

IP Core Network Intelligence: Essential Components and Drivers



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by Mark Bieberich | October 2007

Executive Summary

Conventional wisdom dictates that service and application intelligence ought to be distributed to the edges of service provider IP networks, leaving the core optimized for unintelligent yet scalable and resilient packet transport. This belief is further supported by the emergence of standards that allow 40 and 100 Gbps of throughput per port on next-generation core routers. The logic states that if core network capacity is plentiful and inexpensive, and core routers can scale to keep pace with traffic demand, then intelligence at the core is unnecessary, both in terms of capital expense and operational complexity.

However, a confluence of mounting evidence found in the personalization of business and residential services, large dynamic bandwidth shifts, IP traffic growth rates and IP core convergence plans justify an increasing number of service provider decisions to infuse the IP core with intelligence. According to service provider network planners, the foundation of an intelligent IP core is the deployment of next-generation IP core routers that enable Layer 3 service and application awareness, advanced traffic engineering, adaptive functionality and seamless convergence with the optical transport layer.

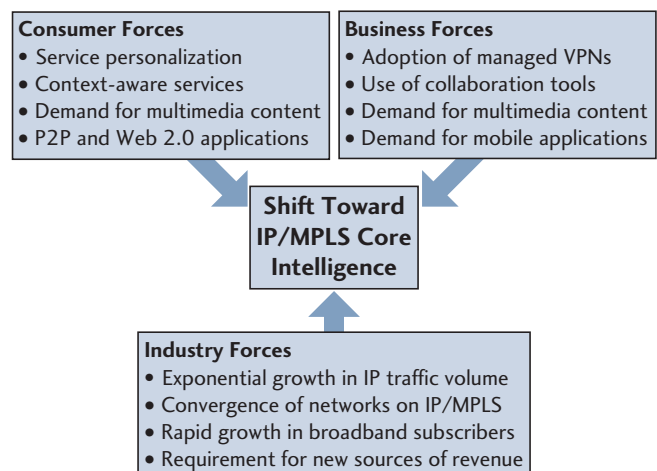
Service providers must choose from a growing number of technology alternatives for building the foundation of the intelligent core, but no option is as proven and reliable as IP/MPLS. Commitment to an MPLS-based IP core remains steadfast among top-tier and competitive operators globally. Alternative approaches claim to offer superior performance, scale and management of backbone traffic. However, a deeper look reveals operational challenges reminiscent of when ATM was a core technology contender. MPLS proves through its market acceptance and maturity that it is the ideal choice for bringing the necessary level of intelligence to the next-generation IP core.

In this Report, we uncover the essential components and drivers of IP core network intelligence (see Exhibit 1). A wide variety of primary research from Yankee Group is used to demonstrate the basis for shifting investment from best effort-oriented to intelligent IP core networks. IP traffic growth rates, service forecasts, and other quantitative and qualitative trends are analyzed in this context. In addition, we examine the benefits and pitfalls of established and emerging approaches to building the intelligent IP core, reinforcing the clear advantages of an MPLS-based IP backbone.

Exhibit 1

Forces Driving Adoption of Intelligent IP/MPLS Core Networks

Source: Yankee Group, 2007



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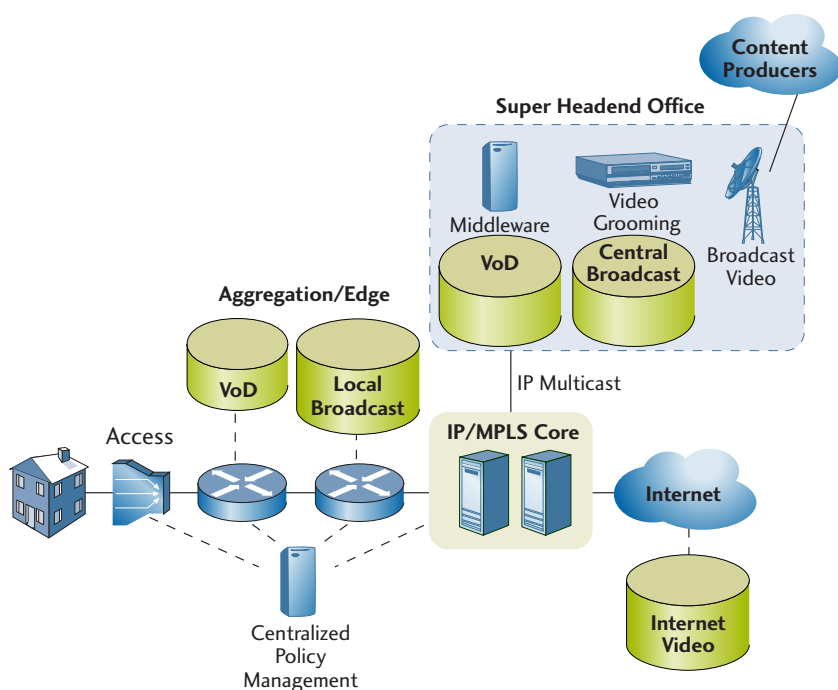
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I. Essential Components of Intelligent IP Core Networks

During the past 18 months, Yankee Group conducted comprehensive interviews focused on uncovering the requirements of next-generation service provider IP networks. Questions posed to network planners focused primarily on the effect of IP traffic patterns, network consolidation plans, and business and residential service adoption on investment in network-layer technologies.

The research considered the impact on capital and operational expenditures of service providers' most strategic initiatives, including multiple forms of IP video delivery; creation of personalized broadband services; the expansion of managed services for businesses; and the ability to generate new revenue streams from nontraditional sources such as advertising.

Exhibit 2
The Role of the Core Router in IP Video Distribution
Source: Yankee Group, 2007



One of the recurring themes throughout the interviews—and the main topic of this Report—was IP core network intelligence and the extent to which it is necessary to achieve these strategic goals. In particular, the subject of network intelligence refers to whether the service provider IP core should be engineered with service-aware, Layer 3 hierarchical structure, advanced traffic engineering and specific adaptive functions. Each of these capabilities is examined below.

Layer 3 Service Awareness

A majority of service provider IP core networks remain optimized for connectivity services, not necessarily for high-value, media-rich services such as IPTV. In service provider networks, core routers are deployed mainly for efficient, scalable aggregation, transport and peering. Therefore, the ability to identify discrete Layer 3 service flows—and then enforce subscriber-level QoS, security and other policies in accordance with business and operational goals—is more commonly distributed to the edge.

As core routers assume a key role in the distribution of multimedia services and content, Layer 3 service awareness grows in importance. Layer 3 service awareness involves numerous techniques to summarize addressing, load-balance traffic dynamically and converge quickly by working around multiple failures. These capabilities are increasingly important as core routers serve as an entry point for over-the-top services, such as internet video, which consume a growing percentage of overall network capacity and therefore must be recognized before the traffic is assigned relative priority at Layer 3 and managed accordingly.

The imperative of delivering a scalable, reliable IPTV service validates the need for Layer 3 service awareness. Many service providers are evaluating the expansion of video distribution networks that can distribute an entire broadcast channel lineup nationally (see Exhibit 2 on previous page). The purpose of these initiatives is to afford service providers the flexibility to build custom channel lineups per region. Another key goal of national distribution is to eliminate multiple, costly satellite receiving stations that are typically deployed one per metro region. At the same time, as the importance of VoD services grows, service providers are distributing VoD traffic via multicast across the IP backbone. This step requires highly efficient, line-rate multicast replication in the core architecture, driving further the fundamental need for Layer 3 service awareness.

Advanced Traffic Engineering

In interviews, service providers affirm that IP core networks still need an assist with respect to maximizing efficiency and performance of multiple traffic types and network topologies. Traffic engineering capabilities such as Equal Cost Multipath (ECMP) and IGP metric manipulation in the IP domain—and Fast Reroute (FRR) and DiffServ-aware traffic engineering (DS-TE) in the MPLS domain—represent important technologies for meeting these objectives.

Use of advanced traffic engineering is now accelerating because of the increasingly complex mix of traffic types the IP core must support. Disparate forms of video, including IPTV, VoD and internet (or over-the-top) video, represent excellent examples of unpredictable, QoS-sensitive and bandwidth-intensive applications that require service providers to maximize efficiency of IP core trunks and flexibility of bandwidth provisioning.

From a supply-side angle, use of traffic engineering is rising because of the availability of next-generation core routers that can dedicate capabilities to multiple services in secure, high-performance, hardware- and software-defined partitions. As a result, service providers have the assurance they need to optimize traffic engineering functions on a single core element to address increasingly dynamic changes in IP traffic volume, network topology and customer demand.

Adaptive Intelligent Functions

The proliferation of applications and services entering and traversing a converged IP core means that the core router emerges as an increasingly critical element in service distribution. Core routers must maintain a key role in administering SLAs and guaranteeing user experiences as a diverse mix of premium, multimedia services contend for core network resources.

To solidify this role, core routers must support a wide range of adaptive intelligent functions designed for scalable, service-aware IP transport. Examples of these functions include enforcing QoS; using active probes to collect IP and MPLS statistics; securing the forwarding, control and administrative planes; and distributing a dynamic mix of multicast and unicast traffic with the same level of scale and line-rate performance applied to basic packet forwarding.

For each adaptive intelligent function, service providers require router vendors to process a broad range of IP traffic flow parameters—address, port, size, time and application among others—at line rate. Superior processing performance in the core is critical for premium services backed by SLAs but also for compliance with security-related functions such as legal intercept.

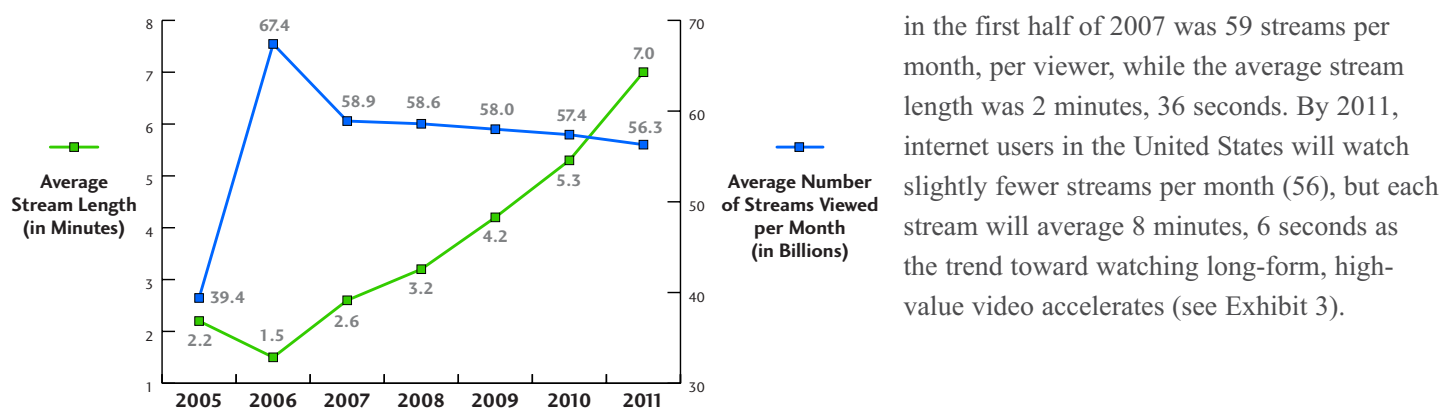
II. Drivers of the Intelligent Service Provider IP Core

According to service provider network planners, no one driver of intelligence in the core is enough reason to change the way core networks operate. However, taken together, the drivers of intelligent core networks represent a powerful and certain motivator for service providers to shift capital investment from unintelligent, inexpensive core networks to service-aware, traffic-engineered, adaptive IP cores.

One of the principal drivers of investment in any IP core network is traffic growth. On Tier 1 operator backbones, Yankee Group estimates IP traffic growth rates to remain constant at 85% to 100% per year for the next 3 to 5 years. For the purpose of this Report, we consider this driver a common, prevailing condition that is a consequence of the principal drivers we explore below.

Exhibit 3 2007 Global Internet Video Forecast

Source: Yankee Group, 2007



Demand for Premium, Personalized Broadband IP Services Accelerates

The adoption of premium, personalized broadband services has undeniable momentum, driving service providers of all types to evaluate how to use the essential components of IP core network intelligence to their advantage. A wide range of Yankee Group research establishes the growth of premium broadband services, especially those that require guaranteed experiences and contribute to exponential IP traffic growth:

- **IPTV:** Despite innumerable early challenges, acceleration in plans for regional and national distribution of IPTV broadcast channel lineups and VoD requires levels of scale, performance and intelligence best met by next-generation core routers. In addition to meeting new capacity and performance thresholds driven by IPTV traffic growth, service providers must comply with established benchmarks in video distribution, including those that pertain to minimal freezes, high availability and expansive content choices.
- **Internet video:** The rise of over-the-top internet video from providers such as YouTube is creating a massive spike in HTTP traffic in the IP core. According to the Yankee Group 2007 Internet Video Forecast, the average

number of streams viewed in the United States in the first half of 2007 was 59 streams per month, per viewer, while the average stream length was 2 minutes, 36 seconds. By 2011, internet users in the United States will watch slightly fewer streams per month (56), but each stream will average 8 minutes, 6 seconds as the trend toward watching long-form, high-value video accelerates (see Exhibit 3).

- **VoIP:** Residential broadband and PC-based VoIP is poised to undergo significant growth. Yankee Group forecasts that consumer VoIP subscribers will grow from 9.1 million in 2006 to 37.7 million by 2011 in the United States alone, with similar levels of growth in other developed markets. Although VoIP does not require the capacity levels of internet video, the growth in users, minutes and VoIP-enabled devices requires the IP core to adapt to significant growth in IP control plane traffic and QoS-sensitive, real-time sessions. In addition, as VoIP traffic traverses service provider boundaries, the core router becomes an important element in ensuring quality sessions.
- **Gaming:** Yankee Group forecasts the online gaming market to increase by roughly two-thirds between 2005 and 2011, growing to a total market opportunity in excess of \$2 billion. Although not as bandwidth intensive as over-the-top video or IPTV, gaming is sensitive to latency to the degree that long lag times can irreparably damage the user experience. As a result, online gaming providers and console vendors with online options (such as Xbox LIVE) have a significant incentive to guarantee bandwidth and QoS for their content, which routinely crosses the IP core at carrier peering points.

Internet video, VoIP and gaming share an important common thread: the long-term success of each application relies on an IP core that can respond intelligently to shifts in usage and demand. This is especially true as usage of consumer-grade peer-to-peer (P2P) and best-effort applications such as web browsing and e-mail continue to increase and contend for bandwidth required by premium applications. Of course, many other emerging premium IP applications such as music and mobile infotainment are on the rise, motivating service providers to improve Layer 3 service awareness, apply traffic engineering and network resiliency mechanisms, and enforce QoS policies.

Rapid Adoption of Managed Services and Premium Applications for Businesses

The global market for managed enterprise services is growing steadily. Managed IP VPN, managed security, software as a service (SaaS) and other offerings feature prominently in service provider plans to increase business service revenue and profitability. Because managed enterprise services are among the most profitable offerings in the service provider portfolio, network planners are building intelligence into the IP core to identify and control managed services traffic in separate, traffic-engineered, policy-supported label switched paths (LSPs).

In addition to managed services, a wide variety of new premium applications is driving service providers to evaluate the use of network intelligence in the core. A clear example is telepresence, a real-time IP-based conferencing and collaboration tool that integrates high-definition video, audio and graphics delivered to business offices and teleworker locations. Telepresence not only requires high-capacity connections among participants, but a responsive, resilient and intelligent enterprise WAN and service provider core to perform effectively. Some of these video-rich applications are best run using the techniques of Layer 3 multicast VPNs.

As managed services, telepresence and other premium business applications evolve to interconnect disparate workers attached to separate carrier networks, the IP core will play an increasingly critical role in guaranteeing user experiences and maintaining SLAs.

Steady Migration to Converged, Virtualized IP Cores

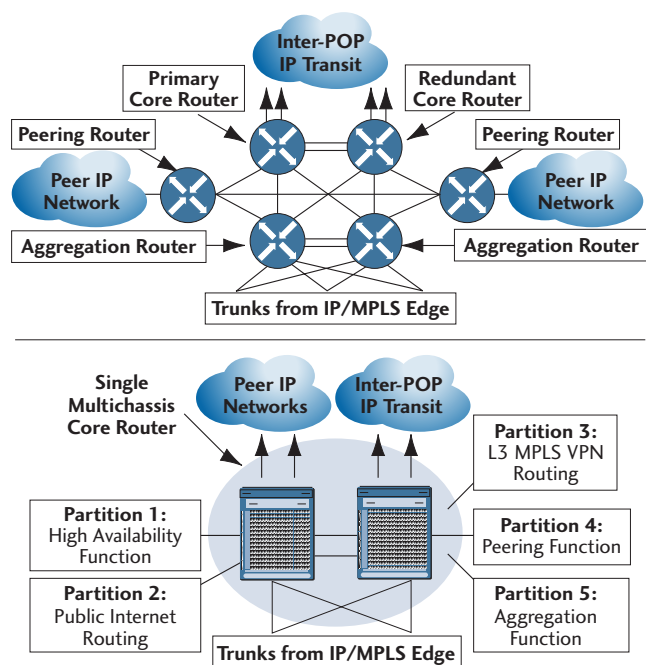
If service providers were committed to building overlay networks to meet demand for premium broadband and managed enterprise services, then the requirement of IP core intelligence would not be as strong as it is today. However, the clear trend among top-tier IP network operators is toward a converged multiservice IP/MPLS core that supports public and private services, business and residential applications, wholesale and retail offerings, and legacy and new services.

With a select number of next-generation IP core routers, service providers can virtualize routing hardware and software resources for these services and other important network functions, such as peering and route reflection, securely on a single system. This capability allows service providers to consolidate POP architecture, which reduces capital and operating costs associated with managing separate systems for particular functions (see Exhibit 4).

Exhibit 4

Virtualization in the Core Enables POP Consolidation

Source: Yankee Group, 2007



Moreover, virtualization of router resources enables service providers to create secure partitions for administrative and control plane functions. The core can be further hardened by integrating Layer 3 routing with automatic cleansing of infected traffic in the network. In addition, dynamic real-time policing of control plane traffic wards off threats directly targeted to network resources. With MPLS, the logical separation of VPNs from the global routing tables help hide the core from outside, boosting security. All of these techniques help fortify the converged IP/MPLS core against a growing number of attacks.

In parallel with the migration to converged IP/MPLS networks, service providers are collapsing silos of service control, aiming to create an environment for introducing new services and applications quickly, cost-effectively and with minimal risk. The business goal of the next-generation service control layer is to maximize the revenue potential of new services and applications vis-à-vis fundamentally unpredictable service demand cycles. Therefore, as the next-generation service control layer emerges, service providers must build a core IP network that is optimized for the dynamic, unpredictable nature of the demand for their services.

What follows this condition is the imperative to embrace the essential components of intelligent IP core networks. For example, to address unpredictable patterns of service demand and user behavior on a converged network, network operators require enforcement of service-aware QoS policies to ensure users are guaranteed the experience they pay for. Because greater volumes of premium services traverse core networks and boundaries, advanced traffic engineering is necessary to bolster network resiliency and improve bandwidth utilization. According to service provider network planners, these and other benefits of building intelligent, converged IP cores enable service providers to maximize revenue from new offerings, helping to justify the business case for next-generation core router deployment.

Impact of Unprecedented Thresholds of Scale

The exploding growth in IP network traffic must be addressed by capacity upgrades in the core. Integration with the optical transport layer through the use of 10 Gbps and 40 Gbps IP over DWDM extended reach interfaces provides one means for increasing core router system longevity. Another way is to support 100 Gbps, which is now on the standards path. In addition to these interfaces, service providers also require intelligent, distributed processing of data and control plane traffic across multiple chassis, reaching new scale thresholds and protecting core router investment. With this capability, in conjunction with the flexible distribution of router resources afforded by secure virtualization, service providers can be assured of meeting exponential increases in IP network load.

Although helpful in addressing capacity bottlenecks, the availability of higher speed interfaces on IP core routers (40 Gbps, or even 100 Gbps when ready) would not change the fact that at any point in time core bandwidth can become a scarce resource. Bandwidth consumption rates of new services and applications are often unpredictable, as evidenced by the soaring utilization rates of P2P applications. When P2P traffic became a serious problem for service providers 3 years ago, the solution was not confined to adding 10 Gbps interfaces and provisioning more fiber. Instead, service providers combined capacity upgrades with network intelligence—for P2P, intelligence came in the form of deep packet inspection devices.

Today, with the migration toward converged IP networks gaining momentum, service providers must address P2P amid an incredibly diverse mix of new, bandwidth-intensive applications, in particular internet video and IPTV. Similar to the response to the threat of P2P, the solution to exponential traffic growth in the IP core must combine capacity upgrades with network intelligence. In fact, the imperative to engineer intelligence into the IP core is much greater today because of the impact of convergence and the

proliferation of IP services for businesses and consumers. Finally, service providers are attracted to adding intelligence to the IP core because the addition of incremental bandwidth in response to service demand fluctuations is economically infeasible and operationally cumbersome.

III. Alternative Approaches to Building the Intelligent IP Core

During the last 2 to 3 years, several alternative technology solutions have emerged that claim to be viable options for building the next-generation service provider core. To date, most of these options, including Provider Backbone Bridging–Traffic Engineered (PBB-TE), Transport MPLS (T-MPLS) and other ways of implementing Layer 2 tunnels, have been confined to limited deployments in metro networks as vendors and service providers work toward standardizing these and other alternatives.

The viability of alternatives to building the intelligent IP core depends on its potential to displace IP/MPLS, which remains the de facto technological foundation for converged service provider IP networks. Although the role of MPLS in the largest, most sophisticated IP backbones is undisputed, vendors with an agenda to displace MPLS remain committed to seeding the market for alternative solutions.

Despite the effort from these vendors, during the next 5 years Yankee Group expects unwavering service provider commitment to MPLS, especially in the core where it is solidified in many high-profile next-generation network plans. Several key attributes underscore the role of MPLS as the ideal protocol for enabling intelligent IP core networks:

- **Maturity:** With more than 10 years of standardization, MPLS is among the more mature and least risky protocols upon which to build the IP core. MPLS has a scalable, resilient control plane based on standards that have iterated extensively since its inception.

- **Advanced traffic engineering:** One of its hallmark features, MPLS traffic engineering provides service providers with the network resiliency, automated provisioning and traffic flow controls necessary to make IP core networks more responsive, reliable and intelligent.
- **Multiservice ready:** MPLS is an ideal core transport mechanism for unicast and multicast traffic, based on its ability to scale in and support point-to-point and multipoint network topologies. Accordingly, MPLS is best optimized in converged, multiservice environments.

Among Layer 3 alternatives to IP/MPLS, the only viable option for building an IP core is the use of native IP with Border Gateway Protocol (BGP).

The remaining alternatives attempt to leverage the inherent scale and cost-effectiveness of optical transport or Carrier Ethernet to justify deployment in the core. However, each of the alternatives referenced next lack either the standardization or the intelligence and flexibility required for next-generation core deployment. In addition, the available vendor products supporting these alternatives are, in most cases, first-generation solutions that require an extensive cycle of operating system (OS) and network management system (NMS) development to compete against established core products based on MPLS.

Less Intelligent Options for the Service Provider Core

An IEEE standard, PBB-TE first generated interest as a solution for metro-area point-to-point transport, but its proponents now tout it as an alternative to MPLS for core network transport. However, several attributes make PBB-TE a poor choice for core transport. Most importantly, PBB-TE essentially removes provisioning and traffic engineering intelligence from the network and places it centrally in the NMS layer. Although the removal of intelligence from the network may be suitable for provisioning point-to-point connections in the metro, it is not ideal for the multiservice core, which requires a provisioning model that adapts dynamically to changes in network topology, bandwidth demand and user behavior. Alternatives based on centralized provisioning are prone to scalability limitations imposed by the n-squared problem. As a result, they are more likely to overwhelm operations quickly as links, nodes and IP traffic increase.

The other fundamental drawback of PBB-TE in the core is its lack of readiness from a standards perspective. Yankee Group believes PBB-TE is 12 to 18 months away from being mature enough for metro-area deployments. In addition, some of the standards PBB-TE employs for critical functions such as automatic path-level recovery and fault management are not fully standardized, which is a particularly relevant problem for the core because of the significant opportunity cost associated with network outages and unpredictable performance. As a result, PBB-TE fails as a viable alternative in the core despite its attractiveness in metro network environments.

A derivative of MPLS, T-MPLS is an ITU-developed standard designed specifically for simple, cost-effective connection-oriented packet transport networks provisioned from a centralized NMS. Although T-MPLS is primarily positioned for Carrier Ethernet-based transport in metro networks, vendor proponents have started to focus on potential benefits in the core. However, similar to PBB-TE, T-MPLS lacks Layer 3 service awareness and support for multipoint network topologies, making it less than ideal for the core.

Although further along in the standardization process than PBB-TE, T-MPLS still requires further standardization of its operations, administration and maintenance (OAM) functions, line and path protection mechanisms, and interoperability with MPLS. In addition, although the T-MPLS standard allows for mapping multiple services (ATM, frame relay, Ethernet), the first generation of T-MPLS solutions are optimized for Ethernet and are therefore not ready for many core deployments.

Apart from PBB-TE and T-MPLS, many vendors position existing Layer 1 and Layer 2 technologies as viable core network design frameworks. Examples include multiple uses of wavelengths and stitched Ethernet VLANs interconnecting IP edge routers in a full or partial mesh topology. Similar to PBB-TE and T-MPLS, these options represent low-cost alternatives to IP/MPLS but lack the bandwidth efficiency and flexible, dynamic provisioning the next-generation core requires.

Coming Full Circle

The key attributes of less intelligent alternatives recall a similar effort more than 10 years ago to position ATM as the de facto protocol for core backbone networks. Champions of the ATM effort also emphasized a less intelligent core built on static provisioning of point-to-point connections that ultimately resulted in n-squared scalability problems and a level of operational complexity that exceeded expectations. Consequently, the industry evolved. With MPLS, service providers embraced a true multiprotocol technology that emphasized service awareness, dynamic provisioning and intelligent traffic engineering for an IP core that was bound to converge and expand.

IV. Conclusions

As service providers migrate toward converged, multiservice IP core networks, network planners are confronted with an important choice. One option is to choose the path of least resistance, which is to design the core network for inexpensive, scalable, simple IP transport. The alternative is to infuse intelligence in the IP core. Based on extensive primary research on this topic, Yankee Group believes a great majority of top-tier and competitive service providers are pursuing this path. Accompanied by exponential growth in IP traffic volume, the drivers of this trend are clear:

- Acceleration in the demand for premium, personalized broadband IP services, such as IPTV, internet video, VoIP and gaming, which require all of the essential components of IP core intelligence to guarantee user experiences.
- Strong demand for high-value, profitable managed services and premium business applications, such as telepresence, which requires an intelligent IP core to enforce QoS, security and other service-level policies so that SLAs are met.
- Momentum toward converged, multiservice IP networks that require more IP core intelligence for controlling and maximizing the revenue potential of a fundamentally unpredictable range of services and applications crossing IP core boundaries.

The influence of these drivers on next-generation core router demand and product requirements is evident. According to service providers, new thresholds of IP core scale must be reached by distributing router resources and processing power intelligently across multiple chassis, increasing system longevity. Integration with the optical transport layer through IP over DWDM interfaces helps consolidate POP architecture. At the same time, these routers have to maintain line-rate enforcement of QoS, enable a rich MPLS operations environment and support secure separation of forwarding plane, control plane and administrative functions across the system.

As a result, intelligence in the IP core affords service providers the following capabilities:

- Distinguish among Layer 3 services and applications
- Employ advanced traffic engineering to a diverse mix of service
- Leverage adaptive intelligent functions in a virtualized environment

To build the intelligent IP core, several alternative solutions promise to challenge IP/MPLS today. However, IP/MPLS affords service providers the standards maturity, proven control plane, advanced traffic engineering, and true multiservice support required for an intelligent IP core. Alternatives based on emerging Carrier Ethernet standards or existing Layer 1 or Layer 2 technologies lack readiness in terms of standardization, multiservice capability and maturity of available product solutions to offer a legitimate alternative to MPLS in the core. As a result, Yankee Group expects commitment to MPLS as the foundation of the intelligent IP core to remain steadfast for the next 5 years.

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