ECI THE ELASTIC NETWORK

APOLLO PROGRAMMABLE OPTICAL NETWORKING

REVOLUTIONIZING OPTICAL NETWORKS

Internet traffic, driven by cloud-5G-IoT applications, is increasingly enmeshing our world. It is calling upon the underlying fiber-optic superhighways to deliver more than ever. Optical networks must still support and exceed simple low-cost-per-bit transport. Now, they must also combine high capacity, flexibility, and robustness to become the best partner to the packet layer in delivering services traffic.

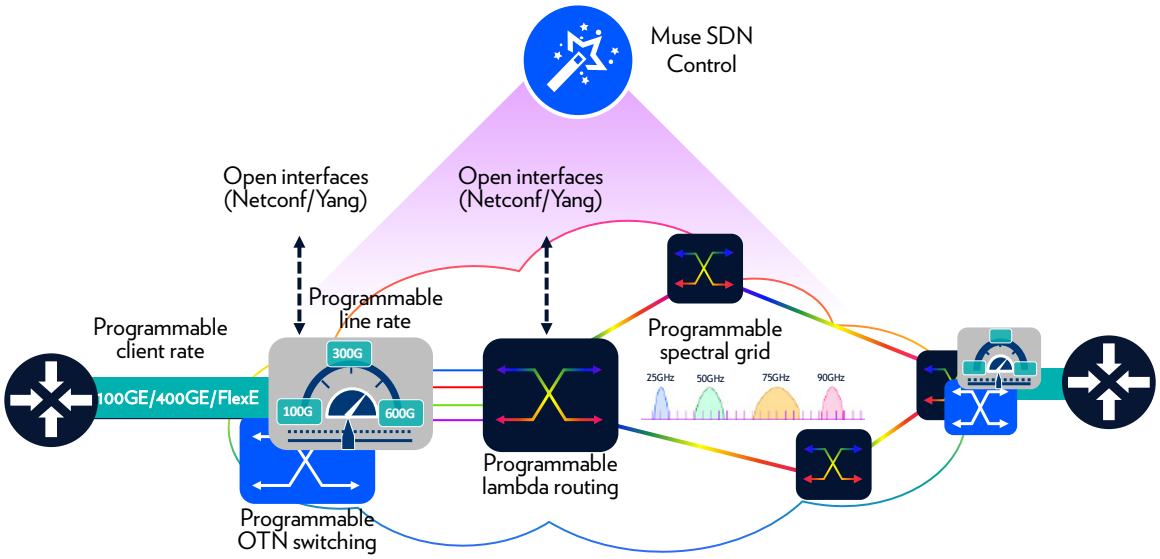
ECI's Apollo programmable optical networking answers the call. Apollo unleashes paradigm-breaking applications that transform the optical network into a platform that generates new revenues and guarantees end-to-end service availability, while simultaneously maximizing transport capacity. Apollo sets up optical paths dynamically and optimizes transmission over those paths with far greater flexibility and granularity than ever before. Through open APIs, Apollo transforms the optical network into a true partner for self-organizing, multilayer networks.

Maximum Throughput
for heavy traffic

Dynamic Restoration
for guaranteed service availability

Customer-Controlled
BW-on-demand for new revenues

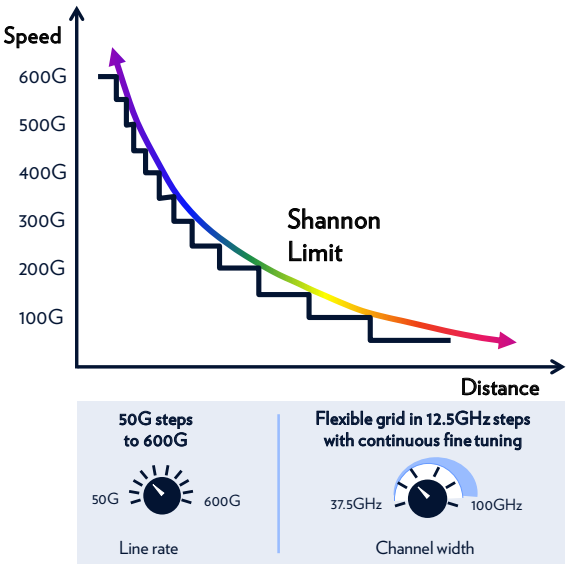
Paradigm-Breaking
reduced day-1 margin requirements



MULTIPLE DEGREES OF PROGRAMMABILITY FOR MAXIMUM PERFORMANCE AND CUSTOMIZATION

Apollo programmatic control spans all levels of optical transport, with multiple degrees of flexibility:

- **Spectrum.** Apollo flexible grid with 12.5GHz granularity delivers major benefits. Spectral width adjusts to match the performance needs of the transmitted signals. For a single carrier, this ranges from 37.5GHz to 100GHz. For multicarrier superchannels or shared spectrum services, Apollo can even create and manage flex-grid channels spanning several hundred GHz. With flex-grid, only as much spectrum as is needed is assigned, ensuring optimal use of fiber capacity.
- **Line rates.** Apollo software-controllable "knobs" tune the modulation scheme, baud rate, and flexible grid channel width, to optimize the line rate — from 50G to 600G, with 50G increments — for the distance to be covered. Transmission approaches the theoretical non-linear Shannon Limit, so that no channel capacity is wasted.
- **Client interfaces**. Apollo has always excelled at providing transparent transport for multiple types of client interfaces, and now extends this to 400GbE for the most data-intensive applications.
- **Line interfaces.** Faster transmission rates above 100G must also handle client traffic smoothly. Apollo achieves this by supporting OTUCn and flexible OTN (FlexO) standards. These map and hand off clients onto a high-speed OTN structure with flexibility and scalability.



- **ROADMs.** Apollo's extensive ROADM portfolio enables end-to-end, all-optical routing and automated wavelength restoration (WSON) for any network configuration. Apollo now boosts its ROADM capabilities even further with flex-grid for optimized spectrum use. In addition, a revolutionary MEMS+LCOS collector overcomes all bottlenecks for the highest level of colorless-directionless-contentionless wavelength add/drop flexibility.
- **OTN switching.** OTN switching provides an optional layer of flexibility for rapid provisioning, wavelength grooming, and automated service restoration (ASON). Apollo's unique OTN switching solution scales capacity smoothly and economically, from the network edge to the core.
- **Control.** To exploit all these new degrees of programmable flexibility, ECI's Muse Orchestrator introduces a suite of SDN applications for service and network lifecycle automation. Based on a cloud-native software architecture, Muse applications can be 'continuously delivered', easing migration and ensuring value in a timely manner.
- **Openness.** This aspect complements programmability, enabling network operators to create modular, disaggregated solutions. Apollo makes available open APIs, based on the OpenROADM MSA, allowing network operators to control Apollo subsystems in a multivendor network. In addition, at the transport level, Apollo now extends its traditionally strong support for alien wavelengths to whole bands of shared spectrum

Major Features	Until Now	Going Forward	Benefit
Spectrum Line rates	Fixed Coarse (100/200G)	Flexible Fine (50G steps to 600G)	Programmable throughput
Client side Line side	Multi-service (Ethernet,storage,etc) OTUk, ODUflex	400GE, FlexE OTUCn, FlexO	Programmable transport mapping
ROADMs OTN switching	Fixed grid, colorless, directionless Medium/high capacity	Flexible grid, Contentionless Access-to-core scalability	Programmable routing
Control	NMS (procedural, manual)	SDN (abstract, automated)	Programmability control
Openness	Alien wavelengths	Alien spectrum, Open ROADM	Modularity, disaggregation

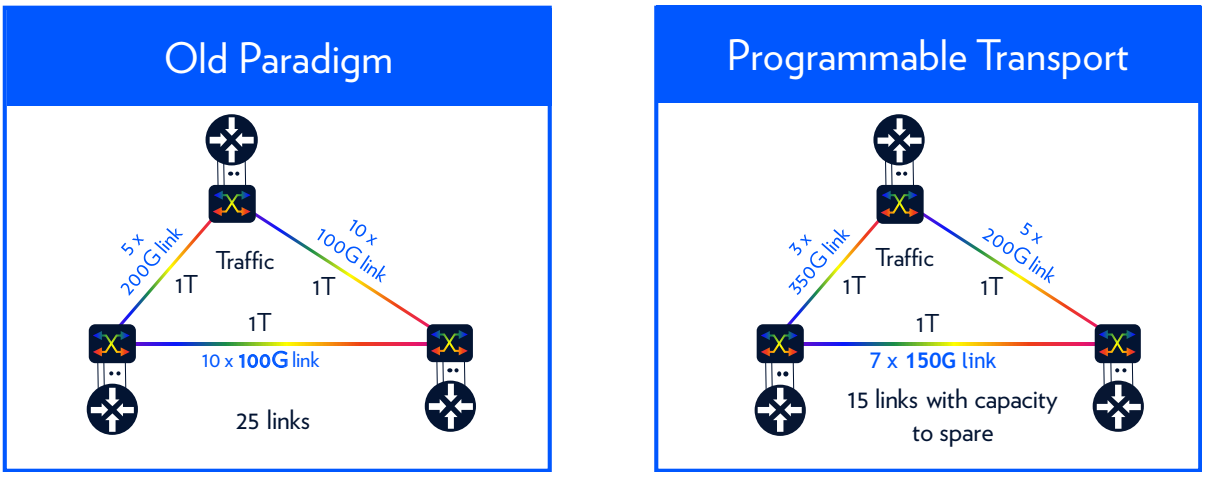
Let's look at some the innovative applications Apollo programmability can deliver.

MAXIMUM THROUGHPUT FOR HEAVY TRAFFIC

Heavy traffic situations always require multiple wavelengths (channels). It is essential to extract the maximum capacity from each channel to reduce the number of costly transponders. Apollo programmable throughput maximizes transmission, based on a route's distance and inherent channel noise, to the edge of the non-linear Shannon Limit, so that no channel capacity is wasted.

To illustrate, let's consider three nodes with a traffic demand of 1T between each of them. Until now, the only rates available were 100G or 200G using fixed 50GHz channel widths. Applying optical planning tools, this produced a best case of 25 links (channels, with transponders at each end) to transport the traffic.

With Apollo programmable transport, by playing with the modulation schemes and flex-grid channel widths, we can do much better. The net result is the ability to carry the same amount of traffic with only 15 links! This reduces the number of transponders required for handling heavy traffic loads by up to 50%, thereby saving substantial capex.



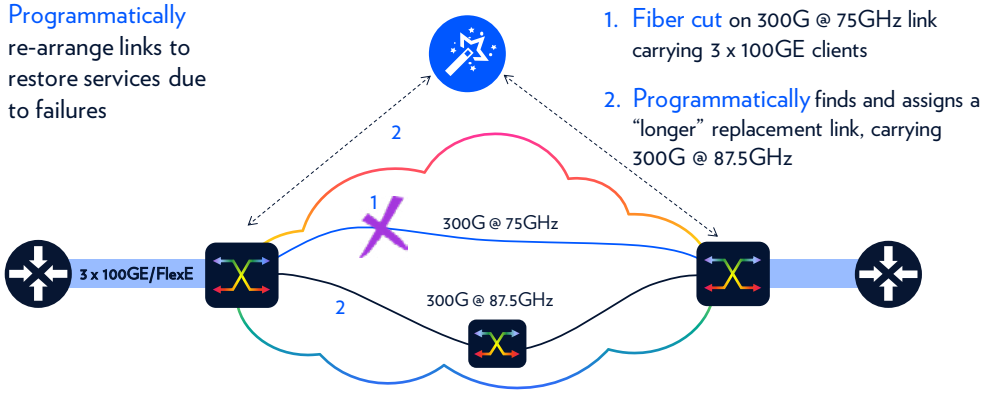
DYNAMIC RESTORATION FOR GUARANTEED SERVICE AVAILABILITY

Architectures, such as WSON that support wavelength restoration, are often constrained by an inability to find alternate lightpaths when link failures occur. By combining programmable optical path routing with programmable throughput, Apollo overcomes this limitation with highly flexible dynamic restoration.

To illustrate, consider a 300G optical link carrying 3 x 100GbE of client traffic. Its channel width is 75GHz. There is a fiber cut and the restoration algorithm looks for an identical link to switchover the traffic, but cannot find one. There is a longer link, passing through an additional ROADM.

However, because of the longer distance, this requires a channel width of 87.5GHz. Apollo programmable optical networking quickly sets this up and restores the traffic over the new link.

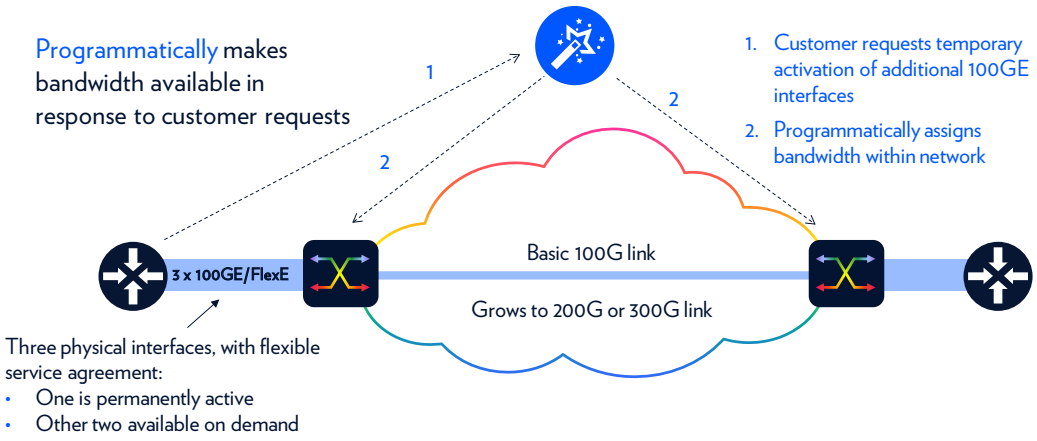
By combining this capability with multilayer control, restoration can be coordinated with the services layer, providing even greater flexibility to maintain SLAs. For example, let's say the optical restoration algorithm could only find a 200G backup path. An originating router using Flexible Ethernet clients could sub-rate the traffic to an equivalent 200GbE stream, and the service can be maintained at a lower rate, rather than be lost altogether.



CUSTOMER-CONTROLLED BANDWIDTH ON DEMAND FOR NEW REVENUES

Platforms like Amazon Web Services let business customers order computing resources on-demand, raising their expectations for similar offerings for telecommunications connectivity. For example, a large enterprise or data center operator may normally require a 100G link between two locations. On occasion, however, there is a need to perform large backups, and to increase the rate to 300G. Apollo programmable optical networking can accommodate this as follows:

- The customer purchases a basic package of three-100GbE physical interfaces from each location to the Apollo network, along with a 100G transport service.
- Through a portal, the customer 'dials-up' additional bandwidth, for 200G or 300G, as needed. The programmable network allocates additional bandwidth resources to accommodate the request, or makes a best effort to do so. The fees may vary, depending on the time of day, and the customer pays just for the additional bandwidth during the temporary usage period.



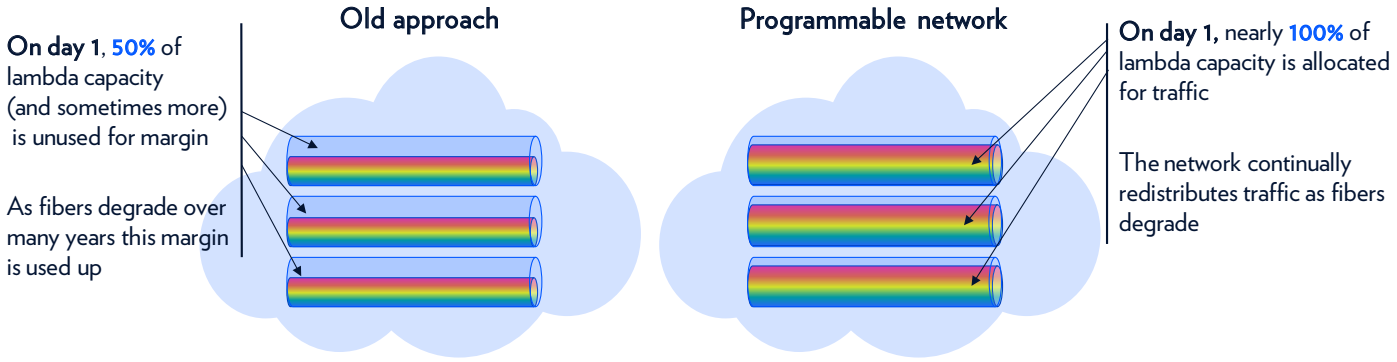
JUST-IN-TIME MARGIN

Many industries operate on the principle of "just-in-time inventory". With optical networks, however, it has been just the opposite. To compensate for future degradation of the underlying fiber, optical routes are overbuilt with a 3dB to 5dB margin. For example, even though a route can handle 200G capacity on day 1, it will only be equipped with 100G. This is equivalent to holding additional inventory for over 10 years!

With Apollo programmable optical networking, it becomes possible to begin implementing "just-in-time margin", producing significant capital savings. In this scenario, the network operator provisions routes on day 1 with transmission rates that are close to what they can actually handle, with very little margin. Instead of overbuilding to a 3dB or 100% power margin, routes can rely on a much lower and more reasonable buffer, closer to a 1dB or 25% power margin.

When the transmission or the routes do eventually deteriorate, programmability can maintain the required throughput in a variety of ways. One way is to employ the flexible spectral grid to increase the channel width - for example, by opening the channel from 75GHz to 87.5GHz. As in the dynamic restoration example above, this gives the signal more room to breathe. This should be straightforward, since most fibers do not use the entire spectrum.

Another approach is to shift some of the line rate to another route that has spare margin. For instance, downgrade a 400G route to 300G, and shift 100G to another existing route. In other words, the network continually optimizes itself. When no amount of reshuffling can accommodate all the desired optical traffic, then the network optimization algorithm (perhaps based on machine learning at this point) simply orders new resources to expand the overall capacity.

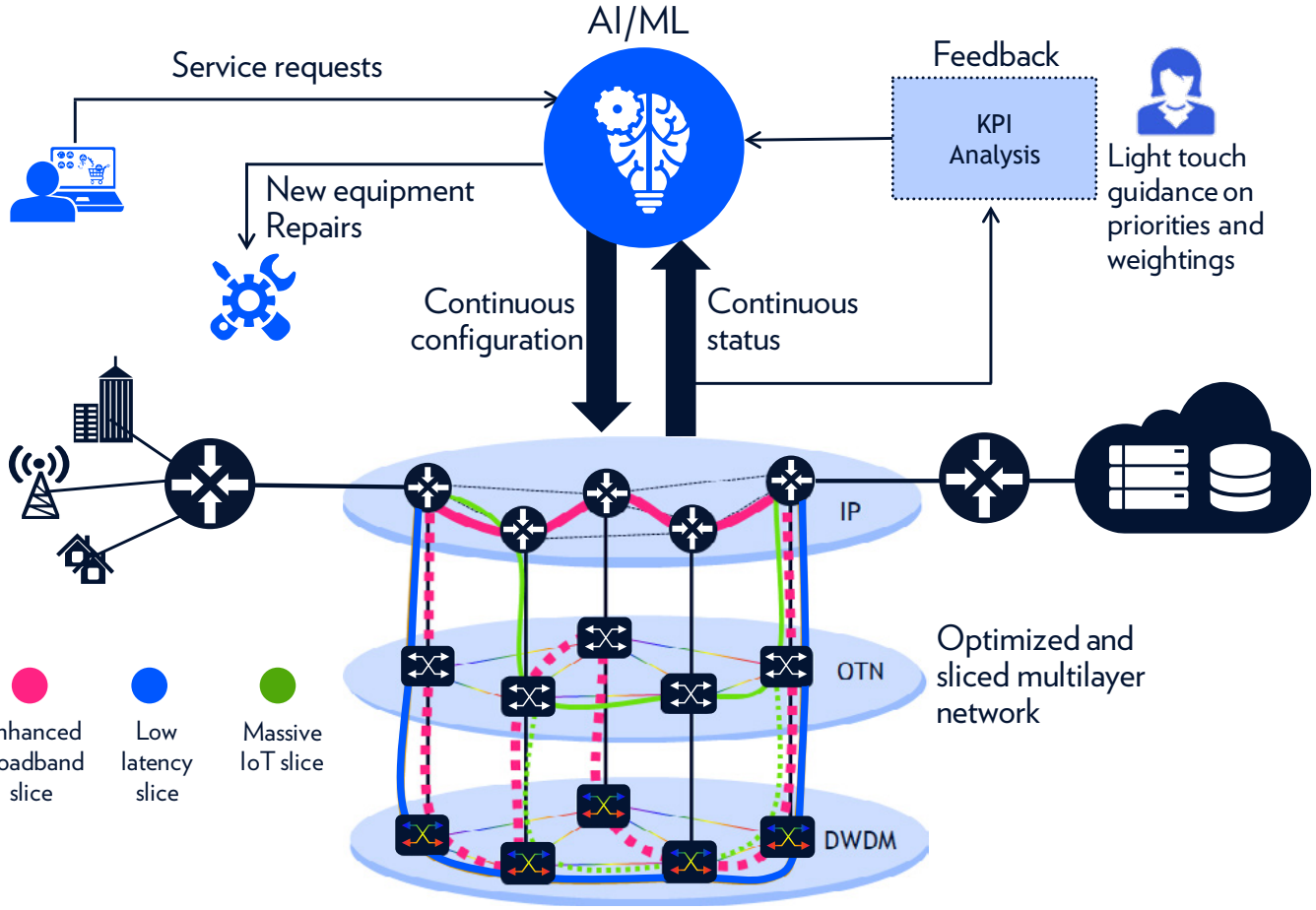


AGILE SELF-ORGANIZING NETWORKS

As we move deeper into a cloud-5G-IoT world, networks will need to deliver assured connectivity services dynamically to both human and machine end-users. The networks must satisfy multiple needs simultaneously bringing on numerous design challenges. They must be able to provision dynamically an array of services with different bandwidth, latency, and duration parameters, and assure their SLAs in the event of network problems. Current methods will undoubtedly result in a network that uses resources inefficiently, and will fall short of meeting user service expectations.

An agile self-organizing network is needed, where human intervention is kept to a bare minimum. For greatest efficiency, this will need to be a multilayer network. For more on this subject, see ECI's White Paper: "On the Road to Agile Self-Organizing Networks".

Apollo programmable optical networking not only makes your optical network more agile and efficient today, it establishes the foundation for next-generation self-organizing multilayer networks.



REVOLUTIONIZING OPTICAL NETWORKS

Apollo programmability transforms the optical network into a dynamic partner for the services layer, while saving on capital and costs.

Area	Challenge	Apollo programmable solution
Heavy traffic routes	Extracting the maximum capacity from every wavelength on heavy traffic routes, to minimize the number of expensive transponders.	Apollo programmable throughput optimizes transmission to the edge of the non-linear Shannon Limit, up to 600G, so that no channel capacity is wasted.
Service and network availability	Improving the effectiveness of dynamic restoration schemes, like WSON, which are often limited by only a few alternate lightpaths.	By combining programmable optical path routing with programmable throughput, Apollo dramatically increases the number of alternate lightpaths.
Customer-controlled bandwidth on demand	To fulfill short-term needs, business customers want to be able to 'dial-up' bandwidth dynamically.	Using the same programmable routing and throughput capabilities that enables dialing-up lightpaths, Apollo can extend bandwidth-on-demand services to end-customers.
Day-1 margin requirements	To account for future degradation, optical routes are overbuilt on day-1 with up to 5dB margin, wasting over half of available capacity.	Apollo programmable optical networks allow for low margin buffers on day-1, making best use of capital investments, and then shifting capacity around dynamically, as facilities degrade.
Multilayer optimized networks	Optical networks must become an open and dynamic partner with the packet layer, for overall service responsiveness and network optimization.	Through open and standard APIs, Apollo can create programmable, modular, and disaggregated optical networking solutions, which interwork smoothly with the packet services layer.

Contact us to find out how to build your Apollo programmable optical network

ABOUT ECI

ECI is a global provider of ELASTIC network solutions to CSPs, critical industries, and data center operators. With the advent of 5G, IoT, and smart everything, traffic demands are increasing dramatically, and network operators must make smart choices as they evolve their infrastructure. ECI's Elastic Services Platform leverages our programmable packet and optical networking solutions, along with our service-driven software suite and virtualization capabilities, to provide a robust yet flexible solution for any application. ECI solutions are tailored for the needs of today, yet flexible enough to meet the challenges of tomorrow. For more information, visit us at www.ecitele.com.