

The Case for Integrating Next-Generation Transport

Scaling the transport network to cost-effectively support the next generation of triple-play, business and mobile services will require integrating packet transport with Reconfigurable Optical Add/Drop Multiplexer (ROADM) Dense Wavelength Division Multiplexing (DWDM) technology.

Executive Summary

Residential triple-play, business Ethernet and mobile broadband will each experience an order of magnitude increase in bandwidth over the next several years. This expectation, together with the shift from circuits to packets, requires a new approach to transport in metro and regional networks and in the core. New technologies like ROADM, packet transport and Automatic Switched Optical Network (ASON)/Generalized Multiprotocol Label Switching (GMPLS) control plane are required, in addition to an ongoing role for next-generation Synchronous Optical Network Technologies (SONET)/Synchronous Digital Hierarchy (SDH). By integrating these technologies into a single platform, service providers stand to benefit from a significant reduction in CapEx as bandwidth scales to multiple 10 Gbps and 40 Gbps wavelengths. Furthermore, significant OpEx savings and faster service activation promise a major competitive advantage to service providers who are early adopters.

Transport Network Drivers

Key applications driving the evolution of transport networks include Internet Protocol Television (IPTV) and Video on Demand (VoD) as part of the residential triple-play bundle; high-bandwidth business services, including business Ethernet; access to Internet Protocol (IP) Virtual Private Networks (VPN) and storage networking; and mobile broadband driven by Evolution-Data Only (EV-DO), High Speed Packet Access (HSPA) and their respective successors.

As shown in Figure 1, IPTV is forecast to experience tremendous growth through the end of the decade. This application, and in particular VoD and other personalized “unicast” TV services, is expected to be the biggest driver of metro bandwidth demand. This growth in demand will be compounded by the tripling in bandwidth required to support High Definition Television (HDTV) streams.

To understand the potential impact these services will have on the metro network, we can use an example of a typical metro network with a headend, 10 exchanges on a ring and 10,000 lines into each exchange. As shown in Table 1, a triple-play service might offer 100 channels of Standard Definition (SD) TV multicast over the metro at 3 Mbps per channel, resulting in 300 Mbps on the ring going to each exchange. Plus, at an estimated 30% penetration for Internet access, we might expect 3,000 subscribers getting 2 Mbps with a 15:1 contention ratio, adding 400 Mbps to each exchange and 4 Gbps to the ring.

Global IPTV Subscribers (in Millions)

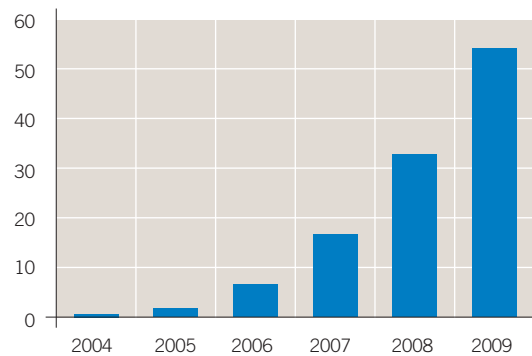


Figure 1. Global IPTV subscribers (Source: Infonetics Research — “IPTV Equipment, Services and Subscribers,” 2005)

	Today	Tomorrow
Lines per Central Office (CO)/Exchange	10,000	10,000
Broadcast TV (Multicast)	100 SD channels @ 3 Mbps = 300 Mbps	150 SD/HD channels @ 6 Mbps = 900 Mbps
High-speed Internet	3,000 subscribers @ 2 Mbps per subscriber with 15:1 contention = 400 Mbps	6,000 subscribers @ 5 Mbps per subscriber with 10:1 contention = 3 Gbps
Voice over Internet Protocol	3,000 subscribers x 25 Kbps with 25:1 contention = 3 Mbps	6,000 subscribers x 25 Kbps with 25:1 contention = 6 Mbps
Video on Demand	300 subscribers x 25% @ peak x 3 Mbps = 225 Mbps	3,000 subscribers x 25% @ peak x 10 Mbps = 7.5 Gbps
Total per CO/Exchange	928 Mbps	11.406 Gbps
Total per 10 CO ring	6.58 Gbps	105.96 Gbps

Table 1. Triple-play metro evolution



Additionally, at peak times, only 3 Mbps of Voice over Internet Protocol (VoIP) traffic is added to each exchange and 30 Mbps to the ring. Anticipating an initial 10% VoD take-up from 3,000 subscribers (300 total subscribers per exchange), with the assumption that an estimated 25% of these subscribers might simultaneously view on demand programming at peak times, another 225 Mbps in demand is added to each exchange and 2.25 Gbps on the ring. This scenario illustrating today's triple-play bandwidth demand results in just under 1 Gbps added to each exchange and slightly less than 7 Gbps on the ring.

The future looks somewhat different. With a mix of Standard Definition (SD) and HD broadcast channels, we can expect the bandwidth per broadcast channel to double to at least 6 Mbps. Furthermore, the number of broadcast channels could conceivably increase by 50% to accommodate community channels and niche programming, resulting in 900 Mbps being multicast on the ring to each exchange.

Broadband Internet penetration could increase to 60%, driving subscriber numbers to 6,000 — with a potential Internet bandwidth increase to 5 Mbps and contention ratios dropping to 10:1, giving 3 Gbps per exchange and 30 Gbps on the ring. Again, voice will have a minimal impact on metro bandwidth. Even at peak times, we add only 6 Mbps of VoIP traffic to each exchange and 60 Mbps to the ring.

What really impacts the bandwidth in the metro are unicast TV services such as VoD. For example, with HDTV movies forecast to require at least 10 Mbps, if 50% of the 6,000 subscribers use this service, and if at peak times 25% want to watch a high definition on demand movie, then 7.5 Gbps will be required for each exchange resulting in 75 Gbps on the ring.

To summarize, the bandwidth to each exchange could increase from just under 1 Gbps to more than 11 Gbps, while the bandwidth on the ring grows from just under 7 Gbps to more than 100 Gbps — an order of magnitude increase.

	Peak Theoretical Bandwidth (Downlink)
UMTS Track	
▪ W-CDMA	2.3 Mbps
▪ HSPA	14.4 Mbps
▪ Enhanced HSPA	40 Mbps
▪ Long Term Evolution (LTE)	100 Mbps
CDMA Track	
▪ EV-DO Rev O	2.4 Mbps
▪ EV-DO Rev A/B	73.5 Mbps
▪ EV-DO Rev C	200 Mbps
WIMAX Track	
▪ Mobile WiMax	63.3 Mbps

Table 2. Peak theoretical bandwidth for mobile broadband technologies

A second key driver of metro bandwidth is business Ethernet. Ethernet is becoming the dominant metro service for large- and medium-sized business customers to interconnect Local Area Networks (LAN), to access IP VPNs and the Internet, and to connect data centers. Ethernet services are also becoming widely used by wholesale customers including Internet Service Providers (ISP), international service providers and, with the advent of pseudowire technology, mobile operators.

As shown in Figure 2, these business applications are driving growth in Ethernet bandwidth as both the number of wide-area Ethernet connections and the bandwidth of those services increase. It shows an increase from 20,000 Gbps in 2004 to 170,000 Gbps in 2010 — another order of magnitude increase.

The final driver having a significant impact on metro bandwidth requirements is mobile broadband. EV-DO Rev A, HSPA and their successors, including EV-DO Rev B/C, Enhanced HSPA and Long Term Evolution (LTE), increase the speed of the air interface from tens of kilobits to tens of megabits, as shown in Table 2.

However, delivering on the promise of mobile broadband will require a simultaneous scaling of the mobile backhaul network, with the bandwidth to a cell site having to scale from one or two T1/E1s to 20 Mbps or more — another order of magnitude increase.

In order to decouple the linear relationship between bandwidth and cost, mobile service providers are moving towards IP and packet transport. In the long-term this means an all IP Radio Access Network (RAN) as defined in the 3rd Generation Partnership Project (3GPP)

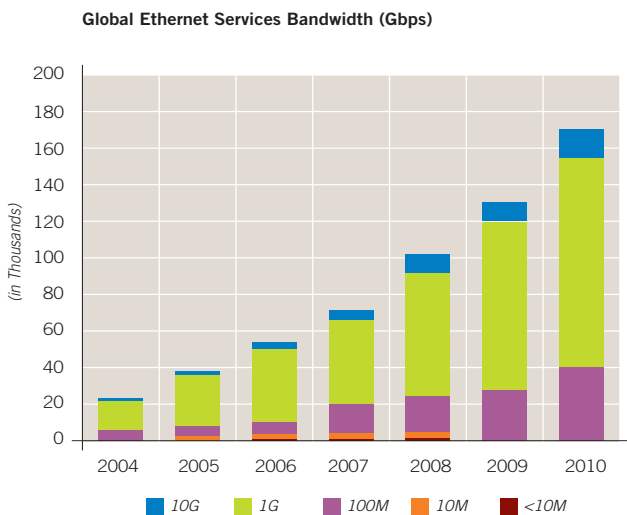


Figure 2. Global ethernet services bandwidth (based on Ovum-RHK, 2006)

Releases 5 and 6. In the shorter term, pseudowire technology is enabling mobile service providers to leverage the economics of metro Ethernet and Digital Subscriber Line (DSL) to transport their Time Division Multiplexer (TDM)-based 2G traffic and Asynchronous Transfer Mode (ATM)-based R99/R4 3G traffic.

To summarize: consumer triple-play, business Ethernet and mobile broadband are each driving an order of magnitude bandwidth increase in metro and regional networks and a shift to packet transport.

The Limitations of Today's Transport Network

Today's transport networks suffer from a number of limitations when faced with these order of magnitude increases in capacity — slow and costly wavelength activation, inefficient pass-through, unnecessary short reach optics and the expense and complexity of too many transport platforms.

Wavelength activation with today's point-to-point DWDM systems and fixed OADMs is complex, expensive and slow (Figure 3). Activating a wavelength requires complex planning followed by a truck roll to every node in the wavelength's path to add transponders and balance and tune the network. This results in higher incremental CapEx, higher OpEx and the time required for wavelength activation measured in weeks. Furthermore, this manual process increases the potential for human error and decreases reliability.

A second limitation of today's transport networks results from their ring-based architectures. In ring architectures, up to 90% of the traffic at each node is being passed through. Performing this pass-through in the electrical domain — Ethernet switch or SONET/SDH ADM — will become increasingly uneconomical as the bandwidth of passed-through traffic increases to multiples of 10 Gbps.

A third limitation results from the use of separate platforms for the WDM layer, for the SONET/SDH layer and for the Ethernet transport layer. This separation requires short-reach optics to interconnect the SONET/SDH and Ethernet layers with the WDM layers and the grid optics in the transponder in the WDM platform, which is often in the next rack. The service provider is therefore paying for three lasers when it could be paying for only one.

A fourth limitation stems from the use of multiple platforms at each node in the transport network: WDM platforms, SONET/SDH ADMs and cross-connects, and Ethernet switches. Multiple platforms require more physical space and energy, which results in higher OpEx for rental space and utilities. Maintenance and repair OpEx is also higher due to multiple platform complexity and excess spares inventory. Multiple OSS platforms in the network operations center also increase complexity and cost.

Finally, the vast majority of today's transport networks lack a control plane, having opted for an intelligent management platform to compensate for a relatively unintelligent network. This lack of a control plane results in a number of limitations. As the network resource inventory is based on "second-hand" information stored externally from the network rather than real-time information held in the network, this results in the limited accuracy of network resources inventory. While this approach makes sense for provisioning across a homogenous network operating in the same layer and from the same vendor, provisioning across heterogeneous networks is slow and complex.

The lack of a control plane in today's optical networks also limits the ability to support more flexible and cost-effective protection mechanisms, such as mesh protection and dynamic re-routing, thus increasing the cost of network reliability and limiting the number of tolerated failures.

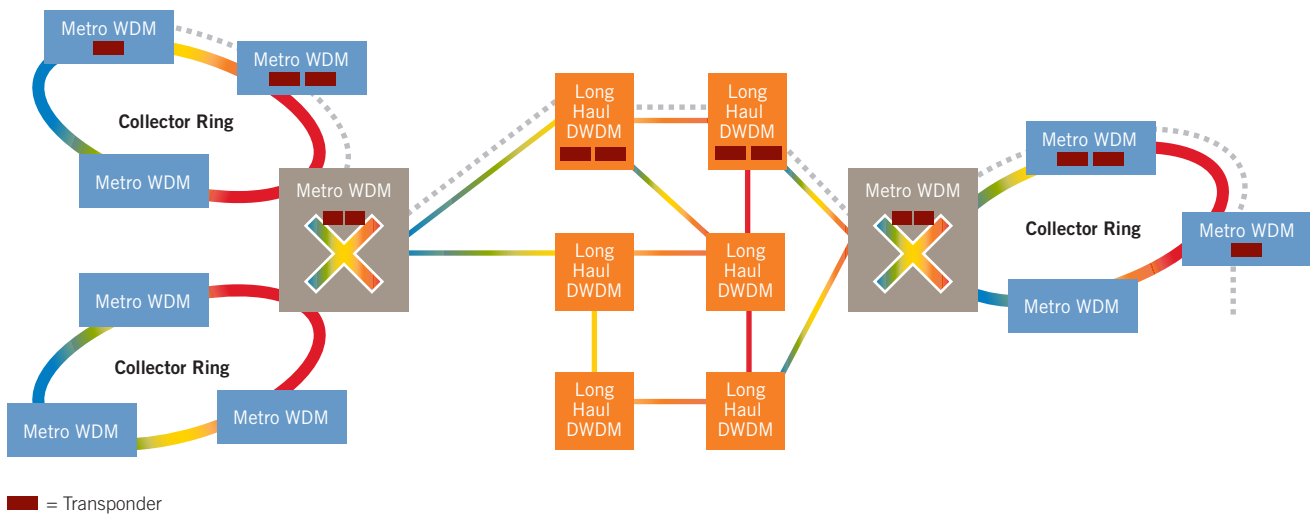


Figure 3. Slow and expensive wavelength activation

With these limitations, scaling today's transport networks to support new triple-play services, business Ethernet and mobile broadband will result in high CapEx, high OpEx and slow service delivery times.

Key Technologies for Next-Generation Transport

Overcoming these limitations requires a number of new technologies, including multi-degree Reconfigurable Optical Add/Drop Multiplexers (ROADMs), an ASON/GMPLS control plane, packet transport and next-generation SONET/SDH.

ROADMs provide a dynamic optical layer to next-generation transport networks. ROADM technology allows wavelengths to be passed through and dropped or added remotely without new hardware and without a truck roll. Multi-degree ROADMs support multiple line ports for hub and mesh applications (Figure 4). Tunable lasers are also a key component of ROADM systems, allowing transponders to be tuned to a particular wavelength while also minimizing spares inventory. In multi-degree ROADMs, wavelengths can be switched from one line port to another remotely, again without new hardware or a truck roll.

Multi-degree ROADMs effectively address a number of the limitations of today's transport networks discussed previously. Wavelengths can be added with no transponders and no truck rolls required at the intermediate nodes (Figure 5), and wavelengths can be re-routed with zero truck rolls, reducing incremental CapEx and OpEx while speeding service deployment time. ROADMs also allow pass-through traffic to be forwarded optically at a much lower cost-per-bit than the Optical-to-Electrical-to-Optical (OEO) layer, thus allowing next-generation transport networks to scale into the Nx10 Gbps range far more cost-effectively.

A second key technology is a control plane based on the ITU ASON and IETF GMPLS standards. By adding the intelligence of a control plane to the optical network, service providers gain a number of important benefits. As the transport network becomes a database of its own resources, service providers will benefit from more accurate inventory, thus reducing CapEx and speeding provisioning. A standards-based control plane provides the ability to provision across heterogeneous networks, thus further speeding up provisioning while lowering OpEx. Finally, a control plane, by reducing the burden on Operations Support Systems (OSS) to provision and manage the network, has the potential to significantly reduce OSS costs.

An optical control plane introduces the option of new protection schemes, including mesh and dynamic re-routing. These protection mechanisms can reduce the cost to maintain reliability, as protection bandwidth can be shared to support a number of connections. Furthermore, more than one failure can be tolerated without service interruption.

As outlined previously, residential, business and mobile traffic is rapidly migrating to packet with IP at Layer 3 and Ethernet at Layer 2. Interfaces between equipment are also moving to Ethernet-based technology. While circuit-based services will not disappear overnight, the transport network increasingly needs to be optimized

for packets. Packet transport avoids the complexity and hierarchy of putting Ethernet packets first into SONET/SDH before hitting the WDM layer. Packet transport offers the promise of more bandwidth for less cost and improved multiplexing efficiency and granularity.

Packet transport requires mechanisms for traffic engineering and resiliency. The likely candidate to address those needs is Transport MPLS (T-MPLS), which provides many of the benefits of IP/MPLS but avoids much of the overhead and complexity that add little value in the transport network. Other possible mechanisms include Provider Backbone Transport (PBT) and IP/MPLS.

While packet transport provides a highly efficient solution for packet-dominated networks, TDM traffic based on SONET/SDH has been the mainstay of transport networks since the early 1990s and will not disappear any time soon. While TDM circuit emulation over packet and synchronization over packet technologies are maturing, they are unlikely to be cost-effective for large volumes of high-speed TDM circuits. Next-generation SONET/SDH will therefore still have a strong role to play where there are high volumes of TDM traffic.

The Case for Integrated Transport

The key elements of a next-generation transport solution have been identified, but why integrate them? Integrating these elements onto a single platform can reduce a number of significant costs. First, unnecessary short reach optics are eliminated by integrating the packet transport and SONET/SDH elements onto the same platform as the WDM/ROADM layer and integrating a tunable transponder into these elements (Figure 6).

Furthermore, CapEx for common equipment, such as power and management processors, is reduced. Space and corresponding rent are reduced, as are power requirements and energy costs. Spares

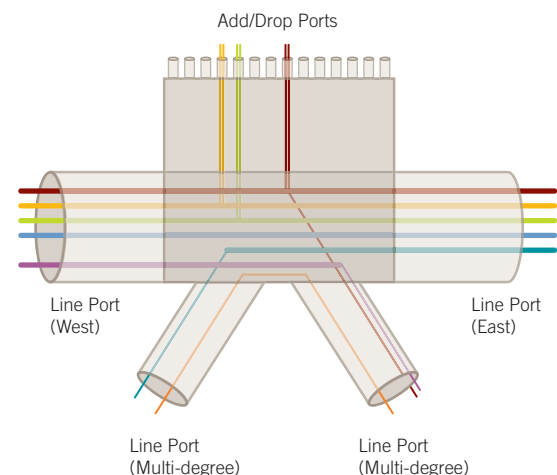


Figure 4. Multi-degree ROADM

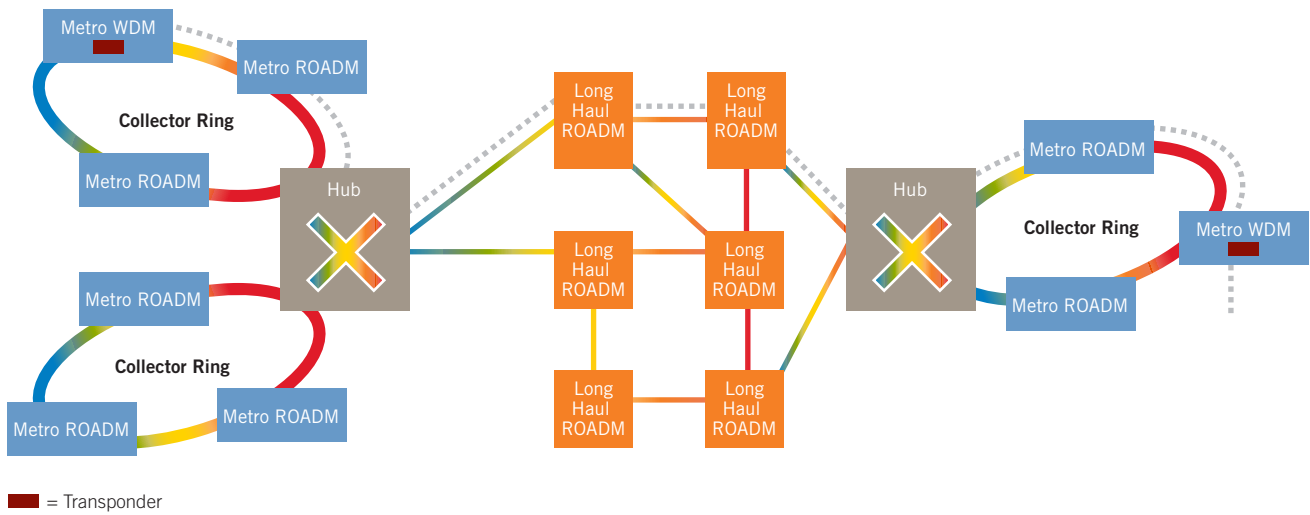


Figure 5. Wavelength activation with ROADMs

inventory is reduced and troubleshooting is simplified, thus lowering maintenance and repair costs. Fewer platforms also result in fewer OSS platforms and simplified OSS integration.

Benefits of Integrated Transport

As illustrated in Table 3, next-generation transport platforms that integrate ROADM, packet transport, next-generation SONET/SDH and an ASON/GMPLS control plane (as shown in Figure 7) have significant potential benefits. Faster service activation and reduced CapEx/ OpEx are just a few of the competitive advantages next-generation transport platforms can deliver.

ROADM technology can reduce CapEx as the network scales by decreasing the number of transponders and supporting optical traffic pass-through. It trims OpEx by reducing planning and truck roll expenditures while accelerating provisioning through point-and-click wavelength activation. An ASON/GMPLS control plane reduces CapEx through more efficient protection and OpEx by speeding service activation times with simplified provisioning and more accurate inventory. Packet transport and next-generation SONET/SDH offer the lowest CapEx for packet and circuit transport respectively. An integrated platform further reduces CapEx by eliminating short reach optics and reducing common equipment. It reduces OpEx in terms of lower rent and energy costs, and accelerates service deployment via simplified OSS.

CapEx Savings

As the number of 10 Gbps in the metro scales, an integrated optical transport platform like the Tellabs® 7100 Optical Transport System (OTS) enables potential order of magnitude cost savings when compared to stacking Ethernet switches or SONET/SDH ADMs (Figure 8). And, when compared to stacked Ethernet or SONET/SDH with a separate ROADM layer, an integrated optical transport platform still offers significant OpEx/CapEx savings.

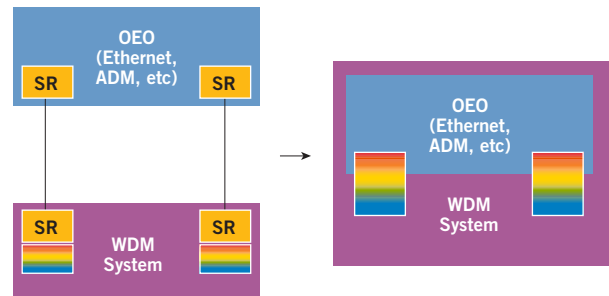


Figure 6. Eliminate short reach optics through platform integration

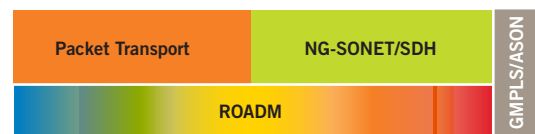


Figure 7. Integrated optical transport



A real-world example of potential savings is demonstrated in Figure 9, showing how Tellabs modeled the costs of supporting a triple-play rollout over seven years for a major incumbent carrier, demonstrating significant cost savings over stacked Ethernet and Ethernet plus a separate ROADM.

Conclusion

In order to cost effectively support the forthcoming order of magnitude increase in demand for metro and regional bandwidth driven by triple-play, business Ethernet and mobile broadband, service providers will need to take a new approach to building transport networks. Combining ROADM, packet transport and next-generation SONET/SDH into an integrated platform with an ASON/GMPLS control plane promises significant CapEx/OpEx savings and service activation speed advantages. The result — service providers can stimulate revenue by offering new services while simultaneously controlling the costs to deliver those services.

	Reduced CapEx	Reduced OpEx	Fast Service Activation
ROADM	<ul style="list-style-type: none"> Fewer transponders Optical pass-through 	<ul style="list-style-type: none"> Fewer truck rolls 	Point and click wavelengths
ASON/GMPLS	<ul style="list-style-type: none"> Mesh protection 		
Packet Transport	<ul style="list-style-type: none"> More efficient for packets 	N/A	N/A
	<ul style="list-style-type: none"> More efficient for circuits 	N/A	N/A
Platform Integration	<ul style="list-style-type: none"> Eliminate SR optics Minimize common equipment 	<ul style="list-style-type: none"> Reduce space and energy Simplified OSS is a new thing 	<ul style="list-style-type: none"> Simplified OSS

Table 3. The benefits of integrated optical transport

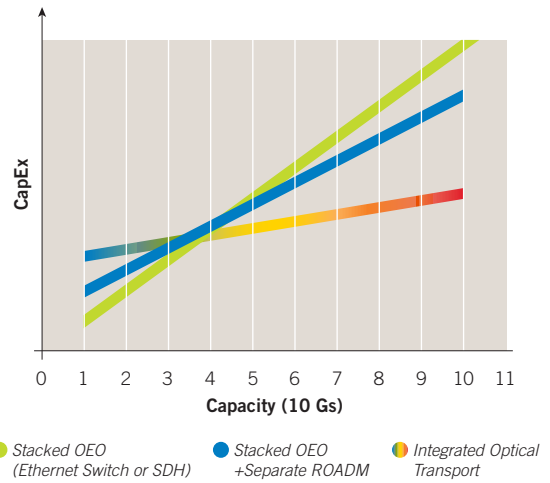


Figure 8. Theoretical CapEx savings of integrated optical transport

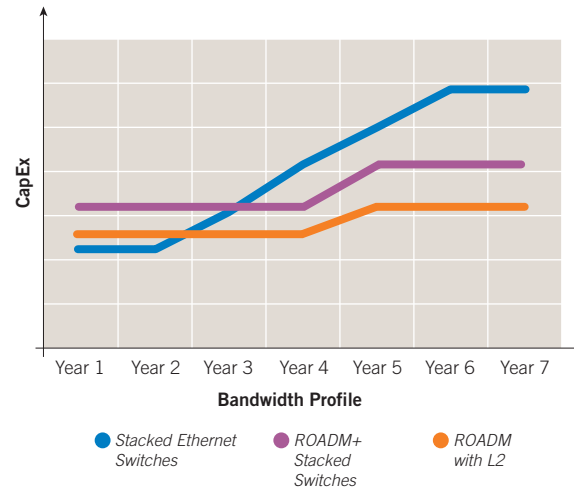


Figure 9. Real-world CapEx example for triple play deployment

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