White Paper

# THE CONVERGED SUPERCORE™

## Using Disruptive Innovation to Solve the Economics of Core Packet Transport Networks

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# Executive Summary

Today’s connected culture has created an “anywhere, anytime, any service” connection model driven by the proliferation of mobile users accessing video and data intensive services from wherever they are, using whatever device they have at hand. The result is a steady increase in traffic that is characterized by unpredictable volume, characteristics, and patterns. To avoid breaking the economics of core network provisioning, service providers must extract every bit of cost out of their core networks without compromising services or reducing quality of experience for their end users. Success hinges on finding an economical, more scalable, and more efficient model for building and maintaining core transport networks.

This can only be achieved with a network (and product) architecture that cuts through the structural costs of the core network. What is needed is a radically different approach, starting with the ASICs that power the platform. Consistent with Juniper’s track record of innovation, we have created a Converged Supercore architecture based on the Juniper Networks® Junos® Express chipset—our fastest and most scalable silicon ever. Just as the Trio chipset was created to solve the challenges of the Universal Edge—services management, subscriber management, and bandwidth management at scale, Junos Express is custom-built to address the challenges in the core of the network—speed, scale, and cost.

Based on the Junos Express chipset, Juniper Networks PTX Series Packet Transport Router is the first device to blend industry-leading packet routing with best-in-class optical transport, making the best use of both technologies. It also marks the first time that a single OS—Juniper Networks Junos operating system—manages both the optical layer and the packet layer. The resulting control and management planes allow service providers to finally minimize the uncertainty and cost of core network planning. Taking advantage of a rich Juniper professional services portfolio that includes traffic analysis, network planning, design, and total cost of ownership analysis, we can demonstrate that this architecture saves up to 65% in network CapEx compared to traditional network architectures [v].

The Converged Supercore and PTX Series are solutions inspired by the real challenges faced by service providers today. For the first time, services can dictate network connectivity and bandwidth, not the other way around.

# Introduction

## Massive Data Growth, New Applications, Unpredictability, and Challenged Business Models

As modern society is increasingly dependent on connectivity and mobility, it is not a surprise that traffic on global networks continues to grow at a near exponential rate. While keeping pace with this bandwidth explosion has been a major, though manageable challenge for every service provider, today’s traffic unpredictability has exacerbated the problem even more. Several industry forces are combining to create a potentially lethal mix of ever growing bandwidth and increased unpredictability:

- Global Internet video traffic surpassed global peer-to-peer (P2P) traffic in 2010, and by 2012 Internet video will account for over 50% of consumer Internet traffic [i]. Its growth shows no signs of abating.
- The consolidation of data centers and the advent of cloud networking allow content and service providers to “migrate” content and compute resources from location to location, based on where they need to be consumed. This creates substantial shifts in traffic patterns as sources and sinks of information can change instantaneously.
- Increased mobility of the content users presents additional challenges. Until recently, there was a clear relationship between the user and the user’s location when accessing the network, as everybody was physically “tethered” to the network. Today’s radio access networks are increasingly capable of supporting high bandwidth applications, including streaming video, and a plethora of mobile devices allows people to consume content no matter where they are. As a result, consumers have “detached themselves” from the network; they are mobile and they can do things on the go that they used to only be able to do sitting in front of their “attached” computers.

The net effect of mobility and cloud computing is that aggregation networks have become less efficient. Aggregation networks are static and are built based on knowing where the users are, where the content is stored, and where the applications are running. All of this is now fluid and dynamic, and hence the core transport network needs to assume this role and provide flexible ad hoc aggregation.

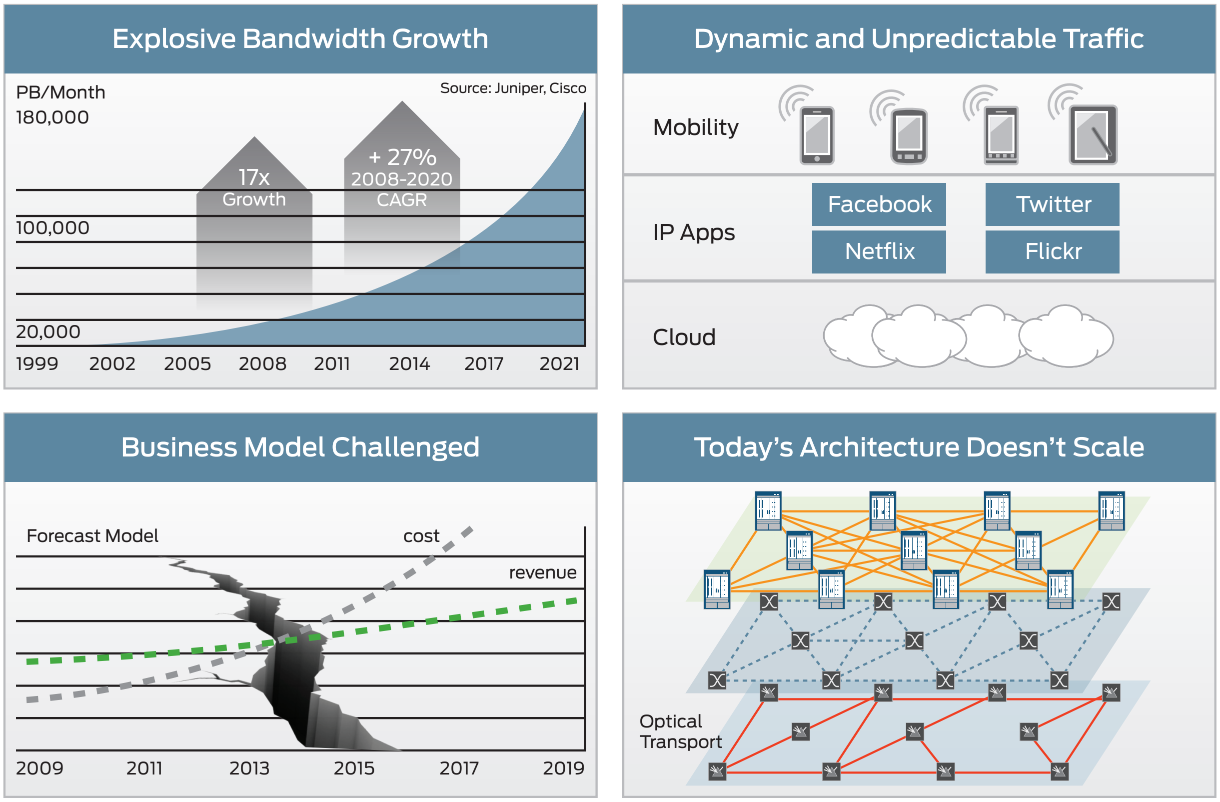


Figure 1: The challenges of modern transport networks include massive data growth, new applications, unpredictable traffic, challenged business models, and a network architecture that no longer scales economically.

It is also apparent that the service provider business model is being challenged, primarily because of the increasing disintermediation, forcing network service providers to carry an ever increasing amount of traffic OTT or "over the top." They have to carry traffic for which they extract no additional income, as all the service revenue goes to the owner of the content. Service provider revenue is restricted to network access sold as flat rate bandwidth plans. For example, Netflix accounts for 24.71% of Internet traffic, topping second place BitTorrent's 17.23%, and third place HTTP's 17.8%. YouTube is the number four driver of traffic with 9.85%, iTunes is in the number six position with 3.01%, and Facebook drives 1.86% of Internet traffic [ii].

As a result, the core of the network has become a cost center, and the goal becomes to relentlessly pursue a strategy and architecture that takes every single bit of cost out of that network, yet making sure that it remains flexible enough to accommodate all that varying traffic while meeting or exceeding the previously committed service level agreements (SLA).

## Time for a Fresh Look

As we look at the way the current core network infrastructure is built, we find that the architecture hasn't really changed over the last 10 to 15 years. Over time, we have built up various network layers; we have an optical transmission network on which we layer circuits; and on top of this circuit network, we have implemented the packet network. These optical transport and circuit-switched networks were originally designed for one purpose —to carry circuit-based services, mainly voice and leased lines. With the advent of the Internet and IP-based services, however, these networks have been increasingly challenged to do something entirely different. Still, we didn't change the architecture, we just stretched it. We threw more and bigger boxes at the network, we increased the wavelength speeds, we added more wavelengths, and now we are very close to the breaking point, both from an economic and an operational perspective.

## The Industry Is Proposing Several Approaches

The industry has been debating various network architectural approaches aimed at solving this set of challenges.

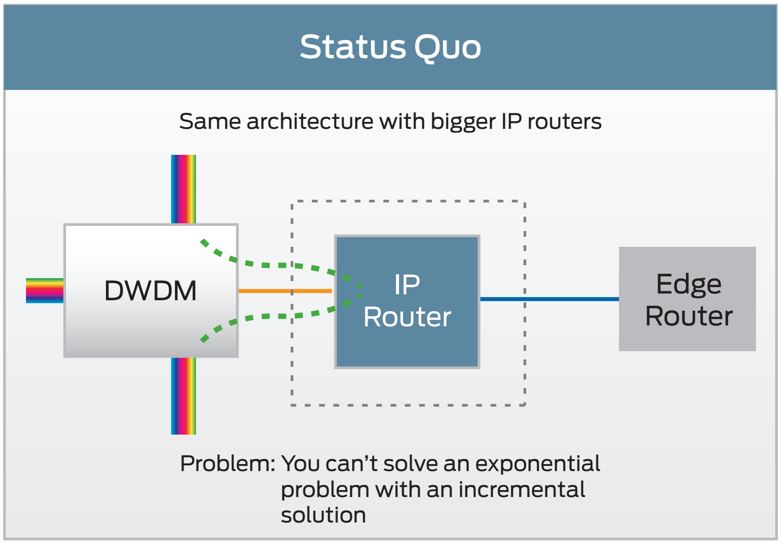


Figure 2a: Traditional L3 IP core network.

The first option is the one we discussed above. Maintain the current architecture —just make everything bigger and deploy more of it. While this may allow keeping pace with growing traffic requirements for a while, it comes with a very high price tag and ultimately can't address the exponential traffic growth curve. Not surprisingly, this is the option of choice for the legacy vendors who favor more of the same to protect their market share, despite the fact that the fundamentals are broken. As one CTO put it, "We need to fundamentally rethink how we're carrying traffic. We have to rethink how we interoperate, how networks are constructed, how routing is done [iii]. In some cases, vendors introduce variations of existing products, or line cards, or both, using software licensing schemes or slight hardware modifications without fundamentally changing the role and capabilities of the original platform. These Band-Aid solutions can never meet the economies and scale needed to address the exponential bandwidth growth and unpredictable traffic patterns.

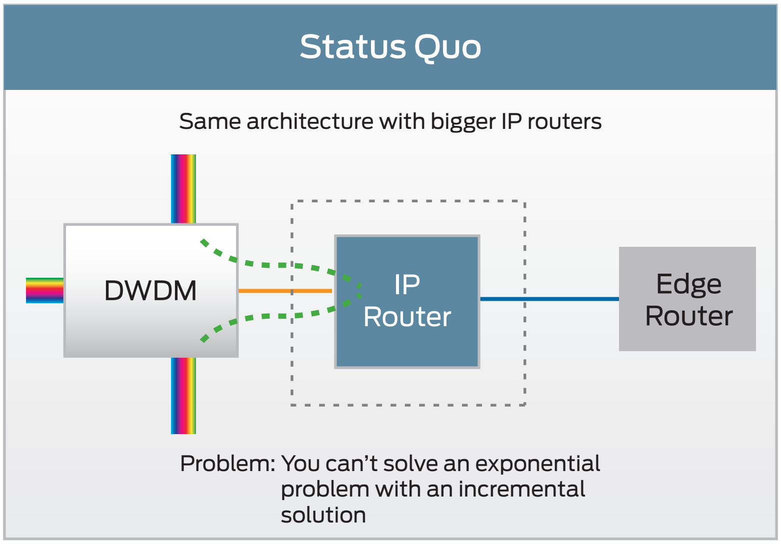


Figure 2b: Circuit-switched core network ("hollow core").

Others advocate "hollow cores", or router free circuit-switched networks surrounded by IP routers, similar to the IP-over-ATM networks we built in the 1990s. This architecture has three major drawbacks. First, you have to provision for peak bandwidth, which is expensive given that peak-to-average ratios of the predominantly packet-based services can be as high as 14-to-1 [iv]. Secondly, the edge network becomes more complex and expensive, since the edge devices need to support channelized Optical Transport Network (OTN) interfaces or fine-grained queuing and shaping ports for VLAN-to-OTN mapping. Thirdly, the protection and restoration mechanisms of the OTN switched network throw even more bandwidth at the problem and, in the worst case, double the necessary equipment investment.

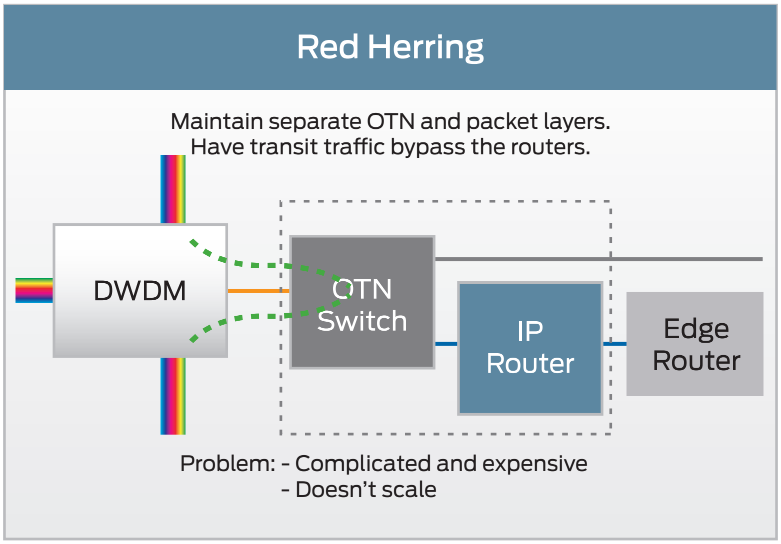


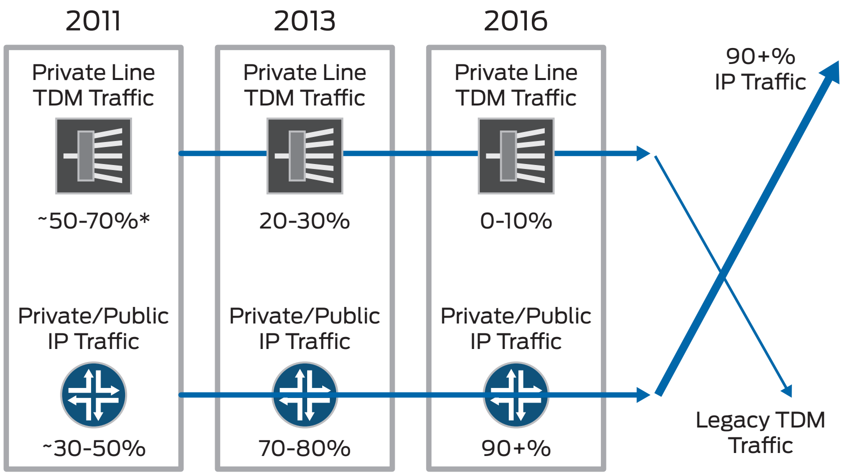
Figure 2c: Router bypass (IP off-loading).

The third alternative is to combine OTN and IP/MPLS devices and to pursue an aggressive bypass or offloading of the IP/MPLS ports. IP offloading boils down to avoiding that IP flows traverse (expensive) IP nodes whenever the cost is not justified. A typical example would be when the IP flow approaches the size of the wavelength it is carried on. It is easy to see that this only works in highly static traffic conditions where the add/drop and transit traffic remains fairly constant in every node. However, even in those scenarios the network will likely be more expensive than a plain IP/MPLS network since many ports will be duplicated on both the OTN and IP/MPLS equipment [v].

## The Converged Supercore

In line with the innovations that Juniper has historically brought to the market, we took a step back, analyzed the problem, started with a clean sheet of paper, and created the concept of the Converged Supercore. The Converged Supercore combines and simplifies different elements from Open Systems Interconnection (OSI) Layers 0, 1, 2, and 3 into a unified and holistic multilayer architecture that reduces complexity, increases the dynamics of the network, improves resource utilization, increases scalability in network capacity and topology, and dramatically reduces the cost of core transport networks.

Juniper's Converged Supercore merges the packet layer with the optical transport layer in a new class of equipment—the PTX Series Packet Transport Router, is optimized for high speed Layer 2 MPLS switching, more commonly known as LSR or label switch router. This makes the PTX Series fundamentally different from other Juniper core network products, as it is optimized for core needs. PTX Series devices are packet transport routers that combine the efficiency of packet technology with the simplicity of switching and the high capacity of optical transport at cost points that are similar to circuit switching. With transport-level performance, the PTX Series can switch LSPs in the same manner as traditional circuits like SONET, SDH, or OTN. Looking at it differently, we can think of the PTX Series as the circuit switch of the future. After all, in a world that becomes increasingly IP and packet-based, LSPs are the circuits of the future. According to a recent study by ACG research [vi], the ratio of time-division multiplexing (TDM) to IP traffic will dramatically change over the next five years. Whereas today, TDM-encapsulated traffic still represents 50-70% of all traffic carried on the core transport networks, this will shrink to 10% by 2016. IP traffic is trending the opposite way, growing from 30-50% to more than 90% in the same time period. In fact, estimates show that, even today, the dominant traffic within TDM circuits is packet-based.



*“Private Line TDM traffic is not increasing; there are no new customers, only some increasing bandwidth with existing customers.”*

*Traffic Precentages from an ACG Research Survey

Figure 3: It’s all about the traffic (Source: ACG Research – July 2011).

As the building block for the Converged Supercore, the PTX Series is purpose-built to optimize the transport of data while maintaining IP awareness. Packet buffering, routing tables, and algorithms are optimized and combined with optical transmission to create an efficient packet transport network with unprecedented scale, simplicity, and operational efficiency. The implementation of the Converged Supercore in the PTX Series platform required disruptive innovation in four areas —silicon, optics, systems, and software.

### Silicon: Junos Express

Juniper invested $40 million to build a chipset optimized for transport. The result is speed and scale never seen before—not Terabits, but Petabits. The Junos Express chipset can scale to 3.8 Pbps to support the massive scale and forwarding capacity that today’s and future core networks demand. This purpose-built silicon is based on Juniper’s intellectual property and includes:

- Optimized MPLS transport logic
- Unique transport algorithms
- Compressed routing tables
- Full delay bandwidth buffer to manage network congestion
- Virtual output queuing for scheduling and quality-of-service (QoS) differentiation

Quite simply, Junos Express is the industry’s fastest and most scalable forwarding silicon. It is also the industry’s first silicon custom built for transport.

### Optics

The Converged Supercore architecture takes advantage of the tremendous progress in miniaturization [vii, viii, ix] and commoditization [x] of dense wavelength-division multiplexing (DWDM) and multilayer technology. This allows the integration of ultra long-haul 100 Gbps transponders directly into the PTX Series routers without sacrificing interface density—another industry first.

## System

The PTX Series is the first system ever to combine native MPLS switching and optical transport to create multilayer optimized networks that achieve significant CapEx and OpEx savings.

The PTX Series Converged Supercore router is a purpose-built system incorporating the best of available technologies. Leveraging our leadership in MPLS, we combine the efficiency of packet switching with integrated optics for high-speed, long distance optical transport. Powered by Junos Express, the PTX Series is a supercore node that delivers:

- 4x the speed of any competitor core platform
- 5x the packet processing capability of any competitor core platform
- 10x the system scale of any competitor core platform
- Industry-leading density at 10GE, 40GE, and 100GE, with integrated short- and long-haul optics
- Yet, the PTX Series consumes 69% less power than any competitor core platform

What does this mean for your bottom line? The Converged Supercore delivers 40-65% CapEx savings compared to a circuit-switched network, and 35% savings compared to a pure IP routing solution [v].

## Software

With Juniper's Converged Supercore, you no longer have a three layered network (optical, circuit, packet) with three operating systems and three network management platforms. You have Junos OS, a single operating system that runs both the Converged Supercore and the services edge and a single state-of-the-art network management system to manage the entire transport network. This seamless integration of the IP/MPLS and optical control and management planes allows coordinated design, modeling, planning, simulation, provisioning, management, and restoration of multiservice networks built using the PTX Series.

The Converged Supercore architecture is designed to interoperate with existing networks and equipment (whether they are built by Juniper or not) to create a high-speed packet transport infrastructure interconnecting the service delivery points of the network where customers connect and revenue is generated. Existing equipment that is Layer 3 capable can be redeployed to the edge to deliver services. This service edge network then uses the Converged Supercore as a highway system to move massive amounts of data at the lowest possible cost.

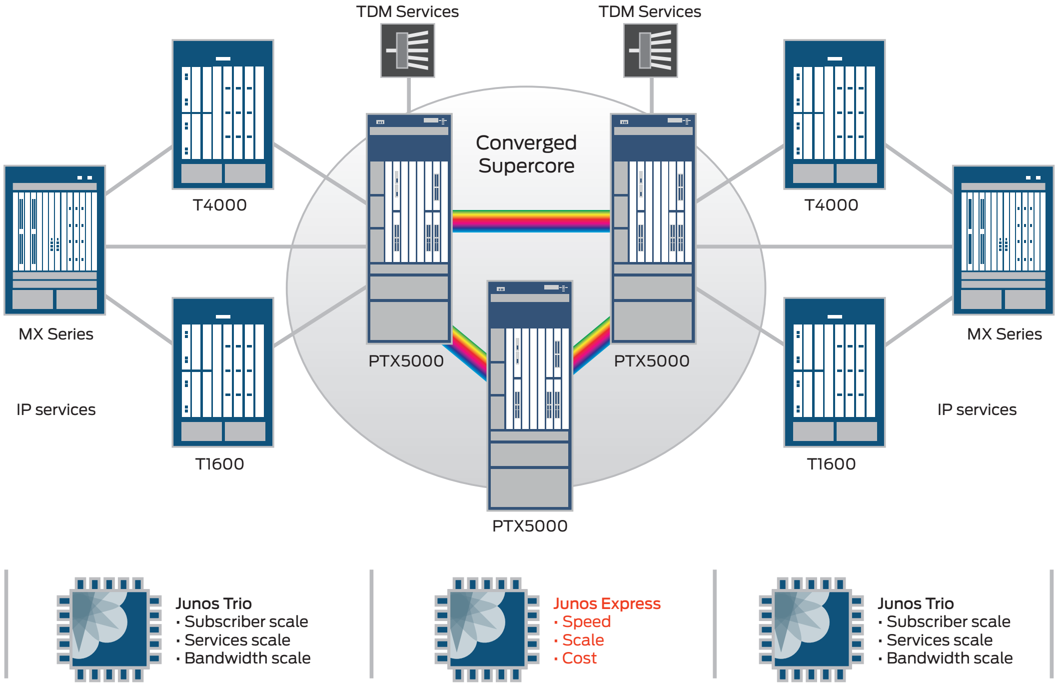


Figure 4: Juniper Networks Converged Supercore™ architecture combines a service-rich Universal Edge with cost-efficient core transport.

There is a clear partitioning of functionality based on the capabilities of the network elements and the ASIC technology they use. At the edge of the network, service providers can focus on subscriber management, service delivery management, and bandwidth management, whereas at the core of the network, the focus can be on higher scale, higher speed, and lower cost. The Junos Trio (for edge) and Junos Express (for core) chipsets have been designed specifically with these capabilities in mind.

## Making the Right Choice

As mentioned earlier, network traffic continues to grow at a rapid pace. The bulk of this growth comes from low revenue Internet services. Naturally, this raises interest in lowering the costs of building and maintaining the core transport network. This is where some make the case for OTN switching as a low cost alternative to IP/MPLS core networks. Historically, the choice between a packet-based (IP/MPLS) network and one based on circuit technology (OTN) was heavily influenced by the silicon cost, but if a router is MPLS-optimized, there is no intrinsic reason why the cost of the packet-forwarding component cannot be approximately that of circuit-switched devices, as the amount of overhead processing is comparable. Thus, cost optimization of modern core transport is driven by the forwarding plane, and more specifically the nature of the traffic that needs to be carried.

One of the most important challenges in transport network capacity provisioning is uncertainty in the traffic demand (both volume and flow patterns), which introduces the trade-off between using a less expensive circuit-switching network (at the risk of having to drop demands due to insufficient capacity) and a more conservative and robust network that easily manages statistical variations, albeit at a potentially higher cost. To compare and contrast the costs of OTN versus MPLS, we modeled the various network architectures described earlier in this document [v]. The results show that the optimal network design depends on different traffic parameters, things such as ratio of peak to average flow demands, number of simultaneous peak demands, ratio of MPLS to OTN port costs, and size of core transport interconnects. After analyzing a vast array of traffic and topology combinations, our study concludes that an MPLS-switched core network is the most cost and performance optimized architecture in nearly all cases.

This modeling also shows savings ranging from 40-65% depending on traffic characteristics such as flow size, peak-to-average ratios, and simultaneous traffic peak occurrences. These factors impact the decision about whether to keep traffic in the MPLS domain or move it to the OTN or optical domain. Belotti et al. [v] have highlighted the importance of statistical multiplexing on multilayer planning, and the importance of considering the different bandwidth provisioning rules applied to circuit and packet networks.

The core network infrastructure must be flexible enough to accommodate changes in traffic characteristics. This will be a critical capability as traffic patterns in the core of the network change due to a number of factors—new applications, data center consolidation, cloud computing, and of course the rise of mobile and video content. Detailed modeling demonstrates that the core of the network needs to be packet-based to be most efficient. Aggregation and multiplexing need to happen at the packet level. Integration of the packet layer and optical transport layer will improve the economics of the core network, both CapEx and OpEx.

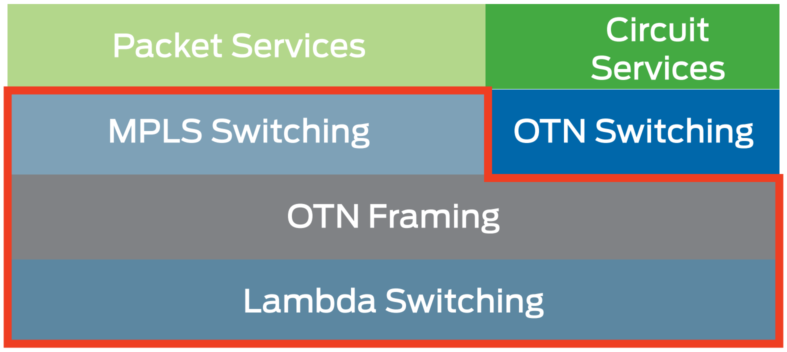


Figure 5: Ideal transport network architecture and network layers supported by PTX Series (red).

Although intrinsically more expensive (at the network level) and based on an older paradigm, OTN is still required as the Layer 1 DWDM transport mechanism that provides framing, error correction, and operations and management that allows an efficient use of the underlying optical wavelength network (Figure 5).

Real-world network design problems are subject to uncertainty in several contexts. These include cost, capacity, and reliability of link and node equipment, and most importantly, the traffic matrix. Although the set of source-destination pairs may be known, the volume of each demand is seldom known with accuracy. This happens for a number of reasons, including inaccurate measurements, dynamic behavior of traffic, and network failures inducing a shift in the demand, to name only a few. The sources of traffic uncertainty need to be identified and accurately described; for instance, it helps to know whether there are lower/upper bounds on the volume of a demand from a source (s) to a destination (d) of the network, bounds on the total traffic volume, or, again, statistical information on the traffic matrix.

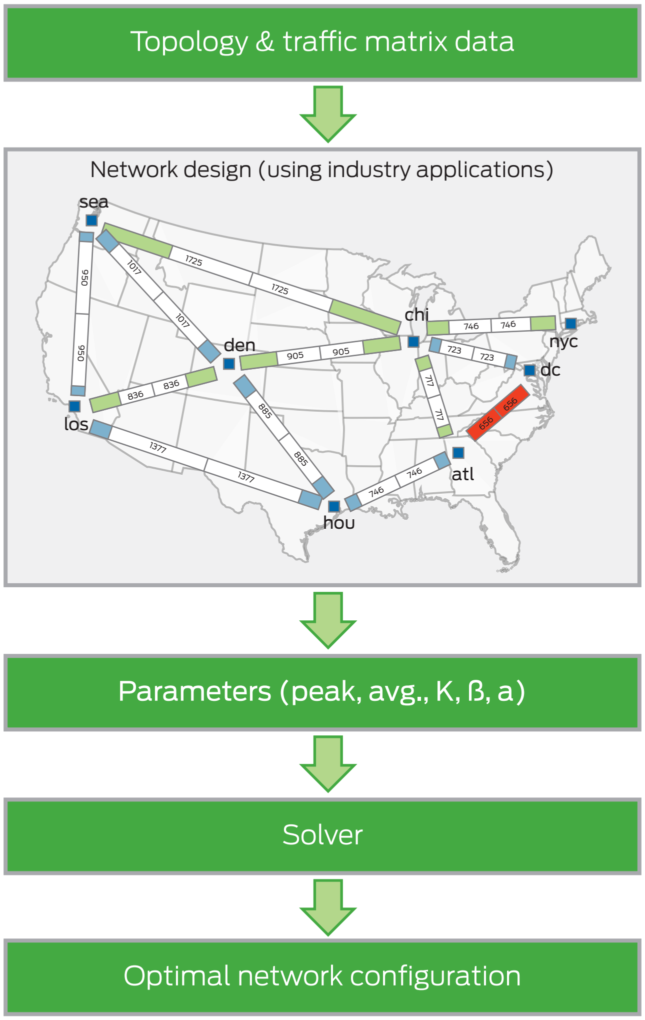


Figure 6: Network modeling service process flow.

From a modeling standpoint, the more accurate the approximate traffic matrix, the better a network that accommodates a loose uncertainty set can be overly conservative, hence very expensive.

To help our customers with the migration to the Converged Supercore architecture, we created a professional service aimed at assisting them in analyzing their core transport network traffic and building a representative traffic matrix. Based on this matrix, we create a transport network topology using off-the-shelf industry design tools. Then we compare this network against the alternatives we discussed earlier. This process is illustrated in Figure 6. As the network cost modeling tool is very fast —typically achieving 99% optimality in 20 minutes or less, we can easily run "what-if" scenarios to verify the impact of changing traffic conditions on the architecture and associated cost. To date, we have done this detailed analysis for 10 of the top 20 global service providers with excellent feedback, as it allowed these operators to not only understand how their traffic patterns are affecting the network architectural design, but also compare the optimal network architecture to alternatives and map out migration strategies towards implementing a Converged Supercore.

## Implementing the Converged Supercore

Once we have our optimal network configuration, it is time to determine the best strategy to evolve to the Converged Supercore. While every network is different, Figures 7 and 8 illustrate two possible insertion scenarios.

The first application for the PTX Series is as a Supercore MPLS router to create a highly scalable, very high-speed, low cost transport network (inner core). The IP routers that formed the original core network can now be repurposed as service delivery devices (outer core). When equipped with integrated long-haul optics, this scenario has the additional benefit of simplifying network operations by collapsing the MPLS and OTN transport layer into a single management plane. Today's core IP infrastructure consists of several networks built on top of each other with no apparent coordination between the various overlays. Every link in an upper layer is realized by one or more paths in the next lower layer. For example, an IP link between two Internet routers may be realized by one or more light paths in the underlying optical transport network. As these networks are typically managed by different groups within the service provider organization, there is little coordination between the layers, and we end up with multiple networks and multiple management systems.

The Converged Supercore simplifies this, as it provides the functionality of multiple layers in a single platform, supported by a single operating system (Junos OS) and a multilayer network management system (NMS).

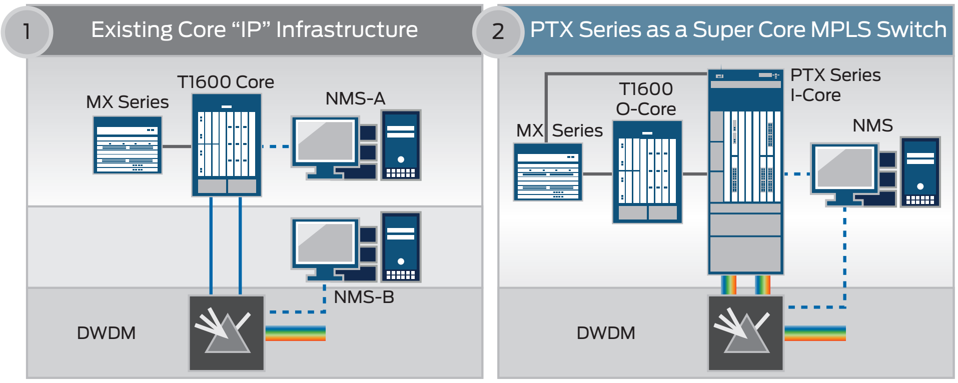


Figure 7: Using the PTX Series as a supercore MPLS Router.

In the second scenario, we add an aggregation function to simplify the network even more by collapsing both aggregation and core router functions into the supercore and redeploying the Juniper Networks T Series in the edge network. As both the T1600 and T4000 Core Router support Packet Forwarding Engines (PFEs) based on the Trio chipset, they can easily be repurposed as service delivery platforms similar to Juniper Networks MX Series 3D Universal Edge Routers, thus protecting the investments made in the platform.

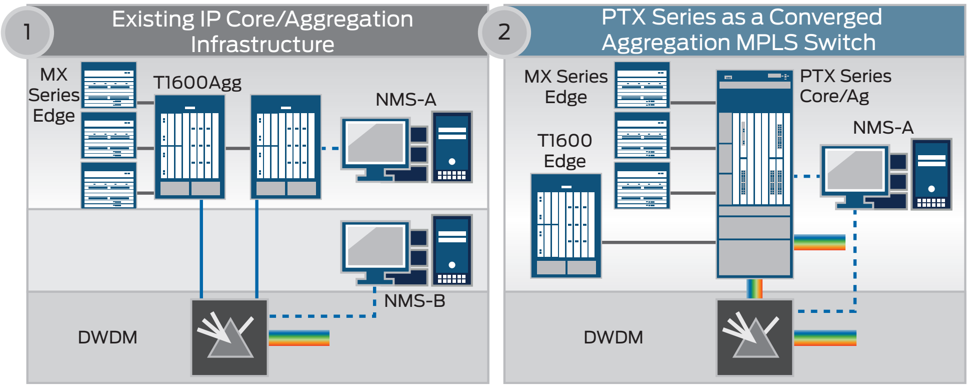


Figure 8: Using the PTX Series as a converged aggregation/supercore MPLS Router.

In both cases, the net result is a simplified architecture and simplified operations. We went from a multilayer network with multiple management systems, separate provisioning and protection rules, and most likely multiple operations and engineering groups, to a network that unifies the packet and the optical transport layer. By converging network management into a single plane, there is an opportunity to harmonize the engineering and operations groups as well, resulting in simplification not only in the network, but also from an organizational perspective. Note, however, that the service provider maintains the option to keep the operations of the core and aggregation networks separate by virtualizing Junos OS for each function. The Converged Supercore introduces additional hierarchy in the network by creating a very high-speed infrastructure that transports information at the lowest possible cost without impacting the service delivery capability at the edge of the network. This hierarchical structure is a natural evolution of the existing IP/MPLS network architecture, since in many cases service providers have deployed IP routers in an LSR role. In contrast, introducing an OTN switching layer complicates the network with a new layer of hardware and software.

Furthermore, the quality of service of the network is maintained if not improved. When traffic profiles and patterns change, the network doesn't drop packets, it flexibly adapts. In addition, a service provider has the opportunity to migrate some of the existing services to the new core. Services like Gigabit Ethernet which today are typically provisioned over a circuit type of connection, can now be provisioned over a packet connection with a direct positive on the cost and hence the pricing of the service. As a result, end users benefit because they can buy a lower cost service, while service providers benefit because the packet infrastructure allows them to carry more of those services over the same amount of bandwidth with the same quality of service, thus improving the bottom line. As an additional benefit, the performance of this Converged Supercore becomes more predictable due to the applied transport mechanisms, while the protection mechanisms are load independent and the latency is reduced.

## Conclusion

Core transport networks are at a crossroads. Service providers are under intense pressure to grow their core networks while reducing costs. Juniper's Converged Supercore introduces a new network model that enables service providers to take uncertainty and cost out of core network planning and provisioning with an architecture that makes the best use of available technology—creating a packet transport system that employs MPLS for routing and OTN for transport.

With Juniper Networks PTX Series Packet Transport Routers, service providers can operate their core networks more efficiently as they no longer have to "throw bandwidth at the problem" (in the form of "nailed-up" circuits), but rather grow their networks with well planned phased investments, while guaranteeing that resources are used with the highest efficiency.

With this knowledge and strategy in hand, service providers can let the services guide the architecture and the evolution of the transport layer. This is a welcome new capability in the hands of service provider executives, who were forced to take a more bottom-up or network-driven approach in the past—an approach they can no longer afford in today's richly connected and content hungry global culture.

The PTX Series is a solution inspired by the real challenges faced by service providers today. Now services can dictate network connectivity and bandwidth, not the other way around.

It is time to tackle demand once and for all. It is time for a new network.

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## 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. The company serves customers and partners worldwide. Additional information can be found at **www.juniper.net**.

**Corporate and Sales Headquarters**
Juniper Networks, Inc.
1194 North Mathilda Avenue
Sunnyvale, CA 94089 USA
Phone: 888.JUNIPER (888.586.4737)
or 408.745.2000
Fax: 408.745.2100
**www.juniper.net**

**APAC and EMEA Headquarters**
Juniper Networks International B.V.
Boeing Avenue 240
1119 PZ Schiphol-Rijk
Amsterdam, The Netherlands
Phone: 31.0.207.125.700
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