixed between the layers	Highest flexibility across the layers
Network Management	Separate operating systems	Integrated operating systems
Benefits	Traffic aggregation and statistical gain optimized over the layers	Easy to design and implement, statistical gain is optimized over the layer
Costs	Expansions lead to inefficient equipment adds	OpEx costs will not decrease if operational ways do not change

Table 1. Architectural Differences

Budgetary constraints simply will not allow operators to continue to expand existing networks without major consideration to consolidation, convergence and operational efficiencies. In some cases, it is easier for operators to initiate an overlay of a new network rather than to initiate efficiency improvements for existing networks. However, many will choose to slowly evolve their networks to the flatter architecture. The inflection point of 100G being deployed in the networks provides the perfect opportunity for operators to re-evaluate their networks to ensure that:

1. When 100G pipes are deployed they are fully utilized.
2. The number of network elements in the data path is reduced to lower operational (OpEx) and capital expenditure (CapEx) costs.
3. Traffic flow and the interaction of the layers are optimized to increase the value of the new network.
4. A flexible core network can serve as the basis for service innovation across both mobile and wire-line networks.
5. Converged platforms and newer architectures will meet operational criteria as well as deliver a more service-oriented and application-centric network (Table 1).

In the optical domain, multiple technologies (SONET/SDH, OTN and DWDM) require a data, control and management plane for each technology (Figure 1). Ensuring interoperability between management planes and hardware layers is a constant challenge and often results in a mismatch of network requirements. This, in turn, limits an operator's flexibility to use the network for more revenue-oriented services. And while provisioning times for new services have decreased, they are still not fast enough to offer the potential for up-selling and bundling of services that operators can leverage for additional revenue.

As operators plan their next-generation service networks, they will need to examine traffic patterns and then optimize between the IP and optical layers for the lowest capital and operational expenditures (Figure 2). CapEx is a simpler target for cost reduction, yet OpEx tends to be the majority of network cost and maintenance. “More than 50 percent of the initial operational cost of a core network deployment is in the installation, planning and lighting of the initial wavelengths. Expenses related to fault management of the network, which are more than 30 percent of ongoing operational costs, are the other major operational cost.”[2]

Why Standardization Is Important

The fact that convergence between the optical and IP layers brings benefits to operators (Table 1) is commonly understood. However a high degree of complexity exists due to the fact that there are multiple vendors and technologies deployed throughout the layers. The real challenge today, is to provide scale and interworking within and between the layers.

Figure3 demonstrates that using standardized interfaces such as the NNI+ creates global convergence of the layers within a network, as well as multi layer optimization, which will have the largest impact when applied to the end- to- end network.

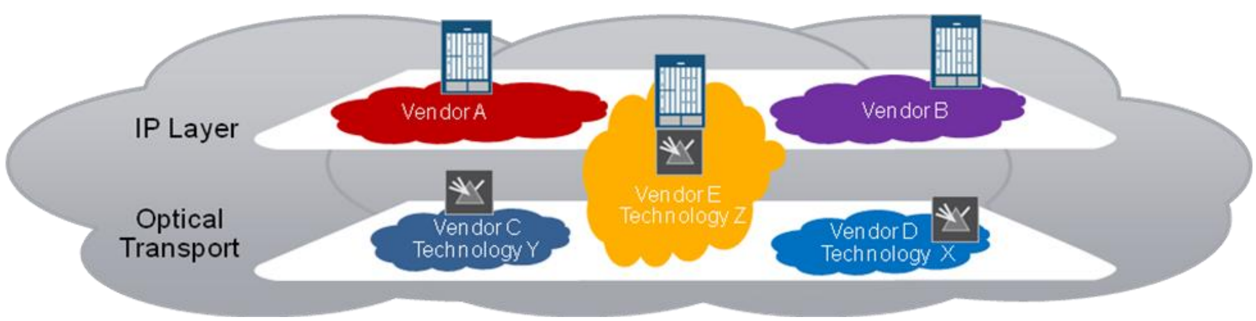

Figure 3: Need for Solutions to Provide Scalability and Interworking within and between Layers

The Cost Benefits of IP and Optical Convergence

There are four main areas of capital and operational cost savings that can be achieved when converging IP and optical technologies and building next-generation, service-oriented networks:

1. LSR routers are already proven more cost effective with immediate CapEx savings of 20 percent because 1) of the lower port price than regular core routers and 2) because they

do not need to support the large routing tables BGP peering requires. Less processing and memory are added, and LSR hardware focuses on fast switching elements rather than on higher order processing, a major capital savings. A Supercore network can be built using just LSRs; some Layer 3 core routers sit only at the necessary core peering points, thus lowering the total cost of the core network.

2. **LSR routers with integrated colored optics:** Integrating colored optics into a router immediately results in a lower total cost of ownership, as one set of client interfaces are eliminated. Depending on the interface, the cost of the IP/optical connection is now approximately half the cost of separate and nonconverged technologies. A smaller footprint and lower power requirement contribute to even larger operational savings because the optics now resides in only one platform: 40 percent savings in power and up to 60 percent savings in floor space is feasible if separate transponder shelves are eliminated.

3. **ROADMs** are another cost-effective way of switching traffic. The lambda-based switching is high capacity and uses minimal power consumption. ROADMs plus LSR switches are the foundation of many next-generation scalable networks.

4. If the NMS is using an interoperable control plane for management, it can manage both domains. Operators can choose to manage both domains as a single domain or as two separate domains, thus gradually evolving to an optimized management structure as soon as the operational processes are adapted to it. Once operators decide to deploy integrated IP and optical platforms, they may want to **merge their data and optical planning groups** into one organization; if they do, the operational savings can be tremendous. Typically, each group operates with its own topology database and manually hands off the network update or change to the other organization. ACG Research has reported that eliminating the ongoing dual processes from each group into one work-flow process operating off a single database can save 50 percent in operational costs. If the manual configuration and provisioning of the combined process can be automated, then operators can save up to 90 percent in operational costs.

As operators plan their next-generation service networks, they will need to examine traffic patterns and then optimize between the IP and optical layers for the lowest CapEx and OpEx.

Building Blocks for Next-Gen Integrated Packet Transport Networks

There are many options for operators to increase efficiencies as they tailor their next-generation networks to realize profit from their networks. In addition to these options there are also some less obvious building blocks that can enable faster provisioning and more efficient fault management of the networks.

As an example, NSN and Juniper Networks joint Integrated Packet Transport Network (iPTN) solution delivers integration of the IP and optical layers via a single OSS and delivers an interoperable control plane where the router remains the master and is closely connected to the optical transport layer. Utilizing an interoperable control plane for both IP and optical products reduces the number of elements required for qualification in the OSS/BSS network.

The converged Supercore, by definition, has an integrated data plane, an integrated GMPLS control plane with multilayer optimization capabilities that runs across the converged IP/optics products.

In Figure 4, Juniper Networks PTX (which introduced the LSR and the MPLS Supercore) is paired the with Nokia Siemens Networks' (NSN) flexible DWDM transport system hiT 7300, enabling the IP and optical layers to be managed as one network element. HiT 7300 provides excellent capacity times reach performance: 96 wavelengths of 100G for greater than 2000km reach. Planning tools from NSN also enable end-to-end multilayer optimization of the entire IP and optical network, another key building block for a new MPLS service-oriented Supercore.

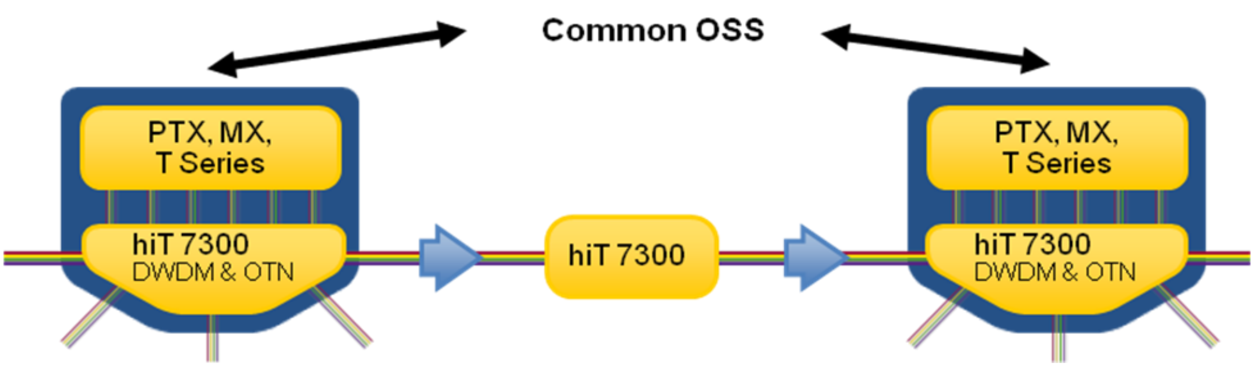

Figure 4: Integrated Products Form a Single Entity Controlled by a Common OSS

Converged Supercore and Multilayer Optimization (MLO)

An integrated IP transport network creates a flatter and less hierarchical network, which optimizes traffic for consumer applications and customer services. Adding an offline network planning tool can optimize a network design by providing cost savings from 25 to up to 65 percent. Adding MLO to a converged platform produces an operationally more efficient platform and delivers immediate cost savings. Multilayer optimization requires an end-to-end service transport approach across all technologies. It can become a powerful and vendoragnostic planning tool that ensures services are individually processed, aggregated and forwarded at the optimum layer. Coordination between layers maximizes the efficient use of resources and minimizes operational complexity. In contrast, manually planning a core transport network and IP and optical converged network demands excellent engineering skills and considerable expertise. "What-if" scenarios must be created for both the IP and transport topologies to cover the multiple failure scenarios and shared risk group vulnerabilities.

Benefits of Multilayer Optimization: Service Provisioning

The management plane is another building block of multilayer optimization where the velocity of service provisioning can be improved. A single OSS link for both IP and transport products increases the service velocity with faster network provisioning because the NMS platform, such as NSN's TNMS system, only sees one network element to manage. With the optical and IP elements tied to the same TNMS, the entire network is now operated and managed in a way in which most transport operators are used to operating.

Multilayer optimization can also enable the network to adjust traffic onto differing layers of the network. If there are underutilized 40/100G lambdas, traffic can be adjusted to the IP layer where statistical multiplexing can fully load the connection. If the IP links are running hot or very full, more traffic can be adjusted to the lower layer where the cost per bit is less expensive. Balancing the traffic between the two layers maximizes the transport infrastructure and minimizes the overall network cost. This ties the planning, previously done at multiple layers, together into a single layer that is tightly integrated with the network management system.

Transport topologies are not always the same as router topologies; understanding and planning around the shared risk link groups is vital for converged networks.

Here are some use cases for MLO:

- Routers can learn the virtual topology map of the transport network via the GMPLS NNI+, which enables client routers to establish multilayered optimized IP/MPLS routing decisions because they understand the shared risk group implications.
- Physical resources in the transport network are allocated only if required by the client routers, and resources of the virtual network can be shared by these different clients.
- Routers can automatically establish transport connectivity via the GMPLS NNI+ signaling without any interaction with the transport network operator (assuming network access rights are established via policies).

Benefits of Multilayer Optimization: Fault Management

The largest ongoing operational cost (~30 percent) in the core transport network is fault management, [3] and this is where MLO can be a tremendous operational benefit. Efficient service protection restoration requires redundancy in both the IP and the transport layers. IP failures require redundancy in the IP product via line cards; however, transport networks require the reservation of capacity for protection, which can be either dedicated or shared capacity depending on the service level agreement.

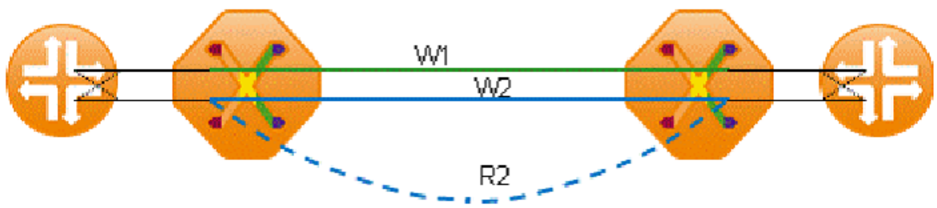

Figure 5: GMPLS FRR for Mesh Restoration, Two Levels of Protection Are Applied

There are several use cases (Figure 5) where GMPLS shared mesh restoration is applied as a protection mechanism against double failures.

Use Case One: Protection is used against double failures. Here, a fiber break triggers a fast reroute to initiate a fast (50ms or less) transaction and send the traffic onto a different path. The transport system then provides an alternate path and advertises it to the router (depending on topology, with minimal overlap with the original path). The router then automatically assigns this path as the new protection path. This shared risk group information must be communicated to fully understand all the diverse route paths and any limitations on those paths.

Use Case Two: Saving on protection resources. If quality of service is applied in the network it can enable some traffic to be restored at a slower rate, which then enables the routers to run at higher rates of capacity. All traffic is protected at the IP layer only, where often the maximum load is only 50 percent. If quality of service is enabled and half of the traffic is high priority and half is low priority, then some traffic can be restored on a slower time scale by setting up a connection on the optical layer via the GMPLS NNI+. The IP layer can be loaded at a higher percentage; possibly up to 66 percent (33 percent is now protected at the IP layer and 33 percent at the optical layer). An example is Telefonica,[3] a company that has shown that the solution can result in capital expenditure savings.

Use Case Three: IP layer anticipates potential hardware failures in the transport network by bit error rate (BER) monitoring. The BER is constantly monitoring any drift in performance or systematic deterioration of the transmission quality, and if it reaches a certain point, will trigger a fast reroute at the IP layer. This is a hitless protection mechanism and eliminates downtime by establishing greater resiliency, thereby reducing operational costs in the network.

Typically, this sharing of information between the IP and optical layer rarely works today, if at all. Transport topologies are not always the same as router topologies; understanding and planning around the shared risk groups is vital in converged networks and is an integral requirement for lowering the cost of managing multiple faults across the IP and optical domains.

Operators that deploy different vendors for IP and transport will rarely find this communication actually works. Supporting the GMPLS NNI+ standard is a step in the right direction for communicating shared risk. However, there are many potential use cases, and any router and transport pairing with or without integrated optics will require full standards compliance and thorough testing of the use cases to ensure that the shared risk groups are fully compatible. Some vendors, for example, NSN and Juniper Networks, have worked through the full standards of compliance and have conducted extensive interoperability testing with the GMPLS NNI+ standards and demonstrated increased operational savings when deployed together.

Joint solutions build on a standards-based approach and are typically more feature rich, which is really resonating with operators. In Figure 6 the converged products operate an end-to-end IP and optical transport network where the network is managed with one control plane and one management system.

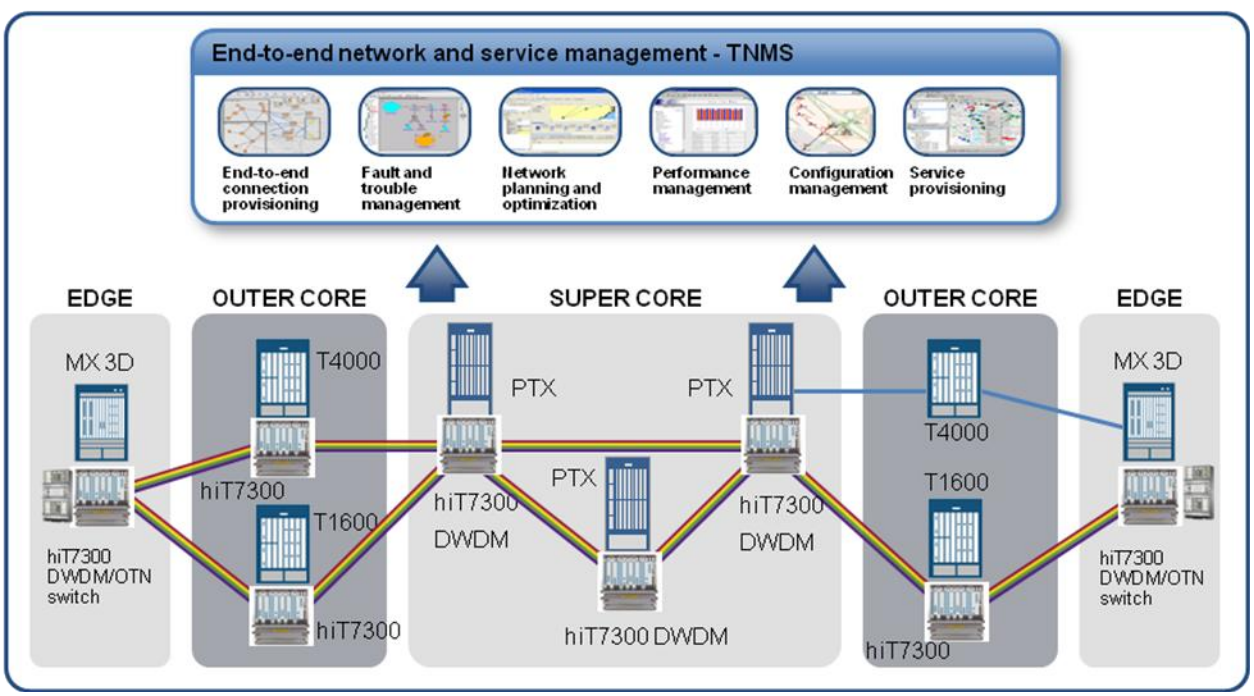

Figure 6: End-to-End Network that Maps the L2/3 Logical Topology to the L0/1/2 Physical Topology

This multilayer optimization is a key requirement to reducing high fault management costs. The 30 percent fault management cost can be reduced in half if the TNMS is used for both layers. Otherwise, restoration must be done manually, merely increasing the ongoing operational costs.

Most IP and optical interfaces are somewhat proprietary, which makes it harder to interoperate between vendors and across layers. How each vendor implements the standard and depth of that implementation will impact interoperability, making it a challenge to manage an end-to-end network. Some vendors have addressed this problem. For example, Juniper Networks SDK enables multiple application platforms to operate within the router without additional hardware. It is one of the core components of the joint development work done by NSN and Juniper Networks, which showcases how suppliers can be in full compliance of the GMPLS NNI+ standard currently in draft.[4]

iPTN: The New Normal

Figure 7 displays the advantages of data plane, control plane and management plane integration, as well as the multilayer optimization benefits. The combination of these enables an end-to-end optimized network.

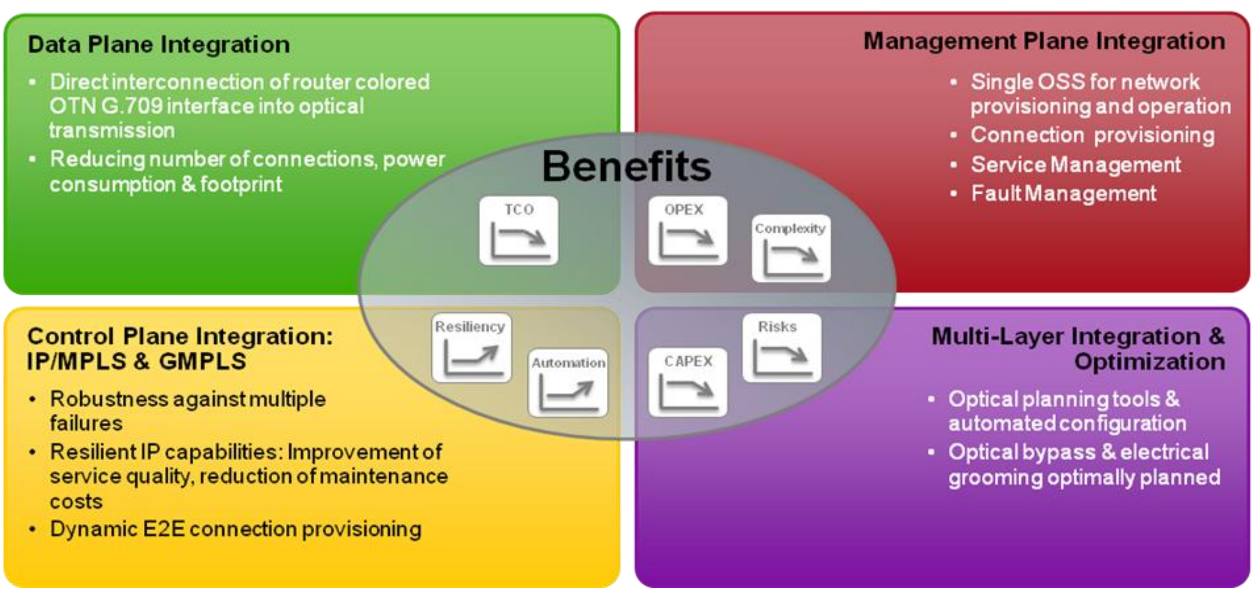

Figure 7: The Benefits of Integration

Some operators have already converged the IP and optical layers to gain efficiencies in their operations and lower their capital costs. Content providers such as Google and cable operators such as Comcast have single network teams that manage both router and optical equipment and in some cases have automated the application flows to maximize network utilization. Converged products and organizations show that massive traffic can be handled by these new networks and that a flatter architecture indeed delivers higher efficiency and lower operational costs — exactly what operators need.

Business case analyses and numerous network studies have provided insight into cost dependencies and comparisons of network architectures and technologies. Early adopters of converged technology are also early adopters of converged control planes, breaking new ground and providing the model for other operators. These resources and "pioneers" are providing a solid foundation for all operators to leverage the network for the optimal customer experience.

References:

[1] Cisco VNI 2012

[2] Most business case or TCO statements in this document are from the numerous studies Michael Kennedy, ACG business case analyst, has publically documented.

[3] Telefonica paper on Survivable IP/MPLS-Over-WSON Multilayer Network Optimization http://www.opticsinfobase.org/jocn/abstract.cfm?uri=jocn-3-8-629

[4] Draft-beeram-ccamp-gmpls-enni-00.pdf (a companion to RFC 4208)

Acknowledgements: This article is sponsored by and based on contributions from Nokia Siemens Networks and Juniper Networks.

About Juniper Networks

Juniper Networks is in the business of network innovation. From devices to data centers, from consumers to cloud providers, Juniper Networks delivers the software, silicon and systems that transform the experience and economics of networking. Additional information can be found at Juniper Networks (www.juniper.net).

About Nokia Siemens Networks

Nokia Siemens Networks is a leading global enabler of telecommunications services. With its focus on innovation and sustainability, the company provides a complete portfolio of mobile, fixed and converged network technology, as well as professional services including consultancy and systems integration, deployment, maintenance and managed services. It is one of the largest telecommunications hardware, software and professional services companies in the world. With over 130 DWDM customers worldwide, Nokia Siemens Networks provides a migration path to Terabit Optical Transport. Operating in 150 countries, its headquarters are in Espoo, Finland. www.nokiasiemensnetworks.com

ACG Research is an analyst and consulting company that focuses in the networking and telecom space. Our best-in-class subject matter analysts have a combined 120+ years of experience and expertise in telecom segments that address both technology and business issues. We offer comprehensive, high-quality, end-to-end business consulting and syndicated research services.

ACG Research delivers telecom market share/forecast reports, consulting services, business case analysis, product and service message testing. ACG provides you with accurate market share data, strategic and tactical advice, services and products, and timely answers to the industry questions so that you can better understand market dynamics and grow your telecom operations more efficiently and profitably.

Coverage areas focus on the service provider and enterprise spaces in the following domains: Carrier Architecture, IP Video/CDN, Managed Services, Security, Business Case Modeling and Analysis, CPE/Broadband, Telepresence, IP Optical Transport, Mobility, Cloud, Data Center, Carrier Routing and Switching, and All-IP.