TRANSPACKET
white paper

Transport alternatives for wavelength services

A carrier's guide to wavelength service deployments

Executive summary
Datacenters trigger a growing need for dedicated capacity across fibre-optical networks. Wavelength services are offered to datacenters and service providers requiring a dedicated high capacity with strict latency requirements. However, a wavelength service is typically not a physical optical transparent wavelength through the carrier's network. This whitepaper discusses wavelength service transport methods and requirements. Virtual wavelengths fulfill the requirements of a wavelength service, while avoiding dedicating wavelengths or fibers across the network, thus considerably lowering the carrier's production cost.

Transport alternatives for wavelength services

A carrier's guide to wavelength service deployments

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Introduction

Datacenters are one of today's most important drivers for bandwidth. Typical needs involve high capacity low latency connections for inter- and intra- datacenter connectivity. Wavelengths across fibre-optical networks are often the preferred choice of transport for this purpose because it enables a dedicated bandwidth with low and fixed latency. Other prominent wavelength service customers are service providers and large businesses in need of dedicated high-capacity connectivity. These customers typically rent wavelengths from carriers with both national and international fibre-networks.

Carriers with fibre-optic networks, especially the Tier 1´s, are offering wavelength services to their customers. The name of the service stems from the wavelength in the Wavelength Division Multiplexing (WDM) technique, enabling physical wavelengths to be put up across an optical network. However, there is not a consistent definition among carriers on what the wavelength service actually is and what it contains. Typically, the service is not an optical input to the carrier's network, but involves an OTN-framing and a dedicated transport-channel across the carrier's network.

A dedicated transport-channel fulfills the capacity and latency requirements of wavelength services. It does however have a high production cost since vacant capacity cannot be utilized for lower priority services, like for e.g. VPN and Ethernet-services. On the other hand, VPN and Ethernet-services do not fulfill the latency and capacity requirements of the wavelength service. Virtual wavelength services are based on the TransPacket FUSION network technology enabling Ethernet to fulfill the capacity and latency requirements of a wavelength service. Since dedicating wavelengths or similar is then no longer needed, it enables the carrier to bring down production cost to the level of an Ethernet service.

Wavelength service transport alternatives

This section brings an overview of different transport-methods for offering wavelength services. What type of service might be precisely defined as a wavelength service or not is a long story and perhaps more a matter of definition. What is more important is the user of the service and the properties the user requires from the service. Typically, the applications of such services are both internal by the carrier, connecting routers or switches, and external customers buying wavelength services. From a user-perspective, how the service is actually produced becomes less important, what matters is what type of service actually is being offered and that this fulfills the user requirements. In this section we discuss the properties of different types of wavelength service or "static-line" type of offerings and explain pros and cons for these services seen from both the one who is offering the service (the carrier) and the user of the service (customer) perspective.

Alien-wavelength

A native wavelength service has an optical input to the optical network, and is a physical wavelength without framing. It is typically fed directly into the optical multiplexer of a Coarse WDM (CWDM) or Dense WDM (DWDM) system, as illustrated in figure 1. If a variable optical attenuator and power-monitoring device is inserted between the customer and the multiplexer, the maximum power of the wavelength can be controlled. The wavelength is set up end-to-end through the network, passing only optical network elements, like e.g. optical multiplexers, optical amplifiers and optical switches. In a carrier's perspective this type of service is often called an "alien-wavelength service" since the carrier has not full control of parameters like protocol, bitrate, customer's wavelength, spectral width, quality and power of the wavelength being transported in the network. The carrier is then unable to guarantee the quality and performance of the service. Therefore, large carriers typically do not offer this service to external customers. This may however be a viable method for internal use by the carrier, if e.g. the wavelength occurs at an output interface of one of the carrier's switches where the carrier has full control on wavelength and output power at its interface.

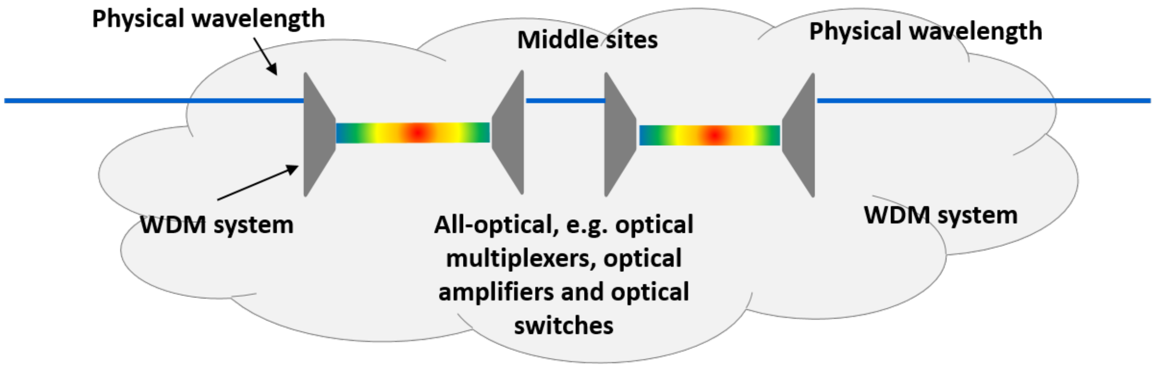

Figure 1: Feeding an alien-wavelength all-optically into a WDM system.

Multi-format Transponder-based wavelengths

If the carrier has transponders at the ingress and egress of the network, as illustrated in figure 2, it enables the carrier to have control of parameters like power, quality, spectral width and wavelength. This is because a transponder does full regeneration of the signal (3R) and offers remote monitoring capability. The wavelength may then be routed end-to-end through the network all-optically. The content of the wavelength (i.e. protocol format of the signal) is however transparent, and not monitored. Hence, the carrier offering the service is not able to give full quality guarantees, e.g. the link may be running with bit-errors. Comparing with the alien wavelength approach, there will be a limitation on both minimum and maximum bitrate supported. This is partly given by the transponders ability to regenerate signals of different bitrates, but chromatic dispersion and other physical impairments in the optical path also play a key-role for distance limitations on bitrates of 2.5 Gb/s and beyond. Carriers do, however, typically not see this as a major drawback since it is desirable to offer capacity services rather than the "raw material" like a fibre or wavelength.

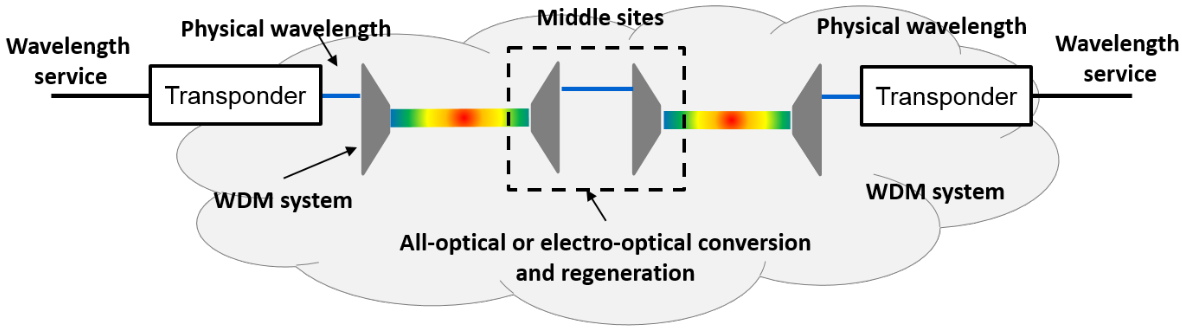

Figure 2, Wavelength service fed through a regenerative transponder into a WDM system.

OTN-transport

Since carriers are concerned about security, reliability and Quality of Service (QoS) of their service offerings, offering full transparency is often not preferred. By using multi-format transponders, the carrier controls physical parameters like wavelength and power, avoiding interference with other wavelengths, but is not able to detect bit-errors and supervision of the content of the signals. However, if the transponder is performing OTN-framing, like illustrated in figure 3, it enables the carrier with full Operation Administration and Monitoring (OAM) functionality, ensuring the QoS of the service and issuing alarms if the expected QoS is not met. Even if this type of service actually is a type of TDM service and not protocol and bitrate transparent, like the alien-wavelength in principle is, this is what major T1-carriers typically call a wavelength service.

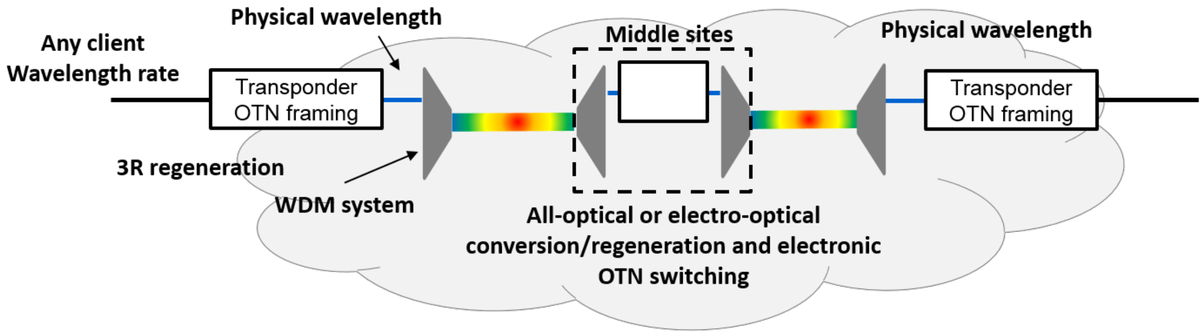

Figure 3, Wavelength service fed through a transponder performing OTN framing, enabling OAM capability. The OTN wavelength may be switched within the network using all-optical switching or using an electronic OTN cross-connect.

OTN sub-wavelengths

However, since there are a limited number of wavelengths in the network, occupying a wavelength through a carrier's network is resource demanding and comes at a corresponding expense. This expense becomes too high for low bitrate wavelengths. The next step for the carrier is therefore to offer a sub-rate of the wavelength, also called sub-wavelengths. OTN enables dividing capacity into chunks of granularity 1 Gb/s using a muxponder, as illustrated in figure 4. Lowest bitrate supported is 1 Gb/s and the ODU-flex format allows framing of signals with any bitrate between 1 Gb/s and 100 Gb/s. Hence, a higher utilization of the physical wavelength can be achieved by multiplexing several OTN channels into a wavelength channel. Since the characteristics of these sub-wavelength services are similar to the characteristic of the OTN based transponder wavelength service, carriers may also offer the sub-wavelengths as wavelength services.

The OTN approach is however still Time Division Multiplexed (TDM)-based, not offering the throughput efficiency of packet switched networks; packet switched networks offer statistical multiplexing, enabling oversubscription and highly cost-efficient networks.

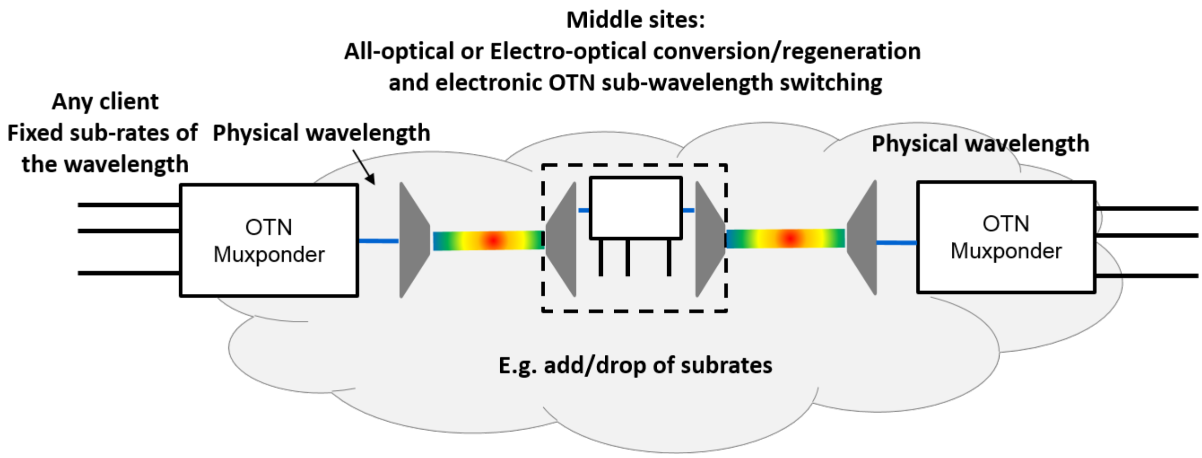

Figure 4, Wavelength service based on "sub-wavelengths" fed through a muxponder performing OTN framing, multiplexing of channels with 1 Gb/s granularity, and OAM. At intermediate nodes in the network, wavelengths and sub-wavelengths may be switched electronically in OTN cross-connects.

Reserved bandwidth across packet switched networks (VPN services)

Packet networks have the ability of handling oversubscription, enabling higher throughput efficiency than networks offering any type of wavelength service. By reserving bandwidth across an IP/Ethernet based network, loss-free connections with a guaranteed bandwidth can be achieved across the packet network. However, the packet network does not offer the same characteristics as the wavelength or TDM based networks. The latency is not fixed, and typically the latency may be significantly higher. Furthermore, there are dependencies between the services; latency and latency (packet delay) variation (PDV) in the packet network depends on the load of the network. Hence, carriers do normally not offer this type of service as a wavelength service but as a VPN service. The drawback of this type of service is, as mentioned, that it does not allow full isolation between the services and an additional lack of timing-transparency due to the PDV. I.e. the service may not be suitable for transparent transport of customer traffic containing timing-critical traffic like e.g. IEEE 1588 synchronization packets.

Virtual wavelengths

While the service-offerings discussed so far show a tradeoff between throughput efficiency, service transparency and isolation, virtual wavelengths avoids this tradeoff. Virtual wavelengths are enabled by the TransPacket FUSION technology. It allows transport across Ethernet networks with fixed, low latency, i.e. timing transparency, and without packet loss. Hence, transport characteristics are similar to TDM based networks, while throughput efficiency is similar to the packet network. As illustrated in figure 5, carriers may offer virtual Ethernet based wavelengths of any capacity up to 100 Gb/s, similar to the OTN-based approach in figure 3.

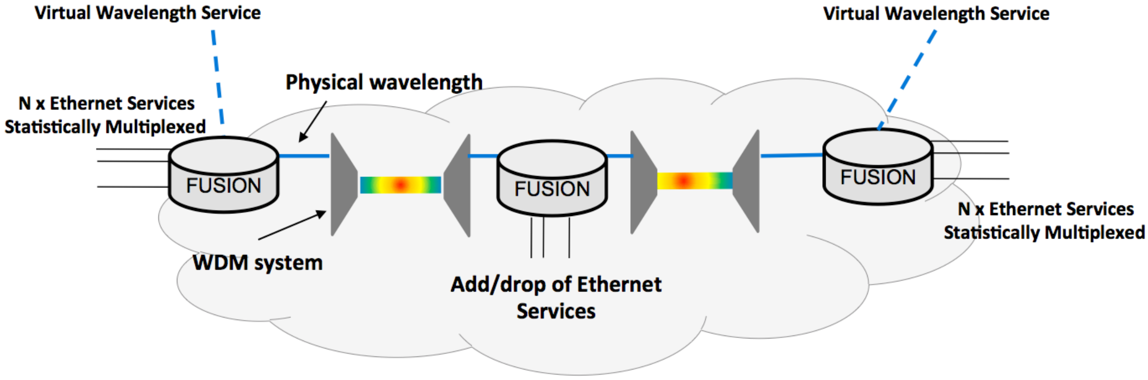

Figure 5, Wavelength service based on a virtual wavelength interface with the same bitrate as the physical interface. Additional traffic may be statistically multiplexed into the wavelength through additional Ethernet interfaces. The virtual wavelength approach also offers OAM capabilities.

Furthermore, as illustrated in figure 6, virtual wavelengths may also be offered for sub-rates of the physical wavelength, similar to the OTN sub-wavelength approach illustrated in figure 4. However, in difference from OTN, FUSION in common with packet networks, allows efficient utilization of the network through statistical multiplexing and if desirable also oversubscription. As for conventional Ethernet networks, additional lower priority traffic may be added through interfaces of any rate, e.g. 1, 10 or 100 Gb/s Ethernet.

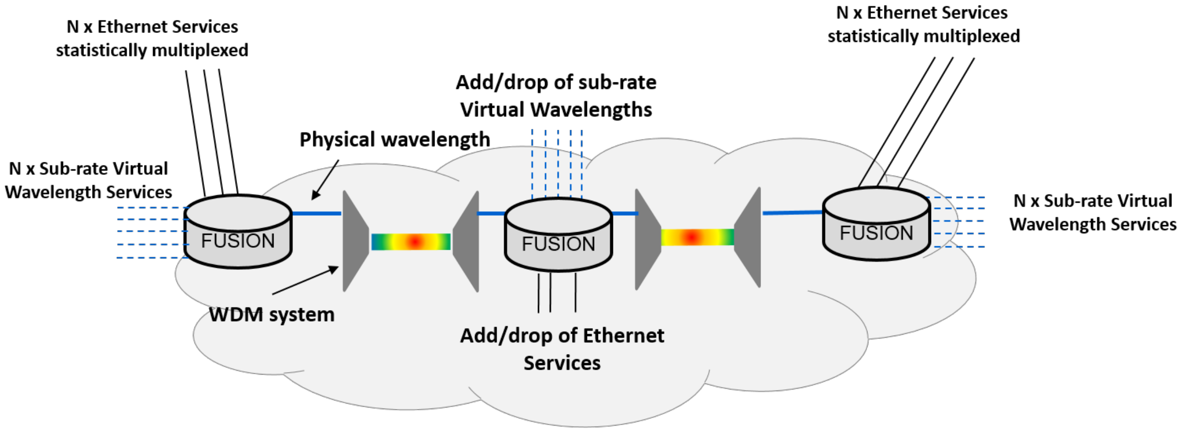

Figure 6, Wavelength service based on offering multiple Ethernet virtual wavelengths of lower rate than the physical wavelength. Additional traffic may be statistically multiplexed into the wavelength through additional Ethernet interfaces of any rate similar or lower than the rate of the physical wavelength. The virtual wavelength approach offers strong OAM capabilities.

FUSION H1 virtual wavelength service network example

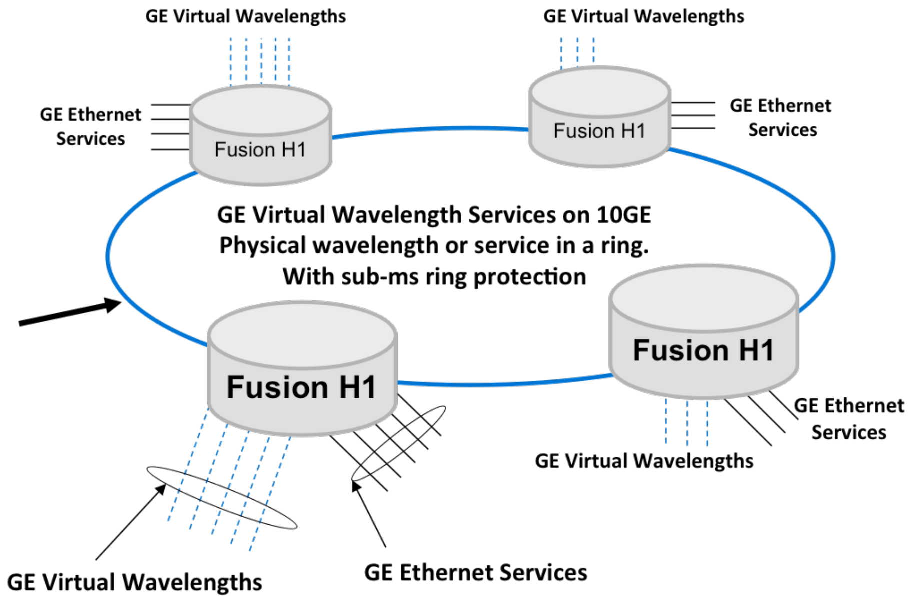

Figure 7, Virtual wavelength services enabled by network applying TransPackets FUSION H1 product.

The TransPacket FUSION H1 node enables 10GE (10 Gb/s Ethernet) virtual wavelength services or sub-rate GE (1 Gb/s Ethernet) Virtual Wavelength Services over an Ethernet based 10GE physical wavelength or wavelength service. On top of the virtual wavelength services, GE Ethernet Services are statistically multiplexed on the same physical wavelength, transparent to the wavelength service. This enables throughput as for packet networks while offering wavelength services. Figure 7 illustrates an example application deploying Fusion H1 in a ring-network offering sub-rate GE virtual wavelength services. Add/drop of the virtual wavelengths enables mesh connectivity in the network, i.e. for any type of logical topology. All other GE ports in the H1 nodes can be then used for offering additional Ethernet Services, which are statistically multiplexed onto the same 10GE wavelength service. Furthermore, the FUSION ring protection switching mechanism enables record-low sub-ms convergence time, protecting the virtual wavelengths in the ring. The same ultra-fast scheme is also offered for protection of the Ethernet Services.

Summary

Wavelength services offered by carriers are usually not all-optical physical connections into the optical network. Transponders or muxponders are applied at the edge of the network for enabling control and monitoring of the signal entering and exiting the network. This type of transport typically applies OTN framing and offers fully dedicated and isolated connections with zero packet loss and a low fixed latency. However, the throughput efficiency is low because the multiplexing is static and not statistical, as in packet networks. Packet networks on the other hand have so far not been able to offer strict latency characteristics as in TDM and wavelength based networks. TransPacket's FUSION technology allows services with TDM characteristics in Ethernet networks. Virtual wavelength services perform as wavelength and TDM services. However, in difference from the wavelength and TDM networks, FUSION allows the throughput efficiency of the packet networks through full utilization of each of the wavelengths using statistical multiplexing.

Hence, using FUSION technology, the carrier's production cost of a wavelength can be brought down to the level of a VPN connection. The characteristics of the different wavelength transport methods has been outlined in this white-paper and is summarized in table 1.

Property		**Alien**	**Transponder**	**Muxponder**	**Fusion**
Transparency	**Bitrate**	Yes/distance (e.g. 10G might need dispersion compensation)	No/weak	No/weak	No
	Protocol	Yes	Depends on product	Depends on product	Ethernet
	Timing	Yes	Typical	Product dependent	Yes
Reliability & Performance	**Loss detection**	No	Depends on product	Yes	Yes
	Protection	No	Product dependent	Product dependent	Yes, ring or 1+1, (ultra-fast, sub-ms)
	Monitoring capability (OAM)	Weak (e.g. power monitoring)	Medium, high for OTN-based	Medium, high for OTN-based	High
Cost		High (dedicated)	High (dedicated)	Medium (dedicated)	Low (shared)

Table 1. Comparison of Wavelength service solutions based on 1) transparency in terms of bitrate, protocol format and timing; 2) reliability and performance in terms of bit errors and packet loss, redundancy and protection switching, monitoring of service; 3) The carriers production-cost of the service.