Considerations

for Migration to a DWDM Network

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Considering how various factors interact with your network deployment is critical to ensuring a successful WDM deployment. This guide to navigating your migration to DWDM gives you the tools necessary to maximise your network's capacity.

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Most of the fibre optic cable in use today was installed years ago, when the typical fibre count was between 72 and 144 fibres. At that time, capacity concerns were solved by using higher fibre counts, making sure that spare, or dark, fibre was deployed.

As time went on, and demand increased, all those spare/dark fibres were consumed by services. There were probaby several instances where users had to decide if they would install more fibre or just defer the opportunities, and revenue, that more fibre would afford.

With the costs of network construction rising and a growing demand for increased capacity on fibre networks, wave division and multiplexing (WDM) has come to the rescue as a 'must-use' technology. Let's explore why.

Concepts

WDM is a simple concept. If you think about your current network as a motorway with only one open lane, WDM devices open all available lanes to allow traffic to flow more freely.

It all starts with the fact that light is made up of many different wavelengths, or colours, and this is the basic principle at work in all the WDM modes: separating the wavelengths so that they can be seen discreetly. There are three main modes – B for bi-directional, C for coarse and D for dense. These are referred to as BWDM, CWDM and DWDM. BWDM is like having a blue pen and a red pen. CWDM and DWDM are like having a small box and a huge box of crayons, respectively.

Despite some differences, for the most part they operate the same way and accomplish the same things, just at different scales. Understanding these technologies and what to consider when implementing them, will help ensure that you are getting the most from your network while maintaining the best path forward.

Terminology

In the context of WDM conversations, it is important to understand that the terms wavelength, channel, lambda, colour and frequency all refer to the same concept; a window used for discrete transmission of a signal. However, they each have a separate, specific meaning, referring to one aspect of the transmission window:

- Wavelength refers to the length of the lightwave and is measured in nanometers.
- In physics, lambda is the Greek letter assigned to wavelength measurement.
- Frequency refers to the frequency of the wavelength in terahertz (THz). These terms are convertible (e.g. 1550nm = 193THz).
- Colour is a generic term that refers to the wavelength, frequency or lambda, because each variation creates a different colour.
- Channel is a reference to the ITU-T (International Telecommunication Union – Telecommunications). ITU-T G.694.1 and G.694.2 are the standards that cover DWDM and CWDM respectively.

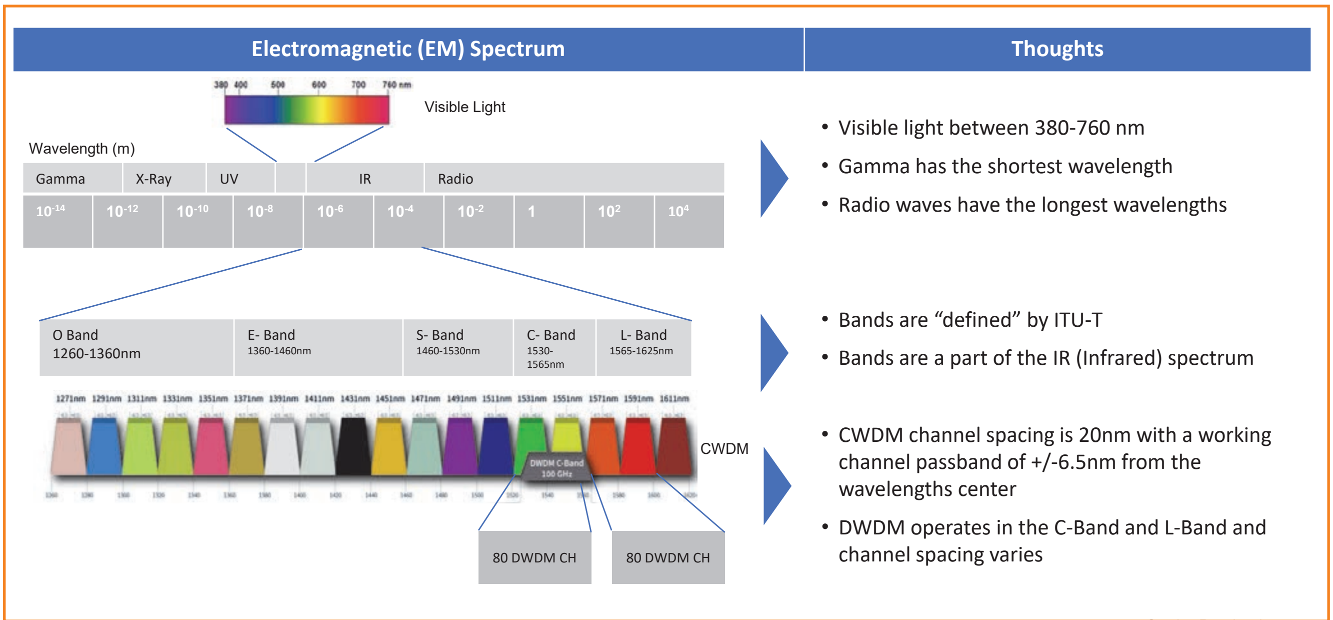

Figure 1: The ITU-T bands

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The channel identifier is assigned to, or refers to, the spacing of the previous terms. For example, it could mean channel 17 (which is 1563.86nm/191.7THz) or it could mean the DWDM channels are 50GHz or 0.4nm wide. Transmission bands or windows are the ITU-T specified tranches of spectrum and are assigned letter identifiers. WDM technology operates in the O-band (1260nm - 1360nm); E-band (1360nm - 1460nm); S-band (1460nm - 1530nm); C-band (1530nm - 1565nm) and L-band (1565nm - 1625nm). Figure 1 (on the previous page) shows the ITU-T bands.

Technology review

Originally, there was bi-directional wave division and multiplexing, or BWDM. This uses the two common transmission windows around 1310nm and 1550nm. The 1550nm window allows for amplification using an erbium doped fibre amplifer (EDFA) and is the standard/legacy approach to run optical networks. In this model, there was a single transmitter and a single receiver on each end of the fibre, transmitting on one frequency and receiving on the other.

In CWDM and DWDM, there are multiples of each (TX & RX) on each end, so you need to have a way to mux/demux at each end of the fibre. This is what enables the multiple TXs and RXs in each location to find their way onto or off a single fibre. CWDM is a mature model and unlikely to see significant development in the optics and transmission capacity because DWDM has already superseded it. It uses multiple wavelengths between 1270nm and 1610nm and the channels are spaced 20nm apart. You can have a total of 18 channels in this mode and each channel uses 13nm for transmission and has 7nm spacing to keep off the adjacent wavelengths.

CWDM uses wavelengths in all the transmission bands. This is because, out of all wavelengths that are used, some of those channels could reside in the "water peak" or "OH peak" wavelengths. If your fibre is not G.652 C or G.652 D-compliant, you may lose the four channels that reside in the 1371nm – 1431nm wavelengths. Certainly, 1391nm and 1411nm are unusable, lowering your total channel count to 16.

CDWM is great for short distances and lower transmission rates (10Gbps or less). Due to the frequencies being spaced through the entire transmission window, the signals carried cannot be efficiently amplified with an EDFA. While some of the frequencies can be post amplified, extending the distance, 60km is the max. distance in a model using all CWDM channels.

DWDM is more recent, at least in adoption in access networks, though DWDM has been used for years in metro and long-haul networks. As technology has progressed, the ability to pack the transmit wavelengths closer together has become affordable. DWDM uses the wavelengths in the C and L bands, 1530nm – 1565nm and 1565nm – 1625nm, and the wavelengths can be spaced 0.8nm (100GHz) or 0.4nm (50GHz) apart.

DWDM is better for longer distances, largely because it is amplifiable with an EDFA (C-band) as well as Raman Amplifiers (C-L band). DWDM is also capable of higher transmission rates, with optics that can achieve 200Gbps. DWDM operates in the C and L bands and is not impacted by the increased attenuation in "water peak" or "OH" wavelengths.

A new technology, that is still being developed, is referred to as Ultra Dense WDM (UDWDM). This uses 0.1nm (12.5GHz) spacing to allow an additional 240 channels in the C-band, for a total of 320. Raman amplification allows the use of the L band, from 1565nm – 1625nm, creating a possible addition of 40 to 320 more channels. That is a total of 640 more in the C and L bands.

The DWDM channels are located within the CWDM channels and represent a subsection of the spectrum used in CWDM. This means that you can have DWDM transmissions inside the CWDM transmission, mixing both if you are not actively using the CWDM channels required by DWDM.

Finally, there are two different mux/demux technologies that will get you CWDM or DWDM: thin film filter (TFF) or arrayed wavelength gratings (AWG). The TFF technology filters wavelengths by "refracting" light through a filter so that only some wavelengths can pass through. The remainder of the light proceeds off the reflection, but the filtered light is passed forward and becomes isolated. AWG works by passing the light through a prism and then through a guide to isolate each wavelength. It avoids the compounding insertion-loss issues that can complicate TFF.

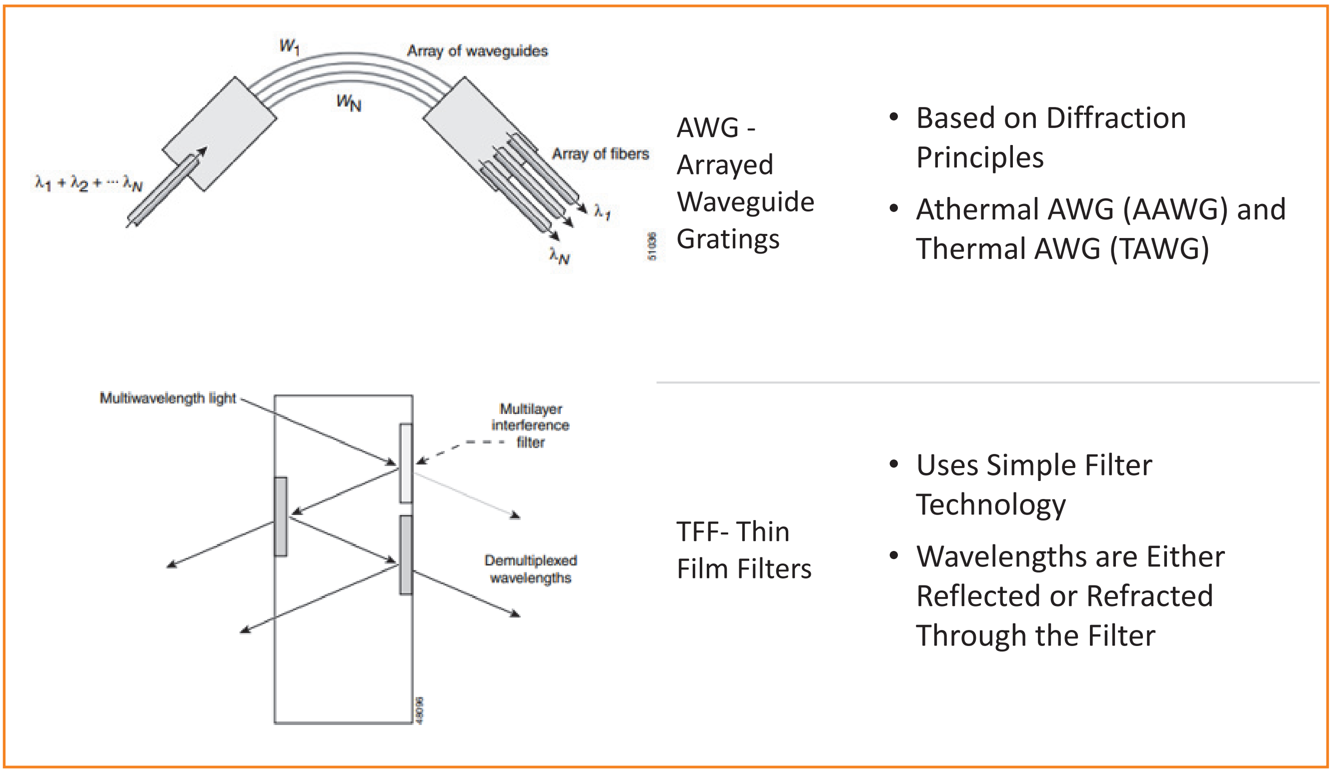

Figure 2: Filter types

Another way to consider the differences is that TFF works by only allowing something to pass, whereas AWG works by passing and separating everything. TFF is a more discrete and precise technology, but it comes with a higher price. AWG is less discrete than TFF, but this is tolerable in many applications. AWG is also cheaper which is also "tolerable" in most applications. TFF costs increase per channel while AWG does not. TFF, however, tends to have better temperature performance.

All these modes of WDM share the same concept but the key difference is that the quality of the active components and the mux/demux has increased to allow significantly tighter spacing, essentially packing more into less.

Considerations for migration to DWDM

There are several considerations when planning a migration to DWDM, some specific to DWDM and others just general points to take into account. Firstly, of course, you need to evaluate your network and decide if you need to add capacity. How much capacity do you need? How much do you need now? How soon do you need the rest? What are you going to transmit over them?

These four questions will guide your decisions and your approach, as well as helping you decide how many channels you are adding today versus how many you will add in the future. Remember, you can start small and pay as you grow. Twenty channels can become 40 channels with a simple add-on module if you plan correctly. Maybe you have 18 customers today and you plan to grow to 40 next year. Do you buy 20 channels today and 20 next year or all 40 today? Poor planning means that you will have to repurchase your original 20 channels.

Also, at this point in the planning, you need to consider your link-loss budget calculations. You must know, if you are going to be transmitting an AM or digital signal, how far you plan to transmit in a worst-case scenario as well as the transmit power and receive windows for the optics that you are using.

This budget will help you decide which technology you employ for your mux/demux. It will also help you decide if you want to start with some channels and upgrade to more in the future, or if you should start with the maximum you plan to need. It is more cost-effective to use one 24-channel mux/demux than to go back and add three separate eight-channel mux/demux.

Which technology do you need for your mux/demux? Will AWG suffice, or do you need something more isolated and precise? Perhaps you are doing ultra-high data rates with coherent optics and you want to be sure that there is adequate

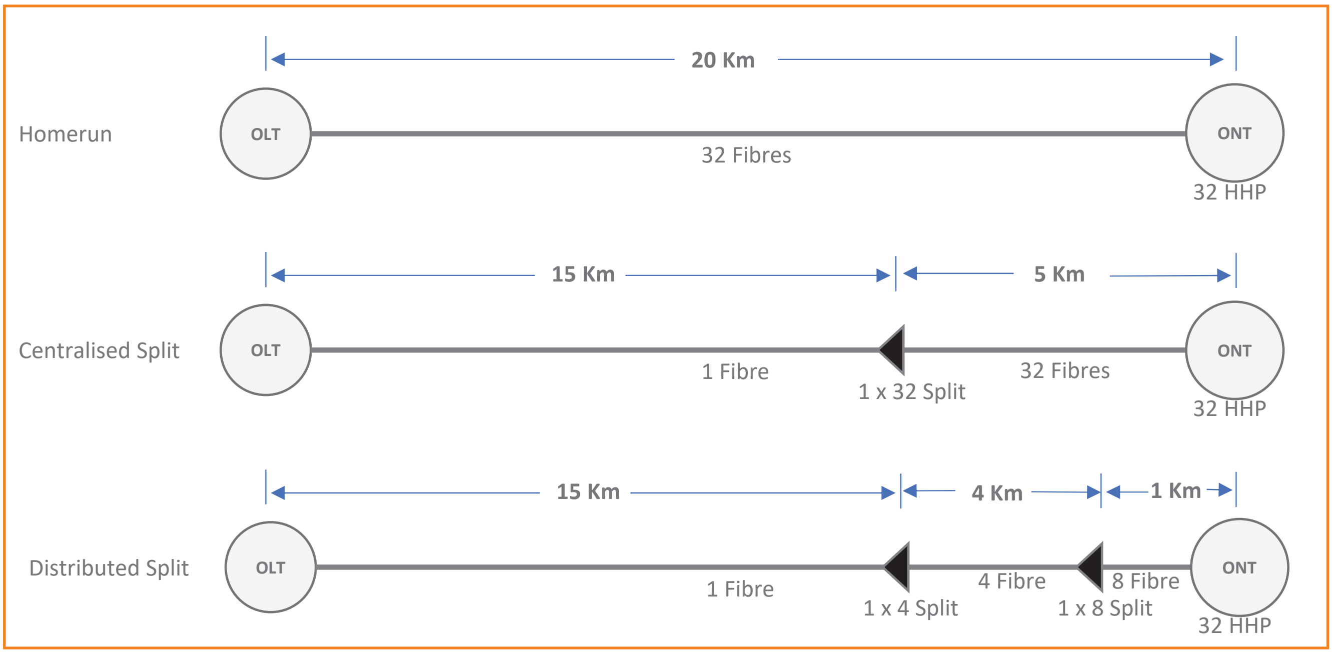

Figure 3: PON architectures

separation. Alternatively, you might be doing multiple 10Gbps networks for different customers and you don't see the need to spend extra money today.

You will want to make sure that you are not mixing AM and digital transmissions. While this may be technically possible to do, it will probably cause issues and problems that you don't expect. It isn't a recommended practice.

If you have an existing application on your current fibre, you need to determine whether it must be on specific frequencies or not. IEEE EPON, ITU-T GPON and RFOG all have set operating frequencies which are determined by the standards bodies that created them. EPON, GPON and RFOG all have set operating frequencies. This means that there needs to be a device added to the network that can translate the frequency from your DWDM network to the required frequency after the demux point.

If the ONT or RFOG device is expecting a signal on 1550nm, but you used 1563.86 (channel 17), you must translate it back there. You must do this post-demux or you will lose the efficiency of the DWDM channels, as there will be an active device on both ends of the passive optical network.

Next, you must decide if you are going to use a centralised or distributed split. A centralised split drops all the wavelengths at one location and all the endpoints must run back to that location, meaning more fibre needs to be run at longer lengths.

A distributed split drops only the wavelengths needed at a given location, but requires the remaining wavelengths to be transported to additional drop locations. A distributed split allows the end locations to be closer to the demux point and therefore the associated fibre runs can be shorter. This benefit, however, is offset by the fibre needed to get from point to point.

Distributed split also requires greater consideration of your link-loss budget – extra splices and insertion points can add up quickly if you're not careful. It's important to consider future-use scenarios as well as today's needs. You can always change your mind if you don't mind the cost and some network downtime.

Ideally, you have dark fibre in your network and you can use this for the DWDM network, migrating existing applications to it. However, if you don't all is not lost. Because the DWDM channels are a subsection of the CWDM range, you can insert the DWDM into the CWDM mux, essentially subdividing the

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WDM technology is an increasingly necessary part of every network, giving you the flexibility to increase capacity while avoiding major construction projects. Considering how the various factors outlined in this article interact with your network deployment is critical to ensuring a successful WDM deployment. This guide to navigating your migration to DWDM gives you the tools necessary to maximise your network's capacity.