5G Transport
A Cost-Effective, Scalable Network Architecture Approach

Introduction

According to a recent Cisco Annual Internet Report (AIR), more than 70 percent of the global population – approximately 5.7 billion people – will have mobile connectivity by the year 2023. This connectivity includes 2G, 3G, 4G, and 5G. More than 66 percent of the global population will be Internet users. More users equate to more devices, all with an insatiable appetite for bandwidth to service their new business and consumer applications.

Some of the many bandwidth needs include video, online gaming, and virtual or augmented reality, challenging service providers with the need for high-density, high-bandwidth connections with low-latency performance requirements. Service providers therefore need to provide the bandwidth to support these requirements, but also meet stringent Service Level Agreements (SLAs) they demand.
Mr. Joachim Horn, Chief Technology and Information Advisor of PLDT and Smart Communications, the Philippines’ leading digital service provider, notes the realities of these challenges.

“With services being always on and customers expecting a consistent and superior level of experience, we are forced to relook at how we plan and design networks. We can no longer plan networks based on average load; we need to plan based on peak load.”

---

Joachim Horn
Chief Technology and Information Advisor of PLDT

For operators to capitalize on this growth and generate new revenue, they must re-architect their network with an eye on efficiency and scalability, while reducing their Total Cost of Ownership (TCO). Efforts to make 5G scalability requirements cost effective is a primary focus of network operators. The effort requires keeping close track of production costs per Gigabyte on the network, and it needs to be considerably lower very soon.

Evolution of the same architecture isn’t enough. Technology continues to evolve with Application Specific Integrated Circuits (ASIC) development following Moore’s Law and Dennard Scaling Law, while optical continues to push Shannon’s limits. From an operational perspective, we see a strong push towards software with automation enabled by Software Defined Networking (SDN), telemetry, machine learning, and artificial intelligence. Network architectures continue to see evolution around multiple layers of the network, from packet to Optical Transport Networking (OTN) to Dense Wavelength Division Multiplexing (DWDM) layers. Each layer evolves around capacity and flexibility, along with added complexities.

Service providers must support the following objectives:

- Enhance the user experience while maintaining or exceeding existing SLAs
- Simplify operational models
- Provide a utilization and cost-optimized network
• Build a highly scalable network, meeting tomorrow’s needs today
• Reduce time to market for new services
• Decrease total cost of network ownership

Meeting these objectives requires focus on four key areas:

1. Build faster networks – higher interface speeds, greater horizontal scaling to increase flexibility and, in essence, follow Moore's Law to lower the cost per bit
2. Improve network utilization and efficiency – enhance traffic engineering capabilities through a centralized controlling entity
3. Increase network operational efficiencies – enable service agility and improve time to market for new services and bandwidth scale-out requirements with a consistent, predictive, and simplified operational model
4. Optimize network architecture – maximize capacity within the constraints of physics while collapsing layers and reducing functional overlap. Reduce total cost of ownership with a reduction in power, footprint, and components, therefore enhancing mean time between failures (MTBF) and providing improved network simplification.

With these objectives in mind, providers must ask themselves if they can meet the demands of tomorrow with an evolution of their current network. Do they need to reexamine technology trends and rethink how to build their network to meet the objectives?

“For PLDT to meet the requirements of 5G, a new transport network was built (and) this transport network has huge capacity, commensurate with the invested resources on the radio network which is needed to commit to a consistent and superior customer experience,” adds Mr. Horn of PLDT. “The network needs to be more efficient and simplified, redundant layers removed, and the number of hops need to be reduced to allow for the most direct traffic path. At the same time, the network needs to allow for flexible placement of edge compute nodes for 5G low latency use cases. End-to-end network slicing capability is also key to support 5G services.”

Current Network Challenges

Traditionally, the focal point for network designs was at the specific network layer required to deliver the service rather than the service itself. Networks were built with the layer focus due to where we were in the technology life cycle and meeting SLAs for the associated service:

• Legacy TDM services required addressing as a silo
• Private Line services were a challenge needing dedicated resources.
• OAM provided from a layer perspective

Figure 1. Enabling high-capacity, service-focused network with total simplification
• Bi-directional, deterministic services provided via a network layer
• SLAs based on layered availability rather than service availability

Networks today are hierarchical and Multi Layered (ML) with each layer acting individually and operating on its own life cycle. These ML networks focus on the layer rather than the services due to technology limitations and the multiple services that require termination on different layers of the network. These network layers consist of OTN/TDM Switching, Packet Routing / Switching and DWDM / ROADM Switching to deliver these services as depicted in Figure 2b below.

These ML networks introduce complexity and redundant functions. The functions must be operationalized and have direct impacts on capital costs. Providers need simplified operations and cost-effective ways of delivering new and existing services with strong service-level agreements as well as enabling 5G and the associated new revenue generating opportunities.

Technology Enabling New Architectures

Technology is advancing, enabling innovation to address the challenges of today and meet future network requirements. These advancements include:

• Router capacity increasing multi-fold – recent industry announcements outline performance capacity greater than four times the largest platforms with a fraction of the footprint and power consumption. These units based on new Network Processing Units (NPUs) that enable multi terabits per second capacity are opening new doors of opportunity for new services and architectures.

• Commoditization of coherent optics – with OTT, web scale and service providers moving to coherent optics at 400G for distances above 10Km, along with the standard efforts, increases the adoption rate and enables higher volumes not seen before.
* Zero Density trade off pluggables with Digital Coherent Optics (DCO) – investments in 7nm processes enable the same form factor for both short reach and longer reach coherent optics in QSFP-DD form factor at 400G. With this common OIF standardized form factor providing zero density trade-offs today, it begs the question of why operate multiple platforms for switching, routing, and DWDM? Figure 4 depicts the expected investment to continue to drive the technology beyond 400Gig in both pluggable and embedded solutions.

* Segment Routing (SR), Enhanced Gaussian Noise Model (GNPy) and Common Industry Models
  - SR provides for source-based routing that leverages a path compute engine and simplifies routing layers to enable the move to SDN architectures and automation.
  - GNPy on the optical side provides for a common central evaluation of optical feasibility across multiple vendors. Developed in the Telecom Infra Project (TIP) Forum, it is based on the Enhanced Gaussian Noise Model.
  - Industry standardization on common models – the industry is pushing vendors for open solutions that enable disaggregation, which allows well-defined models to simplify the move to SDN and automation solutions. Such forums include but aren’t limited to OpenROADM, OpenConfig, IETF, and TIP.

* High Density Circuit Emulation (CEM) and Private Line Emulation (PLE)
  - Field Programmable Gate Array (FPGA) advancements enable 100s of Gbps of bandwidth per FPGA with massive cost per bit reductions in routing eliminating the need for a TDM/OTN switching layer.
  - Enhancements in Segment Routing and RSVP-TE provide TDM like routing, bi-directional, protection, reversion and matching SLAs allowing TDM and private line traffic be carried over a single packet / MPLS infrastructure shared with IP and VPN services.

* Innovation in SDN and telemetry with automation and life cycle management – A model driven approach for automation and self-optimizing networking

**Building 5G Transport Architecture of the Future**

SDN exists to address some of the complexities in operations, but the layers built into the network determine the complexity that SDN must overcome. Multi-layer networks add an extra dimension of complexity from an operational life cycle perspective – the planning, protection, and managing of the network.

As an example, existing Multi-haul solutions (currently deployed across Access, Metros, Long Haul, and Sub-
Sea systems) have greater flexibility to deliver higher capacity at optimal distances with greater than 6000 different set points. ROADMs have delivered on flexibility at the cost of complexity.

To deliver a network optimized around services that scale well beyond today’s capacity and performance requirements means taking advantage of innovations in technology. The 5G network architecture uses the following approaches to meet these needs:

- Supporting legacy TDM services and high-speed private line services over the packet switched network leveraging CEM and PLE to enable network simplification with a single network layer while meeting existing SLAs
- Integrating 400G Coherent optics into high capacity routing platforms with zero density trade-offs
- An end-to-end IP network with segment routing to enable a unified, policy-aware network architecture with seamless integration between the transport and the data-center domains
- Segment routing to provide the network with the most cost-effective end-to-end network slicing capability required for 5G networks
- Central SDN-based solution to enable a programmable network with automation platforms that utilize real-time network telemetry for advanced traffic engineering and control
  - Moving from a mesh-based ROADM architecture to a Hop-to-Hop (H2H) Digital ROADM architecture
    - Eliminates layers with operational simplification, reduced power and footprint
    - Provides optimal capacity by shortening endpoint distances
    - Gracefully transitions from bypass to H2H networks

The 5G Transport network provides simplification and enablement of true optimization as well as advanced service delivery. It supports not only the low-latency demands of new services and stringent 5G requirements, but also provides a future-proof, single-layered network.

**Benefits of 5G Transport Architecture**

As we continue to increase the data rates of the interface, we must contend with Shannon’s limits, which we’re already pushing up against. To overcome this, one of two things must take place:

---

© 2020 Cisco and/or its affiliates. All rights reserved.
1. Pick up and move cities closer together (not likely!)
2. Shorten the distance between endpoints

Shortening the distance between endpoints occurs with a Hop-to-Hop (H2H) architecture. H2H allows true network capacity optimization with network simplification by collapsing network layers and eliminating the complexity and redundant nature of Multi-Layer networks.

Figure 7 below provides a general comparison of three models for a network, with relative costs defined for the three different architectures:

1. Hollow Core (HC) – Hub and Spoke type architecture; dedicated wavelength per terminating site
2. Optical Bypass (OB) – Based on traffic demands optimally bypass a site to optimize capacity
3. Hop to Hop (H2H) – Point-to-point architecture where all wavelengths terminate at all sites

Even though H2H requires more interfaces than either HC or OB, we see relative cost savings based on converging the layers, moving to simplified filtering structures, and using industry standard 400Gig ZR+/ interfaces. Based on modeling of real service provider networks for the different scenarios we see a relative

<table>
<thead>
<tr>
<th>Distance / Capacity Optimization</th>
<th>HC</th>
<th>OB</th>
<th>H2H</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP EX</td>
<td>HI</td>
<td>MED</td>
<td>LOW</td>
</tr>
<tr>
<td>OP EX</td>
<td>MED</td>
<td>HI</td>
<td>LOW</td>
</tr>
<tr>
<td>Scalability</td>
<td>MED</td>
<td>MED</td>
<td>HI</td>
</tr>
</tbody>
</table>

*Based on cost-optimized optics and routing capacity*

© 2020 Cisco and/or its affiliates. All rights reserved.
savings in the order of 40% over a Hollow Core network and an approximate savings of 34% over an optimal bypass network. From the traffic-routing diagrams in Figure 8, you can see the simplification an H2H network brings to traffic routing, which provides overall simplification for the network and life cycle management.

A 5G Transport architecture provides:

• Decreased total cost of network ownership
  - Reduction in power and footprint via integration and elimination of redundant layers
  - Automation increases the useful life of network capacity by ensuring full utilization of transit routes with dynamic traffic allocations.

• Network simplification
  - Single layer H2H network
  - Simplified planning, design, activation, management, and troubleshooting

• Meet and exceed existing service level agreements
  - Circuit emulation and private line emulation to address legacy TDM and private line services
  - Reduction in components improves resiliency and reduces mean time to repair

• Improved time to market of new revenue generating services
  - Service focused network
  - Single layered network
  - Built for automation and telemetry functionality

• Optimized fiber capacity
  - Overcome Shannon’s limits – H2H Architecture decreases optical distances and optimizes the interface capacity.
  - Simplify all the set points of an interface.
Conclusion

Multi-layer networks have demonstrated their ability to meet the industry demands of today’s telecommunication service offerings. While demand for bandwidth continues to grow, the multi-layered approach of today’s networks restricts the service providers’ ability to advance their network. As technology has evolved to enable new ways of delivering services that meet the stringent service level agreements, service providers are re-examining the network architecture to create a more simplified network with reduced total cost of network ownership.

The 5G Transport architecture provides a simplified network by removing redundant layers, legacy technologies, and overlapping functionality. It provides unprecedented capacity and scalability, allowing customers such as PLDT to enhance customer experience. Segment Routing (SR) simplifies the underlay, making it easier to automate through a centralised SDN function and providing a more efficient operation. 5G networking of the future provides end-to-end network slicing and low latency while drastically enhancing customer experience and reducing the cost to serve.