FUJITSU

Application Note

Increasing Capacity on your Existing Optical Line System to 100G+

Application Benefits

- Reclaim wavelengths and improve spectral efficiency
- Extend the life of existing line systems and avoid forklift upgrades
- Keep existing fixed 50GHz grid plan while deploying 100G+ wavelengths
- Deploy 400GbE services over a fixed 50GHz grid network

Functional Elements

- FLASHWAVE 9500 PONP
- FLASHWAVE CDS Micro PONP
- 1FINITY T300, T310 and T700 Transport blades

The market for optical transport services is quickly moving to 100G and beyond. Sales of 10G transponders is expected to decline by 12% each year over the next four years. Meanwhile, 400GbE transceivers are growing at 37% CAGR (compound annual growth rate) through to 2025, and 100G+ transponder port shipments are growing at 31% CAGR through to 2024.

Given that most optical line systems (OLS) in operation today are still operating on the fixed 50GHz grid plan optimized for 10G wavelengths, what are the options for migrating the network to support higher speed services – short of a rip-and-replace upgrade of the network?

Mixing 10G and 100G+ wavelengths

What is the highest speed signal that can be transported in a 50GHz optical channel? As Table 1 below shows, 200G is the maximum. This applies when multiplexing 1GbE, 10GbE and 100GbE services on to a 200G wavelength, but even a 400 GbE service can be split across two 200G wavelengths in order to fit on 50GHz channels.

WAVELENGTH BIT RATE	MODULATION (HIGHEST)	CHANNEL SIZE
10G	OOK/NRZ	50GHz
100G	DP-QPSK	50GHz
200G	DP-16QAM	50GHz
300G	6b4D-2A8PSK+, DP-16QAM	75GHz
400G	DP-32QAM	75 - 87.5GHz
600G	DP-64QAM	87.5GHz

Table 1: Which speeds can fit in a fixed 50GHz grid network?

Problems arise, however, when mixing non-coherent (10G) signals with coherent (100G+) signals over the same fiber. Coherent requires a higher optical signal-to-noise (OSNR) than 10G OOK/ NRZ modulated signals. In fact, they are impaired by 10G signals. Non-linear effects such as self-phase modulation (SPM), cross-phase modulation (XPM), and four wave mixing come into play especially at higher launch power levels. While linear effects like chromatic and polarization dispersion of 10G signals can be managed and mitigated by DCMs, non-linear optical effects are difficult to compensate for.

The dispersion compensation modules (DCM) commonly used on 10G fiber links also cause problems for coherent signals. This is because coherent transponders already have dispersion compensation built-in. The DCMs are not required and they actually add a non-linear noise penalty to the coherent signal

These effects may be tolerable for shorter fiber spans carrying coherent signals that use a lower modulation (i.e. lower bit rate but more robust, for example DP-QPSK instead of DP-16QAM). They become more pronounced and generally the signal degrades beyond repair for longer spans or higher speeds (200G wavelength using DP-16QAM or higher). The type of fiber cable used is also a factor. To identify which fiber spans and circuits pose the greatest risks, a network audit ought to be undertaken prior to planning the migration.

Despite the potential complexities, Fujitsu offers a path for migrating OLS networks to 100G+ in three straight-forward steps.

Extending the fixed grid ROADM network

Step 1: Free up fiber spectrum with a 100G muxponder that replaces multiple 10G transponders

The first step is to eliminate 10G wavelengths to make the network more coherent. This removes a key source of signal degradation for 100G+ wavelengths. Multiple 10G wavelengths can be migrated to a single 100G wavelength with a suitable muxponder. This step also creates some important benefits:

- Reclaims optical channels on fiber spans, potentially avoiding the need to light up additional fibers
- Frees up card slots and ports for future expansion
- Extends operating lifespan of existing network

The Fujitsu FLASHWAVE® 9500 and CDS packet optical networking platforms (PONP) feature 10GbE cards for this purpose. The cards multiplex 10 x 10GbE ports onto a 100G optical wavelength.

Alternatively, when higher port density or the use of a 200G wavelength is desired, the Fujitsu 1FINITY T310 (see Table 2) is recommended. This transponder multiplexes 10 x 10GbE ports onto a 100G wavelength, or 20 x 10GbE ports into a 200G wavelength. Because it has two line-side ports, a single 1FINITY T310 can terminate traffic on a 100G wavelength from two different sites for added flexibility.

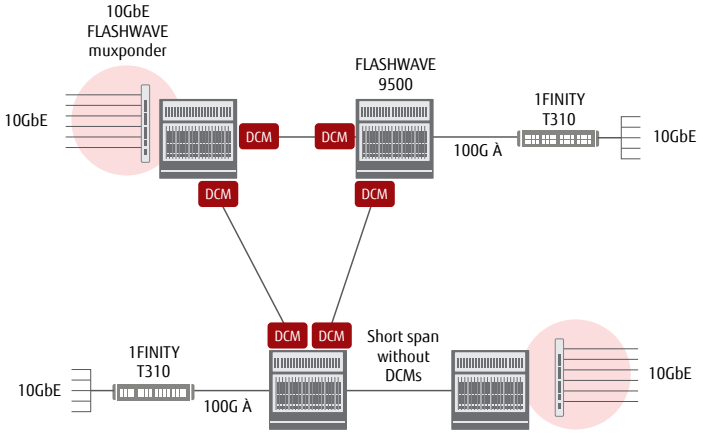

Figure 1: Muxponders replace 10G with 100G wavelengths to free up optical channels and remove signal impairments

Does every 10G wavelength need to be eliminated?

Removing all impairments caused by 10G wavelengths is the ideal technical solution, in order to maximize the reach or top speed of coherent wavelengths with full flexibility. However, depending on the configuration, the effort required can be significant.

Mixing 10G and coherent wavelengths on the same fiber is possible by introducing a guard band between the 10G and coherent wavelengths. A 100GHz guard band is usually sufficient. Lowering the launch power level for 10G wavelengths, for those closest to the coherent channels, also helps. These interference mitigation techniques can be applied selectively to the required fiber spans and circuits determined by a network audit. However, careful attention must be paid to link and node failure scenarios to ensure all circuits can be properly rerouted, with sufficient power and reach.

Step 2: Remove DCMs, if needed

The second step is to remove the second source of signal impairment, the dispersion compensation modules. A rough rule of thumb is that the reach of coherent wavelengths is reduced by 30% by DCMs. The more DCMs in the optical path the greater the impairment, so the most critical spans are the longest ones incurring the most impairment. An analysis of the likely paths across the network for the planned coherent wavelengths would identify the maximum reach needed, the candidate links for DCM removal, and those DCMs that must remain in place to compensate the 10G wavelengths that were not migrated.

Should all DCMs to be removed?

Removing all DCMs across the network provides the maximum routing flexibility and is the ideal solution when most or all the 10G wavelengths have been eliminated. DCM removal extends the reach of coherent wavelengths while reducing the reach of 10G wavelengths. It should also be noted that the fewer the circuits in the network, the easier and quicker the migration process will be. This is case after Step 1, when 10G circuits have been migrated to 100G.

Fujitsu Services can help navigate the potential complexities of migrating to 100G+. Since 2014, our experienced field engineers have migrated over one million optical circuits and developed procedures and automation tools for network auditing, planning, and circuit cut-over that ensure a quick, efficient and seamless network migration.

Step 3: Ready to add high-speed services up to 400GbE

Now that the sources of coherent signal impairment have been eliminated (or the performance impact has been deemed acceptable), new 100G and 200G wavelengths can be introduced on the existing fixed grid network. 100G line rates can be provided using the FLASHWAVE 9500 100G/OTU4 transponder, FLASHWAVE CDS OTU4 transponder or 1FINITY T300 and T310 transponders. Furthermore, 200G line rates can be provided using either 1FINITY T300, T310 or T700 transponders, but only after all DCMs have been eliminated from primary and alternate routes.

A 400GbE service can be transported across the network via 200G wavelengths. This is achieved on the 1FINITY T700 transponder by splitting the client signal over 2 x 200G wavelengths (see Figure 2) for compatibility with the 50GHz channel grid and extended reach.

Supporting coherent signals with 1FINITY Transport series blades

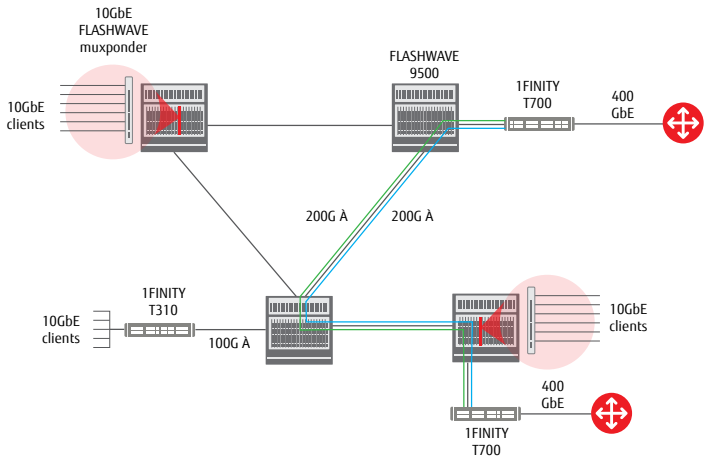

Figure 2: Splitting a 400GbE signal into two 200G wavelengths for transport across a fixed grid network

At the other end of the circuit, the two wavelengths are inverse multiplexed (i.e. re-combined) back to a single client signal. The 1FINITY T700 is a carrier-grade, high port density solution (see Table 2) for 100/400GbE services that supports up to 20 client ports, 4 line ports, and a total switching capacity of 1.6T.

Summary

Migrating a network to 100G+ is achieved in two steps: first, the conversion from 10G to 100G wavelengths, then the removal of DCMs to maximize the reach of 100G+ wavelengths if required. The 'cleanest' path is to perform the migration network-wide, but it is possible to migrate some sections of the network and operate a mixed 10/100G network in other sections. Various measures can be taken to reduce impairments to the coherent wavelengths.

Once the migration is completed, the OLS network is ready to activate new client services up to 400GbE with 200G wavelengths.

FEATURE	FLASHWAVE CDS TM61	FLASHWAVE 9500 TDA2	1FINITY T300	1FINITY T310	1FINITY T700
Maximum Capacity	100G per PIU/card, 200G/shelf	100G per PIU/card, 2.4T per shelf	1T per blade	200G per blade	1.6T per blade
Client Optics	2 × wideband QSFP+ 2 × wideband CFP4	CFP4	10 × QSFP28	20 × SFP+	16 × QSFP28 4 × QSFP56-DD
Client Signal Type	40GbE/100GbE/OTU4	100GbE/OTU4	100GbE/OTU4	10GbE/OTU2/ OC192	100GbE/OTU4/400GbE
Line Optics	Coherent CFP	Fixed discrete	5 × CFP2-ACO	2 × CFP2-ACO	4 × discrete DCO
Modulation	QPSK	QPSK	QPSK/16QAM	QPSK/16QAM	QPSK/6b4D-2A8PSK/ 6b4D-2A8PSK+16QAM/16QAM/ 32QAM
Line Rates	100G	100G	100G/200G	100G/200G	200G/300G/400G
Optical Grid	Fixed	Fixed	Flex	Flex	Flex
NEBS compliant	Yes	Yes	Yes	Yes	Yes

Table 2: Fujitsu 1FINITY Transport series transponders and muxponders

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