Alcatel·Lucent

STRATEGIC WHITE PAPER

Toward a Converged Backbone

Optimizing transport efficiency in a High Leverage Network™ architecture with integrated IP and Optics

As service providers strive to leverage their network assets to deliver a compelling array of innovative business, residential and mobile services to their customers, the optimization of their transport infrastructure stands to play a key role in ensuring profitability and a superior user experience. Closer integration of IP and optical transport networks — long treated as separate domains with limited cross-layer visibility and coordination — offers significant opportunities for reducing transport costs and increasing network efficiency.

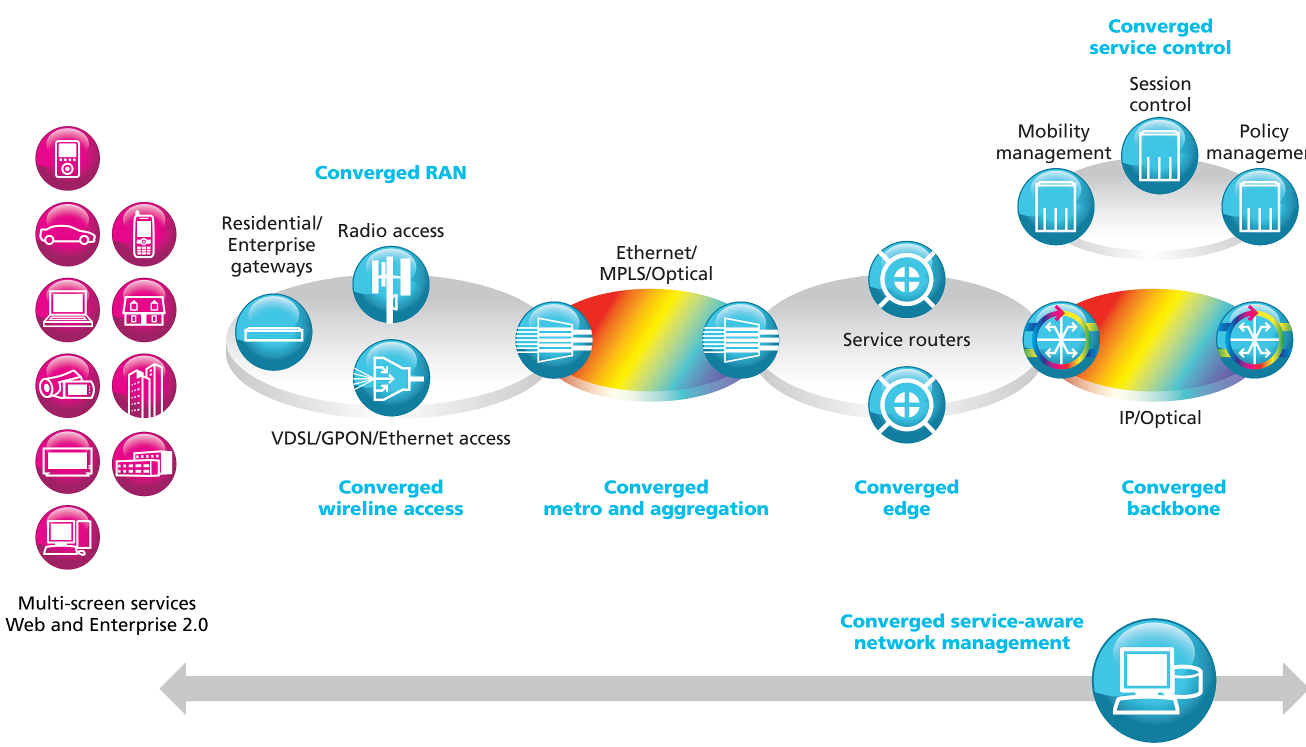
With market leadership across both IP and optics domains, Alcatel-Lucent is taking the lead with a comprehensive Converged Backbone Transformation solution that optimizes transport efficiency regardless of service mix. The Converged Backbone of a High Leverage Network (HLN) architecture will leverage optics and IP in a cohesive fashion, aligning innovations in data plane, control plane and management plane integration that combine to deliver the lowest cost per bit for reliable transport across the backbone for the breadth of existing and emerging services.

High Leverage Network introduction

A High Leverage Network™ architecture addresses the key challenge of how to simultaneously provide efficient, low-cost bit transport and innovative, revenue-generating, value-added services. It enables continuously scalable bandwidth from the access to the core layer with the lowest total cost of ownership (TCO). At the same time, it instruments or equips the network with built-in subscriber, service and application awareness to provide enhanced Quality of Service (QoS) and traffic optimization. This provides the appropriate levels of intelligence within the network to deliver advanced services to end users at the optimum cost.

A High Leverage Network (HLN) is an all-IP network, providing a common, converged foundation from which to deliver new services, with reduced time-to-market and faster return on investment (ROI). It also supports Application Enablement (AE), the Alcatel-Lucent vision of how to expose selected capabilities of the network in a managed and controlled way for enhanced application development and delivery. This allows service providers to create their own attractive IP-based services as well as enhance those offered by their partners and selected third parties, increasing end user Quality of Experience (QoE). This innovative approach enables new business models to address market challenges and opportunities and provides sustained competitive differentiation. The shift from keeping value in the network to extracting value from the network allows service providers to grow revenues and accelerate the ROI from their networks.

An HLN architecture requires four key technologies — wireline broadband access, wireless broadband access, IP and optics — as well as the appropriate software and services that provide the foundation to support AE. For simplicity, an HLN architecture can be thought of as seven different domains, each providing a specific set of capabilities and functions. These domains provide an architectural framework to enable and guide network transformation. Depending on scope and circumstance, service providers may focus on one or several domains, or may address the end-to-end challenge of implementing a complete HLN architecture. This white paper discusses the Converged Backbone, one of the seven domains of a High Leverage Network architecture.



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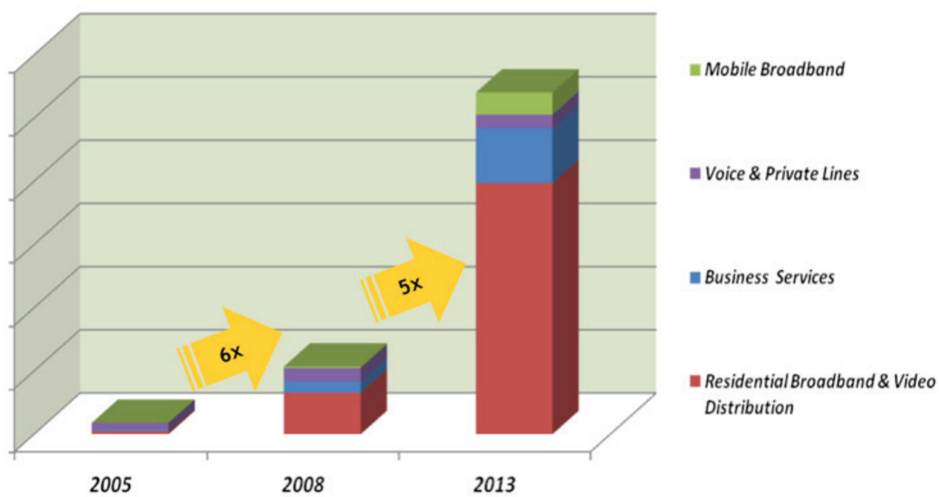
1. Background and market drivers

Driven by a broad range of applications including video and interactive multimedia, the volume of Internet traffic traversing service provider networks continues to increase dramatically. Networks must handle an increasingly diverse array of data flows, ranging from mission critical business and financial data to video, fixed and mobile voice, L2 and L3 VPN services, and Internet access. On top of the traffic growth, new applications and business models are creating new opportunities for, and placing further demands on, the infrastructure. Further, the traffic mix is undergoing a dramatic shift with increasingly high volumes of video and wireless broadband traffic in addition to continued growth in the volume of business services (see Figure 1). The net result of this increase in traffic has often been called the exaflood phenomenon. What impacts the resulting bandwidth crunch more is the pressure on profitability as traffic increases while revenues fail to grow proportionally.

Figure 1. Traffic growth and evolution of traffic mix in service provider networks



Service providers strive to simultaneously balance two conflicting goals. To be successful, they must reduce the cost of reliably transporting high volumes of traffic while extracting appropriate value from innovative new services. In the existing model, service providers find it difficult to extract full value from their network assets and find themselves resigned to the costs of reliably carrying higher volumes of traffic across their infrastructure. The Alcatel-Lucent vision of an HLN architecture is directly aimed at helping service providers monetize the value of their network assets and maximize the efficiency of their infrastructure and the operational costs incurred to manage the network, yielding higher profitability and service velocity.

In order to unify their networks, most service providers have undertaken major efforts to converge on IP/MPLS as the common bearer of all traffic. Operators strive to contain costs and minimize risk as they converge all services to their IP-based infrastructure with efficient Ethernet-based access to an IP/MPLS core, which feeds into the optical transport infrastructure. But often, all they can manage to do is add core routers and corresponding DWDM transport equipment to their network just fast enough to manage the growth of traffic on their networks. They do so at significant cost, and in a manner identical to the mode of operation in the early days of Internet growth.

Where it makes sense, integrating layers of functionality enables the reduction of network elements in the data path and reduces cost and operational complexity. Closer integration of IP and optical transport provides efficiencies in power, space, simplified network planning and fault management, and fewer points of failure. For the service provider, this results in higher efficiency and robustness with lower complexity and at a lower cost of operation.

Taking a closer look at the present mode of operation reveals a very interesting opportunity for transformation of the core network, leading to drastically improved efficiency.

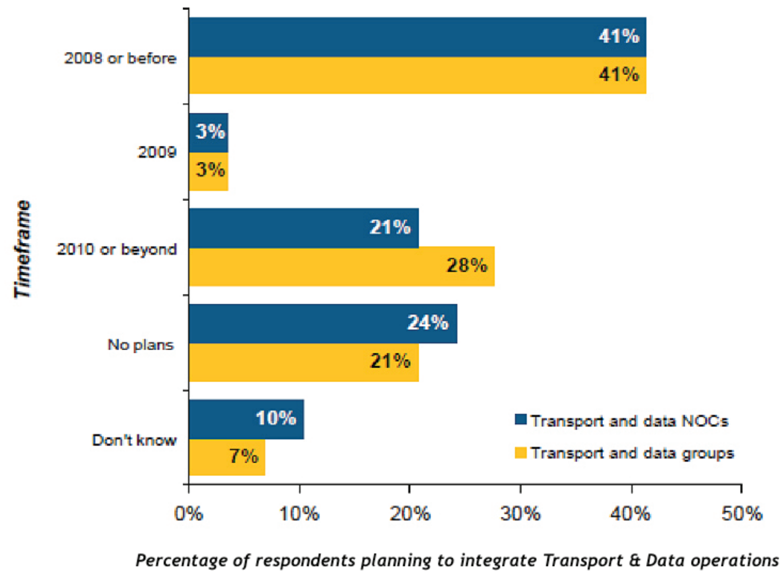
2. Today's core networks

A broad array of traffic is handled by the typical service provider's IP infrastructure today. In addition to extensive volumes of fixed and mobile Internet access, there are a variety of residential services such as IPTV, video-on-demand (VoD) and Walled garden content services, and business services (including Layer 2 and Layer 3 IP VPN traffic), as well as a variety of leased line offerings and links for inter-provider connectivity and Internet peering. Today's core networks include multiple layers of IP/MPLS routing and TDM and wavelength switching.

Today's IP transport networks include optical transport infrastructure as well as a mesh of core routers (P routers), which are fed by service routers or PE routers at the edge. Virtually all traffic traverses multiple core routers en route to its destination as well as on the return path. As a result, pressure is building on core routers to handle the offered traffic. Many are being upgraded to multi-chassis configurations, at significant cost. More ports are deployed even as existing ports are inefficiently utilized. Commensurately, the underlying optical network is also expanded to support the transport of increased traffic load. Service provider Capital Expenditure (CAPEX) grows proportionally to traffic, and is misaligned with revenue growth and profitability. This model is clearly not scalable for addressing the exaflood phenomenon in a cost-effective manner.

Historically, the IP and optical layers have most often been built, managed and maintained separately, by different groups within the service provider and using disparate systems with little interaction. The rate at which service providers adapt their network architectures is often gated by their internal structures and network operations. Some will adopt new integrated technologies more quickly, driving an integration of their planning and operations teams at an accelerated pace in the process. Others, most often the largest tier-1 operators with the most extensive operations and infrastructure, will take a more long-term approach to such transitions. In those cases, the scale of their service offerings (and hence the organizations that support them) often drives structural separation. A surprisingly high percentage of service providers have recently started the process of converging their data and transport planning and Network Operations Center (NOC) groups, while many others (including many of the tier-1 operators) have stated that they do not currently have short-term plans to do so (see Figure 2). Alcatel-Lucent is uniquely positioned to address this reality. The scope of HLN Converged Backbone architectural models will address the traffic mix and operational needs of service providers who plan to converge aggressively, as well as those who will take a longer-term view to consolidating operations.

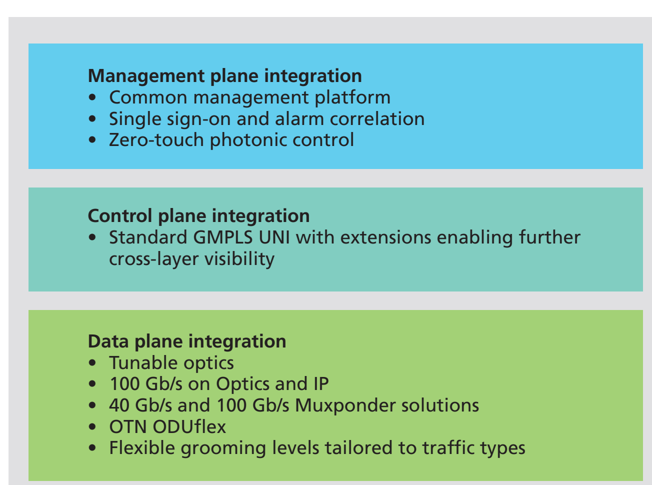
Figure 2. Planned convergence of data and transport groups (network operator survey results)



3. A comprehensive view on optical integration

With leadership across both domains, early time-to-market in compelling new areas such as 40/100 GigE and 40/100G transport, and a compelling HLN Converged Backbone vision, Alcatel-Lucent can provide the broadest range of solutions across optical transport and IP. With the benefit of optical and IP expertise, Alcatel-Lucent is uniquely positioned to address the opportunities of tighter integration by taking a more comprehensive view. The Alcatel-Lucent strategy is focused on the underlying business problems of the service provider, as well as providing a full toolkit that takes into account the realities of service mix and operational and organizational structure, as opposed to necessitating one default technology-based approach or another. Unlike traditional router suppliers who are limited to narrow IP-centric views of the infrastructure, Alcatel-Lucent is planning innovations and integration across the full scope of data plane integration, as well as control plane integration and management plane integration — efforts to enable the fullest extent of benefits in terms of cross-layer visibility and automation, grooming flexibility, resiliency, and overall OPEX optimization (see Figure 3).

Figure 3. Key vectors for comprehensive integration of IP and optical domains



In aligning with service provider goals and operational models, and devising comprehensive options for IP/optical integration, an understanding of the traffic mix traversing core networks today is critical.

An analysis of traffic patterns across typical service provider IP networks illustrates that a significant fraction of the traffic traversing today's core is directed to a relatively small number of locations for Internet peering, datacenters and content distribution. This traffic is homed onto Internet border gateways, which typically exist at a few points within the network. Likewise, VoD traffic predominantly consists of downstream traffic for delivering content. As video sharing, social networking and data-center applications continue to become more sophisticated, this trend is likely to accelerate. Storage of content is being further distributed within the network, and this trend will present a multitude of avenues for optimizing transport costs and improving the end users' QoE. With the rapidly growing volumes of application and content services and managed video content distribution, opportunities to optimize transport in order to reduce peering costs and bandwidth expenses while introducing innovative business models and enabling new revenue opportunities are becoming increasingly appealing to service providers. Understanding the nature and relative volume of these sources of hub-and-spoke traffic will prove important in optimizing the transport network for scalable and cost-effective operation, as will the evolution of service provider strategies for content distribution (CDN) and distributed storage.

On the other hand, the survey of typical service provider IP networks also shows that a significant fraction of the offered traffic is deployed in an any-to-any model, with point-to-point and multipoint connections that are not centralized or homed. Business services such as Ethernet and Layer 2 VPNs are a good example, as are VoIP bearer channels and leased lines. Such services represent a key source of revenue-generating traffic within the backbones of operator networks, and are growing rapidly with the emergence of telepresence and collaborative business applications. Understanding the nature and relative volume of the any-to-any traffic will prove important in optimizing the transport network for scalable and cost-effective operation.

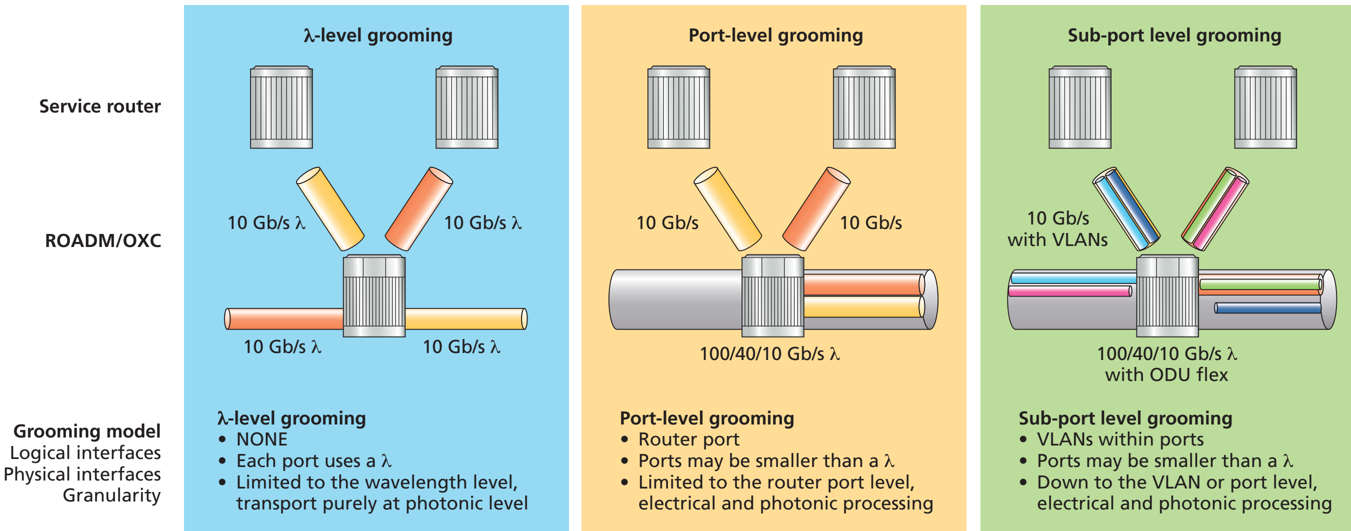
4. The Alcatel-Lucent Converged Backbone Transformation solution

The Alcatel-Lucent Converged Backbone Transformation solution maximizes transport network efficiency, mindful of the service mix within the network. Focused on lowering the total cost of reliable transport, the path toward an optimal solution will vary depending on the scope and relative scale of services offered by an operator as well as their operational environment. To optimize transport network efficiency across the IP and optical domains, the following considerations are critical:

- Maximizing the utilization of IP and transport links in light of the service mix
- Optimizing cross-domain visibility and resiliency
- Minimizing unnecessary processing within the core where possible
- Maximizing the flexibility of the network to carry the desired traffic mix at the lowest cost per bit

Alcatel-Lucent offers three options within the Converged Backbone Transformation solution that maximize network efficiency by mapping the provider's specific service mix and traffic distribution against the transport network's grooming flexibility requirements. As shown in Figure 4, the three architectural models within the Converged Backbone Transformation solution are lambda-level grooming, port-level grooming and sub-port level grooming.

Figure 4. Key architectural models within the Converged Backbone Transformation solution



The common goal across the architectural models is to provide superior economics that minimize the cost of transport in accordance with each service provider's scale and traffic mix. Alcatel-Lucent has put in place an implementation strategy that delivers integrated solutions across all key aspects of the architecture, including data plane interconnection, control plane integration and network management integration. A brief description of each architectural model follows.

4.1 Lambda-level grooming

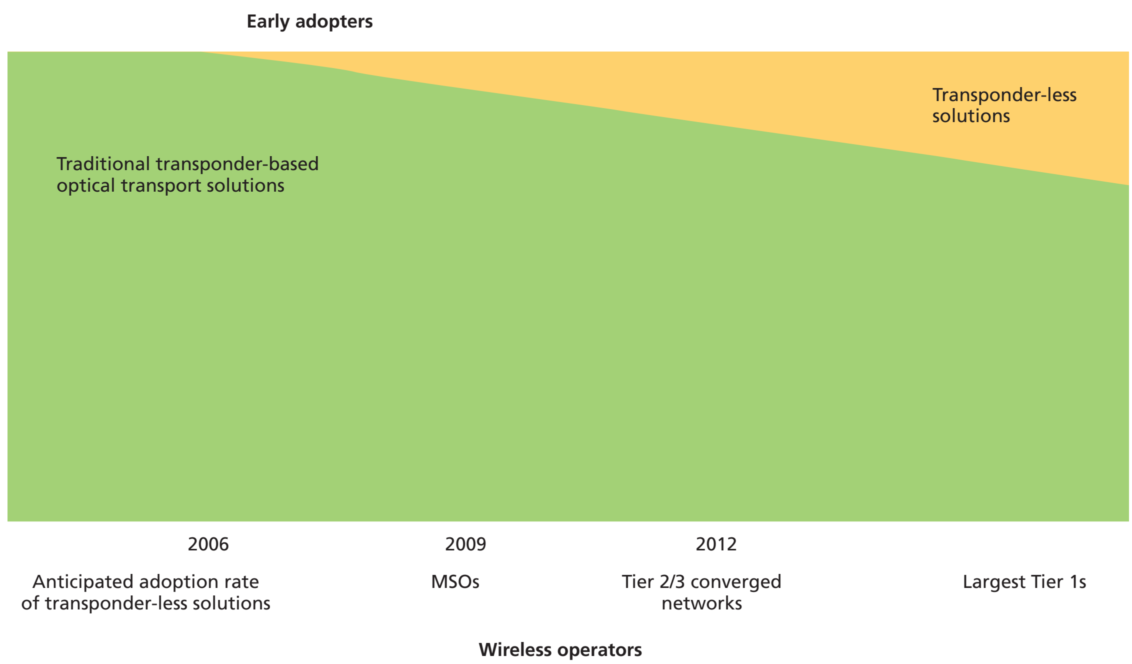
Lambda-level grooming offers the lowest level of grooming flexibility, and can be the optimal architecture for networks in which the relative volume of hub-and-spoke traffic is highest, or networks in which the integration of transport and data operations is desirable and underway. In the Lambda-level grooming model, also known as IPoDWDM, wavelengths (or colored interfaces) are generated directly from the router and are optically cross-connected to destinations across the network, without any grooming below the wavelength level. In this model, each physical port is the equivalent of a single wavelength (or lambda), and the transport domain is purely photonic.

The Alcatel-Lucent service router portfolio incorporates support for tunable optics to facilitate the lambda grooming option. Use of tunable optics enables routers to interconnect directly with existing DWDM transport systems, eliminating the need for external transponders and short-reach optics required for interconnections to the optical infrastructure. While the lambda grooming alternative delivers improvements in CAPEX by reducing optical to electrical (OEO) conversions, and improves OPEX in reducing sparing needs and the costs associated with turning up services, it often proves impractical for long-haul and ultra-long haul applications. And, while this approach takes strides in addressing visibility across the router and transport domains with G.709, it typically requires that protection schemes are done at the IP/MPLS level.

The Alcatel-Lucent Reconfigurable Optical Add Drop Multiplexers (ROADMs), with integrated Wavelength Tracker technology, provide an optimal means to interconnect routers using through paths in this architectural model by minimizing time-consuming and error-prone manual configuration processes. This results in dramatically reduced provisioning and deployment times with alien wavelengths fundamentally addressed within the operators' engineering tools.

Historically, this approach has been more readily adopted by MSOs, smaller tier-2 carriers and wireless operators due to the impact on organizational structure and need for close coordination among the IP and transport teams (see Figure 5). Among the largest operators, the IP and transport teams remain distinct and operate independently and for the most part the organizations have not yet converged.

Figure 5. Rate of adoption of transponder-less solutions varies among types of operators



For those service providers who aggressively seek to interconnect routers directly with existing DWDM transport systems — thus eliminating the need for external transponders and short-reach optics required for interconnections to the optical infrastructure — Alcatel-Lucent provides lambda grooming options that help the operators achieve their goals. For other service providers who elect to transition their operations over time, and to address traffic types not most amenable to lambda level grooming, Alcatel-Lucent provides market-leading transponder-based solutions within the port-level and sub-port level grooming options.

4.2 Port-level grooming

In addition to residential broadband and Internet services, most large operators offer both leased lines and a significant number of private data services that inherently drive any-to-any type traffic distributions within the network. Where the traffic load of these services types (including any-to-any business VPN services) represent a large portion of the overall traffic matrix for a provider, there is a need for increased grooming flexibility within the network to better utilize the network resources and still achieve the lowest cost per bit transported. Without such granular grooming flexibility within the transport network, service providers are faced with the challenge of overbuilding their transport infrastructure in both the IP and optical domains while under-utilizing these assets.

The port-level grooming option offers an incremental level of grooming flexibility and optimizes transport efficiency for networks with a broad mix of traffic not necessarily expected to be dominated by either any-to-any traffic or hub-and-spoke varieties. In this model, conventional black and white optical interfaces interconnect the router and the OTN or DWDM equipment, and traffic can be groomed at the port level onto higher speed optical connections for transport.

Port-level grooming results in CAPEX reductions through P router and transport layer optimizations, maximizing wavelength utilization within the transport network. This architectural model also leverages 10G, 40G, and 100G muxponder solutions for flexibly increasing the bit rate per wavelength in the network while maintaining existing interfaces in the IP domain. The port-level grooming alternative fits well within the present mode of operations for service providers, as it provides a traditional black and white optical interconnect and respects traditional management boundaries.

4.3 Sub-port level grooming

Sub-port level grooming offers the highest level of grooming flexibility among the three architectural models, and optimizes transport efficiency for networks with a significant volume of any-to-any traffic (e.g., L2 business services and leased lines) within the service mix. The sub-port grooming option allows maximum grooming flexibility by enabling VLANs or pseudowires within a port to be logically mapped to optical links using innovative ODUflex technology, which is currently within the standardization process.

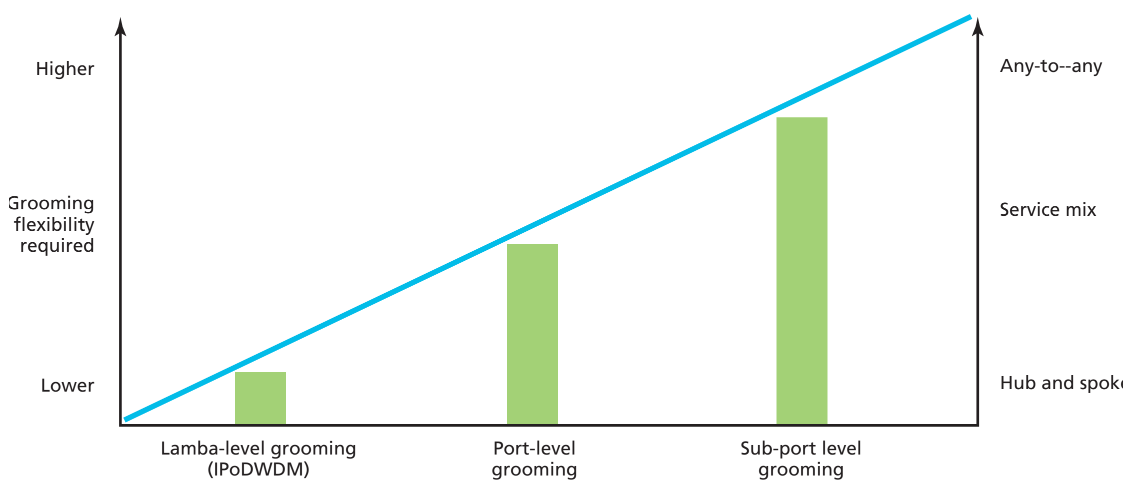
Sub-port level grooming enables finer granularity such that ports do not have to consume the full capacity of a physical port or wavelength by supporting sub-port interfaces or virtual interfaces such as VLANs. Different VLANs from the same router port are mapped to different virtual containers through the transport network and to different destinations using ODUflex and VLAN shaping. ODUflex is a new technology that allows grooming of traffic between optical transport equipment and routers in a manner that efficiently addresses incremental bandwidth growth, in steps as granular as 1 Gb. Service providers no longer have to allocate a full ODU container to each connection, but rather can increase capacity in increments for connections that require them. Through control plane integration, dynamic bandwidth adjustments can optimize the network as needed over time. Further opportunities for enhancing overall network resiliency and fault isolation also emerge from control plane integration.

Perhaps most importantly, this model fits quite well with the existing organizational structure and present mode of operations for large service providers. In tier-1 environments, there is almost exclusively a clear demarcation between the teams that run the data network and those who administer the transport network. This model optimizes the transport infrastructure without forcing any change in the way these operators run their networks today. This is a clear advantage over IPoDWDM solutions that are the sole offering of many incumbent router suppliers, where a level of convergence of operations and network administration is implied and required.

Recognizing typical demarcations in the administration of the IP and optical networks within large service providers, the Alcatel-Lucent solution also offers a set of workflow mechanisms designed to streamline the most common cross-domain network management operations. The integrated management workflow concept provides the NOC with a means to continue exploiting their current operational models and best practices in the IP and optical transport domains, while evolving toward advanced platform integration options. This enables features such as single sign-on to the combined network management service applications, single alarm repository and administration and one-click context switches from IP to optics application views.

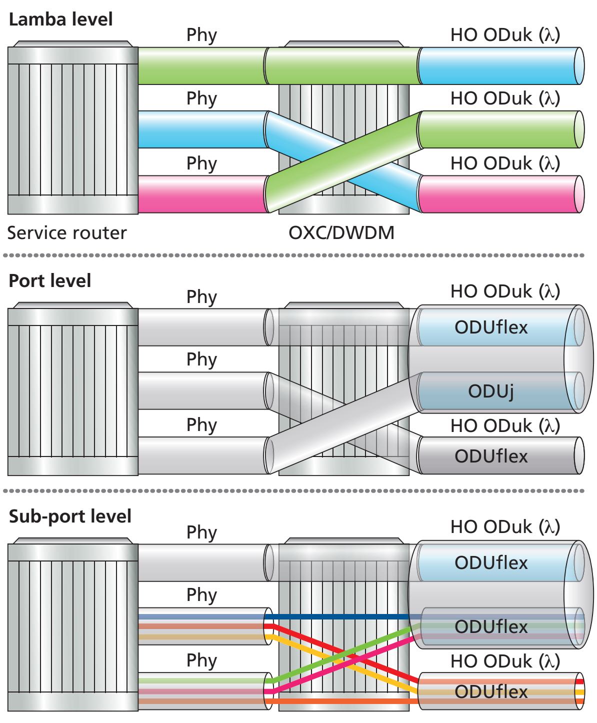
Depending on the service mix, each of the three architectural models within the Converged Backbone Transformation solution could prove to be the lowest cost solution for a service provider's environment, and in many cases hybrid implementations are likely to emerge within a service provider's networks in order to further optimize the transport infrastructure. Where lower levels of grooming flexibility are needed, lambda-level grooming provides direct IPoDWDM links from the router, optimizing the utilization of links throughout the transport network. Likewise, where greater levels of grooming flexibility are warranted, traffic is efficiently aggregated on DWDM links at the port or sub-port level, optimizing the utilization of transport links throughout the network (see Figure 6). In this manner, fewer ports and interconnections between the IP and transport domains are required and the infrastructure is used most efficiently.

Figure 6. Converged Backbone Transformation architectural models to optimize transport based on relative traffic mix



The architectural models for optimizing transport efficiency relative to service mix are summarized in Figure 7.

Figure 7. A strategy that offers architectural models to optimize transport efficiency regardless of service provider traffic mix



Grooming level/ granularity	Services optimized: Internet access, VoD	Mobile broadband	Business services	Voice, private line	Carrier business model
Lambda Wavelength (10/40/100 Gb/s)	X	X			Integrated data and transport operations
Port Router port (10/40/100 Gb/s)	X	X	X		Integrated or separate
Sub-port VLAN/port (BW 1-100 Gb/s)	X	X	X	X	Integrated or separate

Hub and spoke Any-to-any
Traffic distribution

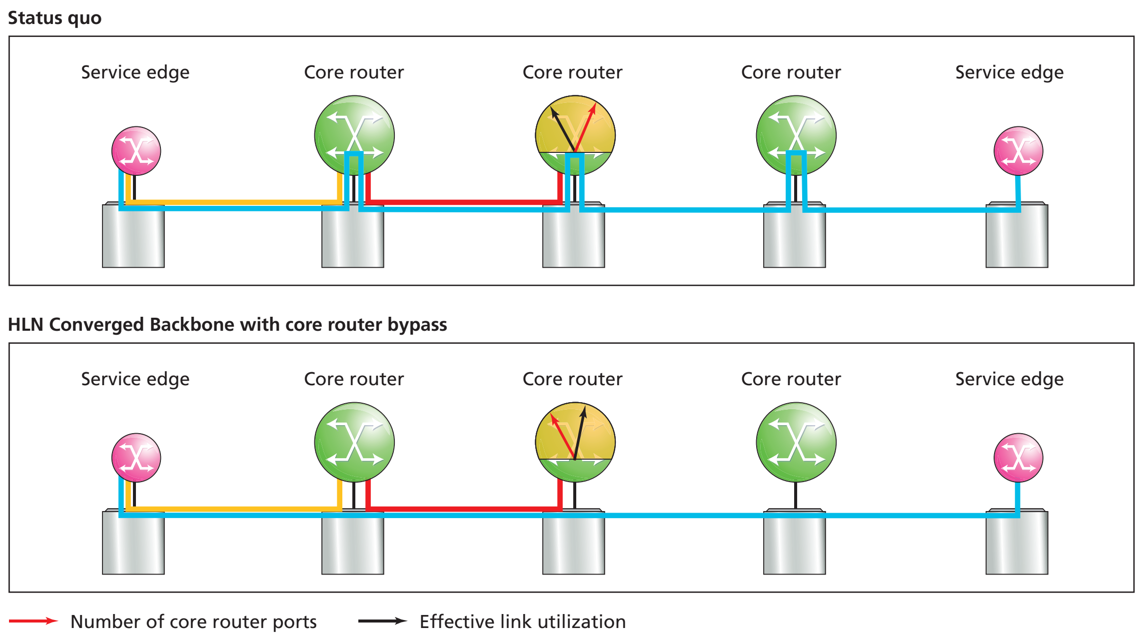
Across all models, further opportunities for enhancing overall network resiliency and fault isolation also emerge from control plane integration. Integrated network management provides visibility across the IP and optical domains and facilitates end-to-end provisioning, troubleshooting and administration.

5. Opportunities for IP offloading

Given that a surprisingly high proportion of today's IP traffic is directed to a relatively small number of locations for Internet peering, datacenters and content distribution, the architectural models described previously also pave the way for further optimization of the transport infrastructure through offloading techniques facilitated by coordination between the IP and optical domains. Whereas today all of this traffic traverses the core IP cloud, there is a significant opportunity to optimize the core by selectively identifying such flows and handling traffic at the lowest possible layer, within the optical transport infrastructure. Identifying and offloading selected flows significantly impacts the cost and complexity of the transport network. Even if 20 to 25% of traffic could be offloaded using direct paths through the optical layer, the savings achieved on core router ports and corresponding drop-side DWDM ports can be quite compelling. Network resources are liberated in this manner, allowing best utilization and further scaling in leveraging assets without unnecessary and expensive upgrades. As video sharing, social networking and datacenter applications continue to become more sophisticated, the appeal of such techniques can also be expected to intensify.

By redirecting the right types of traffic and offloading the core routers from handling packets to which they add cost but no value, Alcatel-Lucent proposes a network optimization that will help service providers streamline their core networks in a manner that can elegantly and cost-effectively scale to address continued traffic growth (see Figure 8).

Figure 8. Opportunity for selective core router offload further enhances transport network efficiency



It is noteworthy that such mechanisms for optimizing infrastructure through offloading are not a new phenomenon, and have been proven in the transition of dial-up from PSTN to IP as well as in several previous transport technologies, such as SDH, ATM, X.25, and Frame Relay. In the envisioned converged core, the offloading happens at the lowest possible layer — the optical layer. Depending on the nature of the traffic, it can be mapped to shortcut OTN circuits or onto an optical wavelength, offloading traffic from the IP core. By handling traffic at the optical transport layer, significant economic and operational benefits can be derived.

6. Conclusion

With the Converged Backbone Transformation solution, Alcatel-Lucent offers the industry's first comprehensive solution to optimize core transport across the full range of traffic mixes prevalent in today's networks. The Alcatel-Lucent approach leverages leadership across the optics and IP domains to offer a comprehensive integrated solution across the data plane, control plane and management planes. This approach addresses the needs of service providers, mindful of their service mix and operational and organizational considerations, and enables them to transform their core networks at their desired pace and in the manner that best suits their operations.

Key innovations that serve as the underpinnings of the High Leverage Network Converged Backbone vision include:

- 100G on optics and IP
- ODUflex
- FP2 silicon innovation
- Zero-touch photonics
- Cross-layer automation
- Integrated workflow management/NMS integration
- Standard GMPLS UNI with extensions enabling further cross-layer coordination and resulting in higher overall resiliency across the IP and optical network

Alcatel-Lucent is uniquely positioned to leverage its expertise and product portfolio in order to address innovative integrated solutions across the IP and optical domains. Any network transformation takes time. Closer integration of optical transport and IP, and the emergence of flexible grooming and IP offload solutions, will be no exception. With decades of experience in network transformations, Alcatel-Lucent offers a comprehensive product portfolio and a broad array of professional services that facilitate this important transition for service providers worldwide.

7. Abbreviations

AE	Application Enablement
CAPEX	Capital Expenditure
DWDM	dense wavelength division multiplexing
GMPLS	Generalized Multiprotocol Label Switching
HLN	High Leverage Network
NOC	Network Operations Center
OPEX	Operating Expenditure
ROADM	Reconfigurable Optical Add Drop Multiplexer
VOD	video on demand
VPN	Virtual Private Network
UNI	user network interface

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