WDM

Wavelength Division Multiplexing

-CWDM vs DWDM-
Agenda

1. Overview
2. Fiber Cable WDM Characteristics
3. CWDM – Course WDM
4. DWDM – Dense WDM
5. Applications – Best Fit - Future?
6. Summary
1 - Overview

- Long and dense routes provided the economic drivers to maximize ROI. DWDM was perfected in the 1990’s.
  - Undersea cables met this criteria early.
  - Transcontinental fiber routes were next.
  - “Fiber Glut” was a consequence.
- R/W issues and unexpected circuit demand became local applications.
Overview

- Short and multi-protocol routes had unique drivers in special applications like Metro’s and video headends.
  - CWDM has lower density but is also 40% lower in cost than DWDM.
  - Video feeds with a variety of analog, digital, RF and control protocols were perfect for CWDM.
  - CWDM is very cost effective in providing circuit relief in lower density TDM Sonet networks. Original CWDM was developed in the 1980’s for MMF.
Overview

- To fully understand the unique problems and benefits of WDM, the characteristics of legacy and current fiber production will be explored. Section 2 on “Fiber Characteristics” discusses the main issues and today’s answers.

- CWDM development and specs are discussed in section 3. It was an original 1980’s product which is now revitalized.

- DWDM development and specs are discussed in section 4. It was developed in the 1990’s.
Overview

- Current applications and current strategies are discussed in section 5. The “Best Fit” parameters and current research on WDM improvements provide insight on expected future applications.
2-Fiber Cable WDM Characteristics

1st window-1970’s
2nd window-1980’s
3rd window-1990’s

Each “Window” provides a historical perspective on cable technology.
Fiber Types - Construction

**Multi-Mode**
- 50/62.5um core, 125um cladding
- Atten-MHz/km: 200 MHz/km
- Atten-dB/km: 3dB @ 850nm
- MMF has an orange jacket

**Single-Mode**
- 9um core, 125um cladding
- Atten-dB/km: 0.4/0.3dB
- 1310nm/1550nm
- SMF has a yellow jacket
Degradation In Fiber Optic Cable

- **Attenuation**
  - Loss of light power as the signal travels through optical cable

- **Dispersion**
  - Spreading of signal pulses as they travel through optical cable
Dispersion
Dispersion + Attenuation
Dispersion Causes

- Modal effects
  - Intermodal dispersion
  - Intramodal dispersion
  - Chromatic
  - Waveguide
  - Polarization mode
Dispersion causes

- Scattering effects
  - Raleigh
  - Raman (SRS)
  - Brillouin (SBS)

- Miscellaneous effects
  - Linear crosstalk
  - Four wave mixing
  - Cross phase modulation
  - Self phase modulation
Attenuation vs. Wavelength

"classic" non-dispersion shifted SMF cable
Low Water Peak

Nondispersion Shifted Fiber

- Optimizes SMF fiber for WDM applications in the 1285nm to 1625nm region by reducing the classic OH peak.
- ITU standard typically 0.2 dB/ Km at 1550nm. (ITU-T G.652.C)
- Zero dispersion wavelength is in the standard 1310nm region.
- Reduces / eliminates the water peak by improved manufacturing process.
Dispersion shifted fiber

- Zero dispersion shifted fiber moves the “neutral” dispersion wavelength to the 1550 low attenuation window. (ITU G.653)

- Because of DWDM FWM (Four Wave Mixing) newer Nonzero Dispersion shifted fiber was developed and replaces Zero dispersion shifted fibers. (ITU G.655)
  - NZD- and NZD+ fiber move the zero dispersion wavelength to either side of the 1550nm point.
CWDM Optical Spectrum

- 20nm spaced wavelengths

CWDM wavelength grid as specified by ITU-T G.694.2

Fiber attenuation (dB/km)

Wavelength (nm)

O-band 1260-1360
E-band 1360-1460
S-band 1460-1530
C-band 1530-1565
L-band 1565-1625

Water peak

ITU-T G.652 fiber
DWDM vs. CWDM Spectrum

1.6nm Spacing  ITU-T G.694.1 standard

DWDM Region

dB

Wavelength

CWDM 20nm channel spacing

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3 – CWDM

- Originally developed in the 1980’s for adding capacity to multi-mode fiber cable routes in campus LAN’s.
  - 25nm spacing in the 850 nm window.
- About 1995, CWDM was revitalized with SMF wavelengths for metro area fiber route capacity increases.
  - The “original” band at 1310nm was used.
- Currently the latest ITU spec G.694.2 defines 18 channels in 5 bands with 20nm spacing.
  - The bands are the O, E,S,C and L.
  - The E band includes the 1385nm water peak so is the last one implemented unless low WP cable is used.
  - Typical capacity of 50Mb to 2.7Gb
Advantages

- Simpler technology allows:
  - Lower power consumption - 20%
  - Smaller space requirements - 30%
  - Can use SMF or MMF cable
  - Can use LED's or Laser's for power
  - Larger individual payloads per channel
  - Smaller and cheaper wave filters
  - Cost savings on start up and expansion
CWDM

- Disadvantages
  - Less capacity than DWDM
  - Less range
  - Regeneration vs. amplification
  - O, A and M functions are not carrier class
Developed in the early 1990’s to add capacity to undersea and transcontinental routes.

Uses the 1500nm to 1600nm band which has minimum attenuation for long distance routes.

Operates in the prime EDFA region

EDFA amps provide maximum distance

Can provide typical 2 to 128 channels of capacity
  - Channel spacing is likely 0.8nm for economy

Typically operates at 2.4Gb and 10Gb

ITU channel plan is G.694.1 (1200ch @ 0.1nm)
DWDM

Advantages

- Maximum capacity system available
- Maximum distance capability with EDFA’s
- Repeater “amp” sites can be reduced
  - MCI and ATT reduced sites by 30%
- Pay as you grow expansion
- Mature O, A and M systems are developed
DWDM

- Disadvantages
  - Complex technology requires:
    - more space
    - more power
    - high accuracy lasers and wave filters
    - Expensive EDFA’s for amplifiers
  - Start up costs are more than equivalent CWDM
5- Applications- CWDM

- CWDM is very flexible and has adapted to specialized applications such as:
  - Video headend feeds for multi protocol signals
  - Campus LAN expansion
  - Lower density capacity “fixes”
  - Short distance capacity “fixes”
  - Metro area distribution and expansion
  - Data center storage routes
  - Spur routes for DWDM systems
  - Applications where low start up and expansion rules vs the alternative DWDM choices
Applications - DWDM

DWDM is the proven “workhorse” of the high capacity and long distance carrier’s.

- Many products are available from most traditional transport suppliers.
- The O, A and M capabilities are world class.
- Secondary market systems are available which can significantly reduce costs.
Applications – Future?

- CWDM continues to evolve into specialized applications.
  - Combination transport and optical routers or switches are being developed now.
  - Add-on CWDM cards are being included in more transport devices as low cost options.
  - Suppliers are continuing to drive down costs and increase capacity.
Applications - Future?

- DWDM research is working on increasing the capacity and distance of future DWDM products.
  - Wide Spectrum DWDM is on the future horizon and will offer more channels.
  - The electronics and chip industry is constantly increasing quality yields which will drive costs lower and increase capability.
  - Combination systems with CWDM and DWDM capabilities are being produced now.
  - FTTP technology intends to expand capacity with a “wavelength per home”.

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6- Summary

- CWDM and DWDM technology continues to advance and provide solutions to applications not imagined or feasible years ago. Each technology provides a unique “fit” and will complement not replace the other.
Thank You!

- *Special thanks is due to many authors and vendors who have provided source material for this presentation. This presentation is not meant as original research but as a compendium of many sources.*