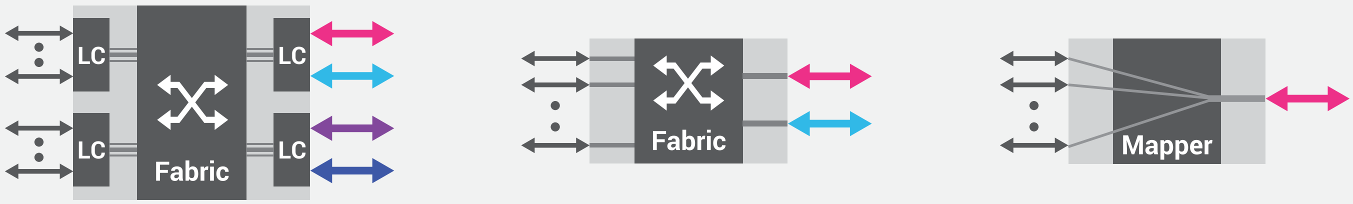
Accelerating Network Transformation

OTN Architecture Evolution

OTN Mission and Building Blocks

> The mission of Optical Transport Networks (OTN) is to provide high-capacity, reliable, and flexible services transport over metro and long-haul distances. In achieving this mission, OTN architectures must support diverse services, be cost-effective, and increasingly, be energy efficient.

In the past, OTN architectures were dominated by end-to-end OTN switching. However, the rapid growth of high-speed services combined with advances in optical technology are driving OTN architectures to evolve. This paper shows how designs that use Muxponders for medium to high-speed services, and OTN Switches and Switchponders for low to medium-speed services, provide the best approach to meet all business requirements with the best economics and energy efficiency.



OTN Switch

- **Platform** containing multiple line cards or sleds
- **Any-to-any** services switching to/from single service ports or multi-service wavelengths

Switchponder

- **Small footprint** line card, sled, or pizza box
- **Any-to-any** services switching to/from single service ports or multi-service wavelengths
- **Economical** and low power

Muxponder

- **Small footprint** line card or sled
- **Maps** multiple services to/from a single wavelength
- **Economical** and low power

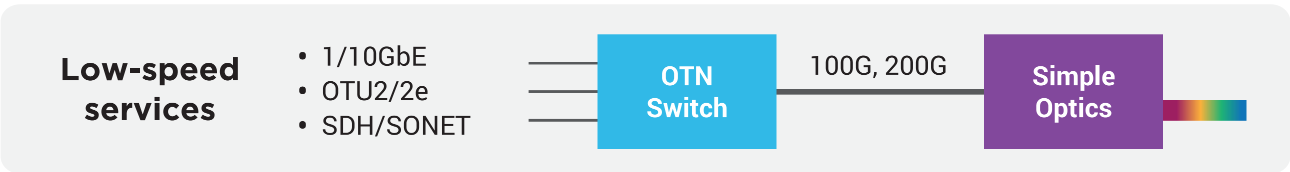
OTN Architecture Building Blocks

Previous Approach

If we look back about ten years, service rates were predominantly 1GbE growing to 10GbE, and line rates were 100G growing to 200G. This translated into about a 100:1 ratio between the predominant line and service rates.

In this situation, it made sense to adopt an end-to-end OTN switching architecture with ODU0 granularity (about 1.25Gbits/sec). Many services could be injected at the edge and work their way through the network always ensuring maximum fill on the expensive 100G or 200G line interfaces. Moreover, services could be provisioned quickly under centralized software control, with no need for detailed network planning.

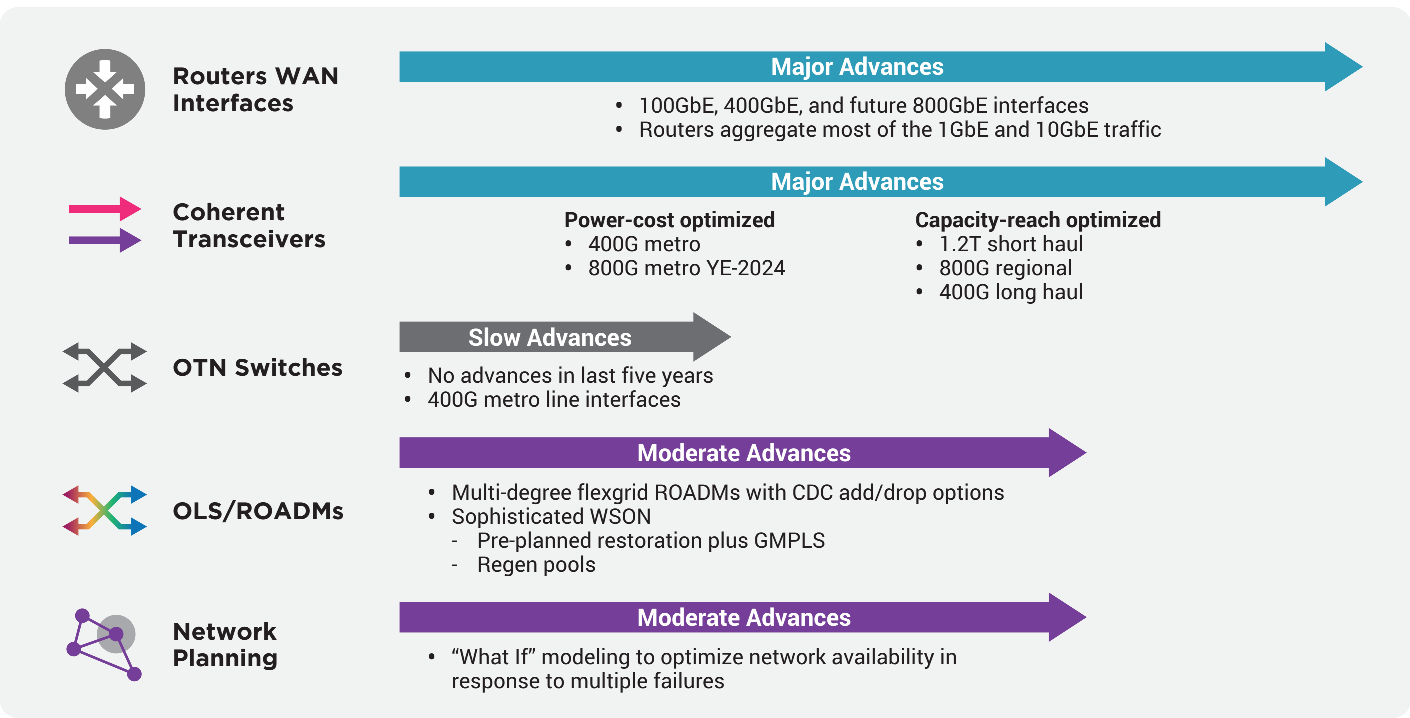
While these OTN networks also made use of DWDM to combine and route multiple wavelengths on common fibers, typically this used passive multiplexers or simple ROADMs.



Previous OTN Architecture when Traffic was Dominated by Low-speed Services

Technology Changes

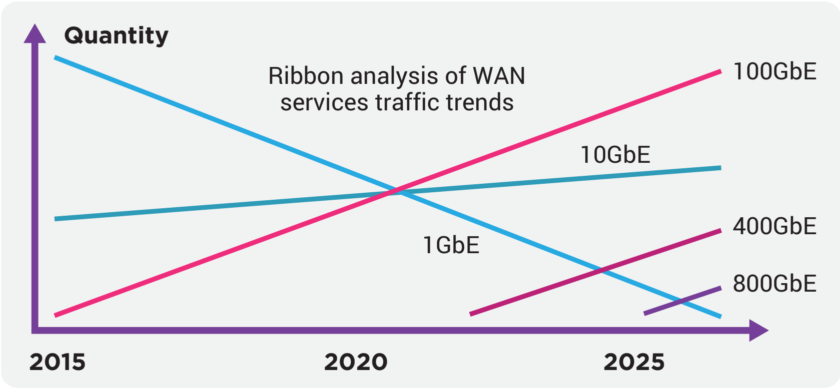
Over the past ten years, networking technologies have advanced at different paces, directly influencing OTN architecture evolution.



Network Technology Advances

Router WAN Interfaces (major advances)

Router and Ethernet switching silicon has shrunk from 40nm to 5nm scale, increasing capacity 80x while using 95% less energy per bit. This has led to router and Ethernet switch WAN interfaces jumping from 1GbE/10GbE to 100GbE/400GbE, with 800GbE forecast in a few years. While there is still some modest growth in 10GbE WAN interfaces, today routers aggregate most 1GbE interfaces.



Relative Growth of Client Interfaces on Wide Area Optical Network

Coherent Optics (major advances)

DSPs for coherent optics have similarly progressed from 40nm to 5nm scale. This has translated into two types of optimizations for coherent transceivers:

- Capacity-reach optimized transceiver modules without hard form factor and power constraints, today delivering 1.2T short haul, 800G regional, and unlimited 400G long haul wavelengths.
- Power-cost optimized transceiver pluggables constrained to small form factors like QSFP-DD, today delivering 400G wavelengths for metro distances with 800G availability in coming months.

OTN Switching (slow advances)

Compared to the above major advances, OTN switching has barely progressed with underlying silicon technology stalled at 16nm. The cost of growing OTN switches to support 100GbE and higher service interfaces far outpaces cost reductions in underlying OTN switching fabrics. In addition, services grooming to maximize wavelength fill can be done with less expensive muxponder and switchponder technologies.

Summarizing the above, we see there is an order-of-magnitude drop in line-to-service rates from about 100:1 ten years ago to less than 10:1 today! When you combine that trend with the fact there have been only negligible in OTN switching technology, we can conclude that the business case for an end-to-end OTN switching architecture no longer makes sense.

	Previous Gen	Current Gen
Predominant line rate	100G	400G
Predominant service rate	1GbE	100GbE
Line rate ratio	**~100:1**	**~4:1**
Business case for pure OTN switching architecture	Strong ↑	Weak ↓

OLS – Optical Line Systems (moderate advances)

ROADMs are the building blocks of OLS to manage and route wavelengths on fibers. Strong advances in underlying wavelength selective system technology enable new and upgraded optical networks to use powerful flexgrid multi-degree ROADMs, augmented with colorless-directionless-contentionless add/drop functionality.

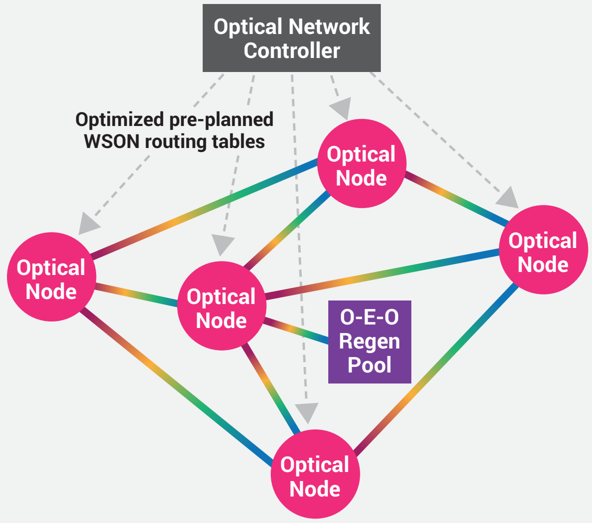
When failures occur, modern OLS like those supported by Ribbon's Apollo optical network system employ advanced WSON (wavelength switched optical network) techniques to re-route wavelengths and maintain service availability, similar to how ASON was used in an all-OTN switching network.

Pre-planned Restoration GMPLS

- An optical network controller plans and distributes **optimized** restoration routing tables
- On failures, the optical nodes **re-routes** wavelengths based on this plan using GMPLS
- Maximizes network availability for given Capex

Regeneration Pools

- Enable creating longer wavelength paths dynamically when needed for restoration
- Can maintain the same wavelength or convert to a new wavelength depending on need
- Reduces optical port count, saves Capex



Apollo Advanced WSON Techniques

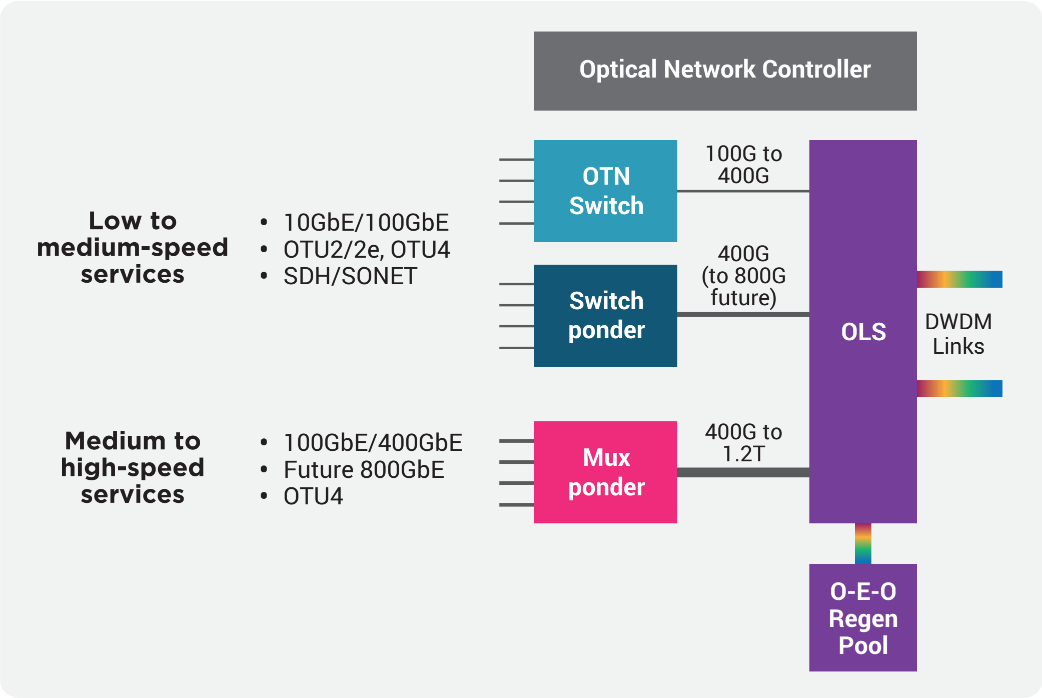
Network Planning Tools (moderate advances)

One advantage of the previous generation's all-OTN switching architecture was that it compensated for weak network planning tools. The fine OTN switching granularity facilitated finding a path for services across the network even if it wasn't optimally planned.

Since then, network planning algorithms and software have become more sophisticated. They include capabilities like multi-layer algorithms, and "what-if" scenario generation to understand how the network responds to various failure conditions. Networks planned today are much closer to a theoretical optimum.

Current OTN Architecture Approach

Driven by the technology changes discussed above, we have largely evolved today to an OTN architecture that uses multiple elements.



Current OTN Architecture for a Broad Mix of Service Speeds

OTN switches and switchponders (new "lightweight" single card OTN switches) continue to aggregate remaining low speed 10GbE services, as well as some 100GbE services that are now considered medium speed. These services are aggregated onto 400G wavelengths.

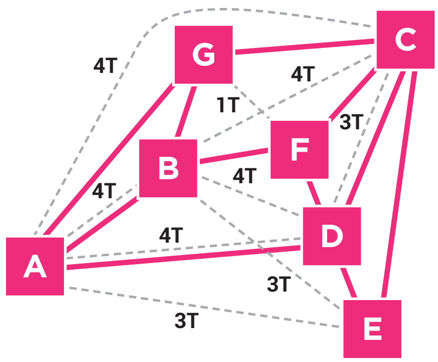
The major change is that most 100GbE services and all higher rate services are now handled using OTN transport. Economical muxponders maps these services onto wavelengths ranging from 400G to 1.2T.

Modern OLS in conjunction with powerful planning tools ensure optimal use of resources with maximum availability.

The dramatic benefits of this approach are demonstrated by a study we performed for a customer who requested that we compare the previous and current approaches for a new metro network. The new network used mostly muxponders for 100GbE services, and different combinations of OTN switches and switchponders for 10GbE and some 100GbE services, to reflect a range of architectural functionalities.

This resulted in a range of benefits highlighted by up to a 50% saving in total cost of ownership, with almost one-quarter the power use.

Node	100GbE	10GbE
A	60	150
B	60	150
C	46	120
D	46	120
E	18	40
F	5	5
G	5	5

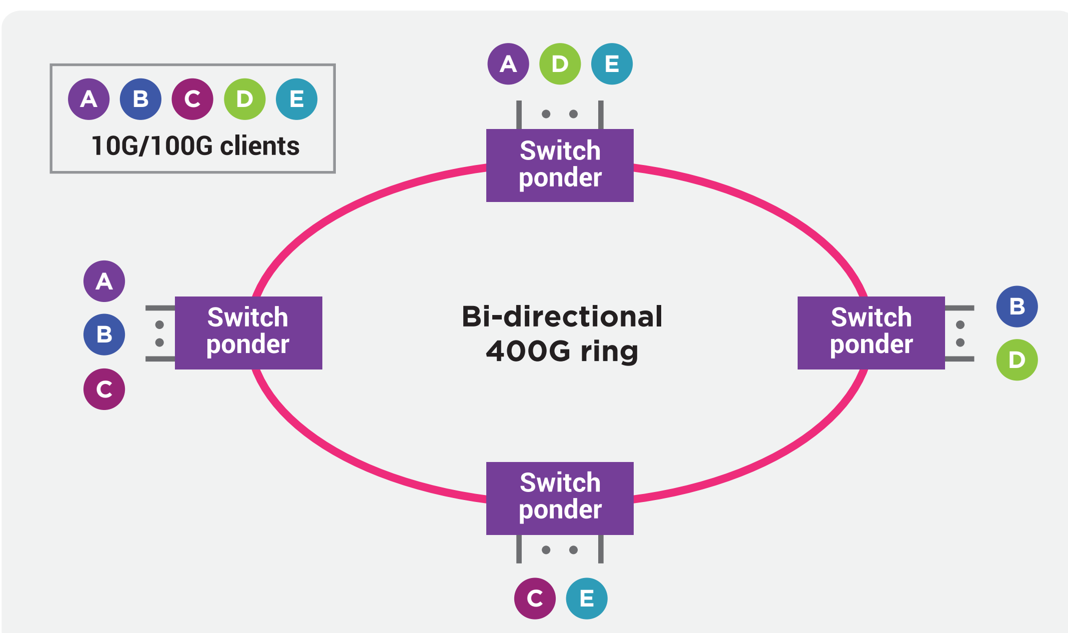


	Only OTN XCs	Muxponders with mix of Switchponders and OTN XCs
Five year TCO	100%	50%-75%
Total Power Consumption	58KW	16KW-30KW
Total Racks	14	7-10

Key Aspects of a Network Study Comparing Previous and Current OTN Architectures

A quick note on OTN switches versus switchponders. While in mesh networks it often still makes sense to use OTN switches for low-medium speed services, in the case of ring networks they can be replaced entirely by much more economical switchponders.

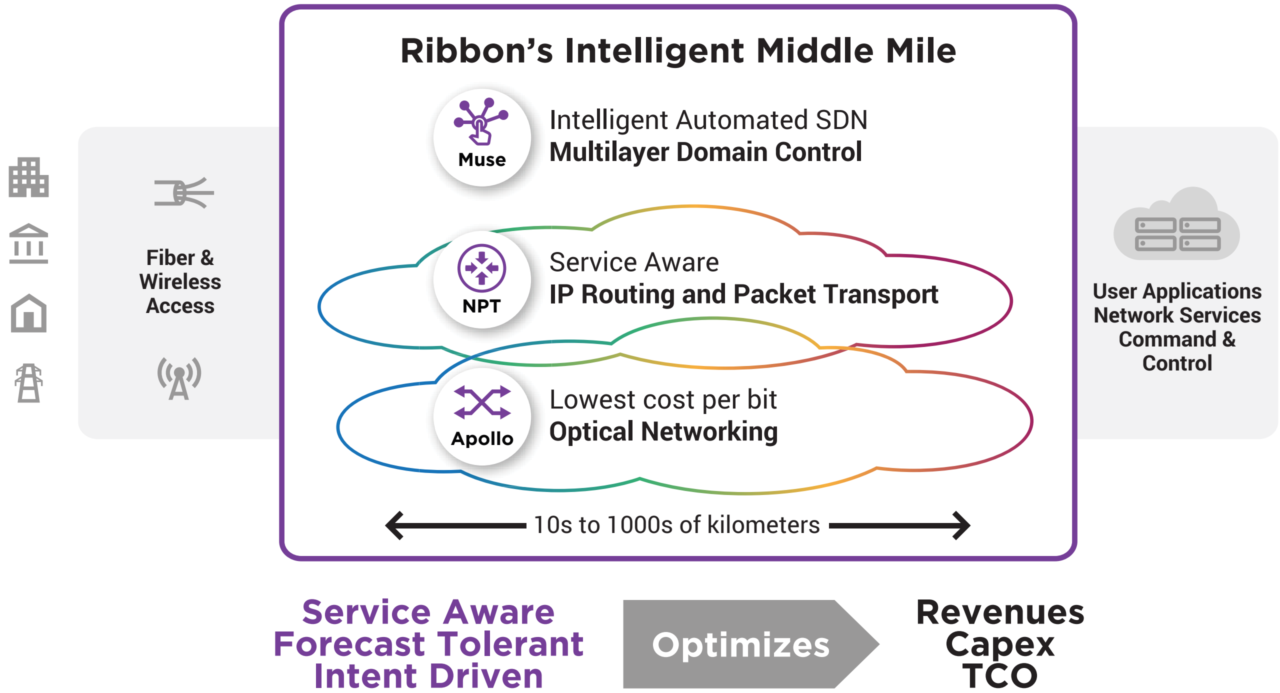
The switchponders provide all the functionality of an OTN switch for flexibly adding and dropping multiple low to medium speed services onto single or a small number of wavelengths. Moreover, the traffic can be routed in either direction in the case of a fiber cut.



Example of Switchponder Use

Summary

As OTN architectures have evolved, so have Ribbon's optical solutions, featuring a complete set of building blocks ecncompassing OTN switching, switchponders, muxponders, and OLS to create optimized architectures for all service speeds – all supporting Ribbon's broader set of solutions for the Intelligent Middle Mile.



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About Ribbon

Ribbon Communications (Nasdaq: RBBN) delivers communications software, IP and optical networking solutions to service providers, enterprises and critical infrastructure sectors globally. We engage deeply with our customers, helping them modernize their networks for improved competitive positioning and business outcomes in today's smart, always-on and data-hungry world. Our innovative, end-to-end solutions portfolio delivers unparalleled scale, performance, and agility, including core to edge software-centric solutions, cloud-native offers, leading-edge security and analytics tools, along with IP and optical networking solutions for 5G. We maintain a keen focus on our commitments to Environmental, Social and Governance (ESG) matters, offering an annual Sustainability Report to our stakeholders. To learn more about Ribbon visit rbbn.com.

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