Technology Ecosystem Evolution for Packet Optical Transport 2.0

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ABSTRACT

Packet optical transport systems (POTS) were created to address the convergence of TDM and packet technologies transmitted over a single common optical core. An ecosystem of **components, products and applications**, as well as support and infrastructures was created to deliver the POTS promise. As we are entering the next-generation of POTS, the question is: what changed in the ecosystem?

This article covers the latest advancements in POTS and highlights the evolutions from the first generation. Benefits of implementing POTS in the core network having increased with POTS 2.0, practical examples of these benefits will be covered throughout the document. As the POTS ecosystem has also evolved, we will look into the paths of influence within the POTS technology ecosystem–and more specifically the evolution of the POTS network test ecosystem–and see how the evolution of technology supports the deployment of second-generation POTS.

1 PATHS OF INFLUENCE WITHIN THE POTS TECHNOLOGY ECOSYSTEM

With the emergence of IP as the technology to deliver all services, service providers have converted their core network to support both TDM and packet technologies over a single common optical core. The transport convergence provided the environment for POTS to emerge as a viable architecture. To build this new network architecture, an ecosystem was created, leveraging multiple technologies to deliver on the promise of a converged core.

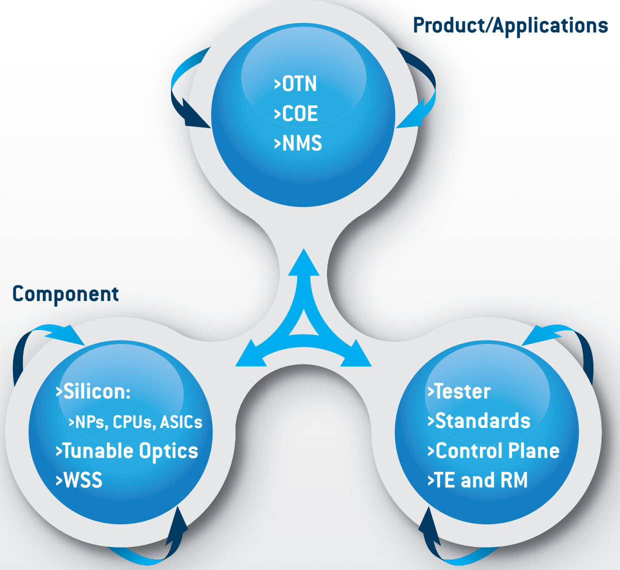

Figure 1. Path of influence within the POTS technology ecosystem. [2]

The path of influence is a conceptual model [1] that was introduced to understand the technology evolution that highlights dynamic and highly interdependent relationships among multiple technologies. Taking into consideration the interdependent nature of technology evolution, the authors identified the three roles of technologies within a technology ecosystem: components, products and applications, as well as support and infrastructure. Technologies within an ecosystem interact through these roles and impact each other's evolution.

As illustrated in Figure 1, when applied to packet optical transport systems [2], this interrelationship of the different roles drives and impacts the evolution of POTS.

1.1 COMPONENTS

The components role is a mix of important technologies leveraged to create POTS network elements. Since its introduction, the POTS components role has evolved to address the new technology requirements brought up by the other roles. For example, advancement in wavelength-selective switches (WSS) allows for simpler ROADM architectures, therefore enabling POTS network elements with reduced power and cooling consumption.

1.2 PRODUCTS AND APPLICATIONS

The products and applications role is assumed by the optical transport network (OTN), as well as the connection-oriented Ethernet (COE) and network management system (NMS). Technologies residing in the different components of the network elements are at the core of POTS. The evolution of these technologies has also enabled POTS to grow into a second generation. With IP convergence used to deliver applications, CoE and OTN have evolved to provide the underlying technologies to make POTS 2.0 the core network architecture to redefine transport networks.

1.3 SUPPORT AND INFRASTRUCTURES

The support and infrastructures role is the glue within the ecosystem. From test equipment used at any stage of the lifecycle, to standards and control plane, to traffic engineering and resource management, this role is influenced by the others, which is why it must also evolve. The following chapters take a look at the network test equipment community of the POTS ecosystem, explaining how its latest developments have influenced this role.

2 WHAT MAKES A PACKET OPTICAL TRANSPORT NETWORK?

Before looking into the details of the network test ecosystem, we will define the packet optical transport system, at least from a test and measurement perspective. Traditionally, a POTS is a packet-based transport infrastructure running on top of an optical transport network (OTN), with an underlying ROADM network. This means that the transport infrastructure is capable of transmitting TDM-based services at the same time as packet-based services. Once the TDM or packet services are mapped into an OTN payload, they are transmitted across the physical layer in a pure optical signal, which means that there is no O-E-O conversion.

As there is a maximum number of wavelengths that can be carried over the physical layer, the only scalability option is to augment the transmission rate, which means that 40G and 100G technologies must be implemented. These new technologies have greatly influenced the components role of the POTS ecosystem, and have been instrumental into the migration toward POTS 2.0.

In practice, there is a component that is sometimes forgotten–the fiber network.

The current fiber plan saw its largest expansion during the telecom explosion of 2000-2001. Then, service providers were installing whatever fiber they could put their hands on. But now, do they have a good assessment of the fiber buried in their network? Can they certify that each section connecting their ROADM network elements can transmit at 10/40/100G? This is why we believe that the fiber network must also be taken into consideration when discussing POTS and network test ecosystems.

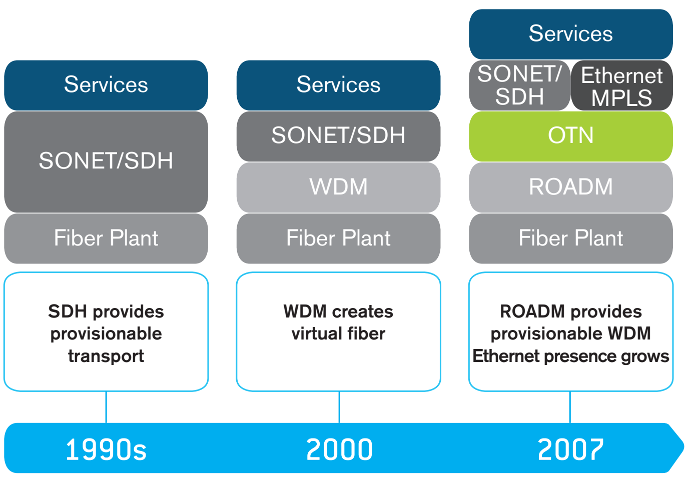

Figure 2. The evolution of optical networking, prior to the POTS era.

Figures 2 [3] and **3 [3]** show how optical networking has evolved, from SONET/SDH deployed in the 1990s up to now. Focusing on the advancement of optical networks until POTS 1.0, Figure 2 examines the development of networks, from the TDM-centric architecture (SDH) to a pre-POTS one. Coupled with ROADMs, the introduction of OTN in 2007 provided the building blocks to create POTS. Figure 3 shows the Ethernet/MPLS-only layer implemented in 2010. This is the turning point where service providers were delivering a packet-based infrastructure over a TDM. It is also the date where multiple network element functions were integrated into a single platform. With these building blocks finally in place, POTS 1.0 was finally available at a large scale.

3 WHAT MAKES A POTS 2.0 NETWORK?

The answer to this question resides in Figure 3. Services are migrated to an IP-centric topology, so voice, video and all of the corporate applications are now IP-based. Looking at wireless networks, LTE/4G technologies are now available to the general public. To address business and consumer services, POTS therefore needs to be IP-enabled.

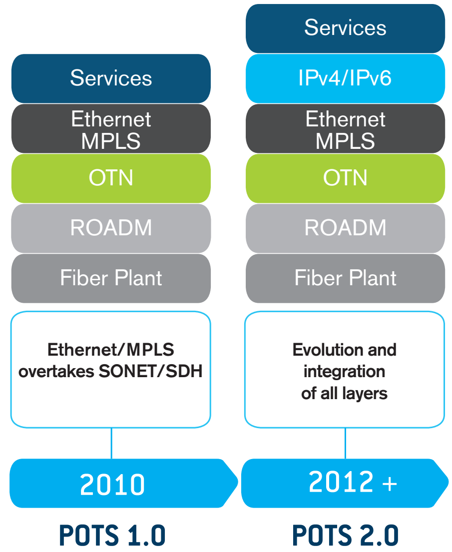

Figure 3. Figure 3. Optical networking evolution to POTS x.0.

Time-to-market optimization and dynamic network management are becoming the norm–at all layers. The only way for service providers to differentiate their offering and keep up with their competitors is to implement a control plane at all network layers.

OAM is also present in the different transport technologies. Implementing OAM functionalities at all layers is a challenge from a POTS perspective, and could be the deciding factor when it comes to integrating POTS into service providers' operational processes.

On the data switching front, all MEF services (E-line, e-LAN, E-tree and E-Access services) must be offered. As the first generation of Ethernet services were mostly transparent, key performance indicators (KPIs) were assessed for the complete Ethernet connection. With the deployment of Carrier Ethernet 2.0, not only have services evolved as more and more applications are being deployed over an Ethernet-based network, but KPIs now need to be measured on a per-service/ per-class of service basis. From a service activation perspective, test methodologies have also evolved. There is now a shift from legacy test methodologies, such as RFC 2544, to the ITU-T Y.1564 methodology adapted to current Ethernet services.

From an OTN perspective, the capability to efficiently deliver services in native format has been an issue ever since Ethernet started being deployed as a core technology. With the latest revision of the ITU-T G.709 OTN recommendation and the additions of ODU0 and ODUflex, Ethernet services can now be delivered efficiently in an OTN core. Carrier Ethernet-centric core architectures will therefore require the implementation of ODU0, ODUflex and the capability to cross-connect payloads at the ODU level.

ROADM networks must become cost-efficient. In this case, less is more. By deploying colorless, directionless and contentionless ROADMs, service providers will have a flexible transport platform to build for the future.

Finally, POTS networks can switch any wavelength to any fiber. The main issue with this functionality is that each fiber link must be capable of transporting 40G and 100G wavelengths. As the rate of the optical signal is going up, the 50 GHz optical filters found in ROADM networks impact the wavelength OSNR.

4 POTS 40G/100G NETWORK TEST ECOSYSTEM

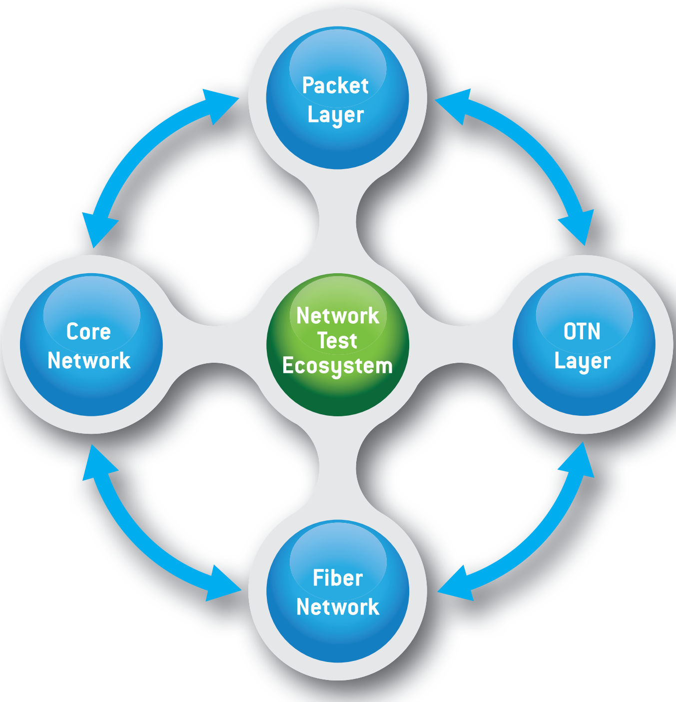

Figure 4. The POTS network test ecosystem.

The POTS network test ecosystem is composed of four distinct roles: the packet layer, the OTN layer, the core network and the fiber networks.

4.1 THE PACKET LAYER

The packet layer is based on current Carrier Ethernet 2.0 and MPLS/MPLS-TP capabilities. From a test and measurement perspective, service QoS/SLA validation has experienced a major evolution. In the TDM world, everything is bit-oriented–a reality reflected by key performance indicators. Ethernet technology has brought a frame-based architecture. With frames validated at every layer 2 processing device, an eventual transmission error will be detected, and the frame discarded. Using BER as a KPI no longer makes sense, as the bit error would never get through the network.

To reflect this technology transformation, KPIs had to evolve: BER was replaced with frame delay, frame-delay variation and frame loss ratio. As first-generation Ethernet services were mostly transparent, KPIs were assessed for the complete Ethernet connection.

With the deployment of Carrier Ethernet 2.0, not only have services evolved, as more and more applications are being deployed over Ethernet-based networks, but KPIs must be measured on a per-service/per-CoS basis.

4.2 THE OTN LAYER

The OTN layer is the most important one from a POTS perspective. This technology enables the transport of any service over an optical network. Without it, there would be no POTS. That being said, the OTN layer is not really easy to test, as it is embedded into the ROADM network.

4.3 THE CORE NETWORK

The third role found in the network test ecosystem is the core network. Service providers are using multiple networks to deliver services. From access to metro to long-haul, they deploy core architectures that enable them to efficiently deliver services. Each core architecture has its own features that serve to deliver OPEX/CAPEX-friendly services. Again, network resiliency and network quality are essential for ensuring that services are delivered according to SLAs.

4.4 THE FIBER NETWORK

The fiber network is at the base of the network test ecosystem. Optical signal-to-noise ratio (OSNR) measurement is fundamental to ROADM quality assessment. As wavelengths can be routed through any fiber in the network, multiple paths can be used to deliver services. Since delivery is dynamic, the wavelength can be routed through multiple filters, therefore hiding the signal into the amplified ROADM noise. To properly quantify OSNR in a ROADM network, service providers must verify that their optical spectrum analyzer is ROADM-friendly and can remove the in-band noise from the signal. Ultimately, the POTS network is as good as the fiber network. Characterizing chromatic (CD) and polarization mode dispersion (PMD) is a must to ensure that the link/network can deliver services.

5 SUMMARY

The road to POTS 2.0, although possible with today's technologies, will not be an easy one. The advent of the MEF's Carrier Ethernet 2.0 means that service providers' must now deliver multiple classes of service, manageability and the capability to interconnect with wholesale providers. With these new capabilities, service providers will be able to offer new products like bandwidth-on-demand and cloud-based applications, in addition to their current mobile backhaul and business services. To deliver these new MEF-based services, they will need a single, flexible core architecture.

And, to achieve this over a single converged network, OTN will need to be leveraged. The newly introduced ODU0 and ODUflex mappings provide the flexibility and efficiency required to transport Ethernet-based services. With the introduction of OTU3 and OTU4 interfaces, OTN has the infrastructure to deliver 40G and 100G rates.

To offer bandwidth-on-demand, dynamic optical network provisioning, and deliver on their promises, new-generation ROADMs must be flexible, colorless, directionless and contentionless.

Each element of the POTS network test ecosystem is important and can surely cause major headaches. This is why testing and monitoring the POTS network throughout its lifecycle is how service providers can deliver quality services.

In summary, POTS 2.0 provides a converged transport platform to deploy legacy, current and future applications/services. With the evolution of POTS, we now have a core network technology that is simple and efficient, and this is exactly how service providers were hoping things would turn out.

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Printed in Canada 12/04

Assessing Next-Gen Networks