



# Beyond SDH


Roadmap to 100Gb Optical Connectivity

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## Agenda

- Optical roadmap to 40G & 100G optical links
- OTN – Optical Transport Network (successor to SDH)
- DWDM, Wavelengths, Lambda services



## Now: 1 – 10 Gbps

Technology	Year	Bitrate
1 Gb Ethernet	1998	1024000 kbps
2.5G STM-16	1988	2488320 kbps
10G STM-64	1996	9953280 kbps
10GbE LAN PHY	2002	10312500 kbps
10GbE WAN PHY	2002	9953280 kbps




## 10 Gbps is FAST!

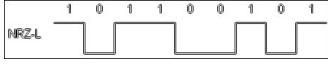
Speed of Light in glass: 20 cm per nanosecond  
0.2 mm per picosecond


Bitrate	Bits / m	Bit time
2.5Gbps	13.6	366 ps
10Gbps	54.8	91 ps
40Gbps	220	22.7 ps

Desktop CPU: 3GHz - reaching fundamental limits of heating/cooling/power consumption of controllers

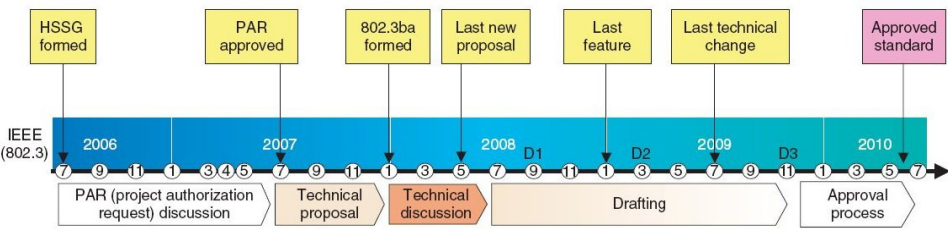


## SDH and Ethernet Optically Identical

- Same NRZ line coding 
- Intra-Office Eth: MMOF 850nm, 300m  
SDH: SMOF 1310, ~2km
- Short Range SMOF 1310nm, ~10-20km
- Med Range SMOF 1550nm, ~ 40km
- Long Range SMOF 1550nm, ~ 80km
- 10GbE WAN PHY = STM-64 = 9.953 Gbps



## 40GbE / 100 GbE




- 802.3ba specifying 40G and 100G Ethernet
- Draft 1.0 spec released Oct 2008, Draft 1.2 in Feb 2009
- Final spec approval expected mid-2010

Distance	Medium	40G Ethernet	100G Ethernet
Short	Copper	40GBASE-KR4 4 x 10.3125 Gbit/s	40GBASE-CR4 4 x 10.3125 Gbit/s parallel coax cable
		40GBASE-SR4 4 x 10.3125 Gbit/s, 0.8 μm parallel ribbon fiber	100GBASE-SR10 10 x 10.3125 Gbit/s, 0.8 μm parallel ribbon fiber
Medium	Fiber	40GBASE-LR4 4 x 10.3125 Gbit/s, 1.3 μm CWDM (20-nm spacing)	100GBASE-LR4 4 x 25.78125 Gbit/s, 1.3 μm LAN-WDM (5-nm spacing)
			100GBASE-ER4 4 x 25.78125 Gbit/s, 1.3 μm LAN-WDM (5-nm spacing)


SMF: multi-mode fiber  
 SMF: single-mode fiber  
 CWDM: coarse WDM  
 LAN: local area network

**Annotations:**

- No RJ45 – existing copper cabling not supported
- MMOF requires multiple fibres
- 40G defined as short range only – datacentres and servers
- 100GbE not compatible with DWDM
- Multiple Parallel 10Gb channels




# Optical Transport Networking



## Previous Long-haul

<p>PDH – G.705 1977-2001</p> <p>E0 – 64kbps <b>E1 – 2.048 Mbps</b> E2 - 8.448 Mbps E3 – 32.064 Mbps STM-1 – 155.520 Mbps</p> <p>Twisted pair, coax</p>	➔	<p>SDH – G.707, G.957 1988-2007</p> <p>STM-0 – 51.8 Mbps <b>STM-1 – 155.520 Mbps</b> STM-4 – 622.08 Mbps STM-16 – 2.488 Gbps STM-64 – 9.953 Gbps STM-256 – 39.813 Gbps</p> <p>Coax and optical fibre</p>
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### OTN – G.709, G.959.1

2001 - present

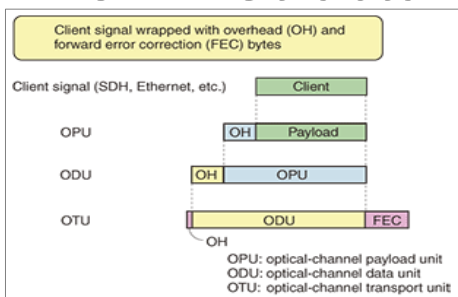
	Transport	Payload (ODU)
<b>OTU1</b>	<b>2.666 Gbps</b>	<b>2.488 Gbps</b>
OTU2	10.709 Gbps	9.995 Gbps
OTU3	43.018 Gbps	40.150 Gbps


Designed for optical fibre and native DWDM



## OTN Structure

- Client Traffic encapsulated in “Digital Wrapper”
- OTU transmitted directly on DWDM optical channel
- Client Traffic native Ethernet, IP, ATM, SDH, or arbitrary CBR bitstream – “IP over DWDM”
- Overhead provides timing, OAM notification, nested optical performance information, provisioning info
- FEC provides error correction of noisy analog optical layer, monitors optical quality O-SNR






## Long Haul 40G

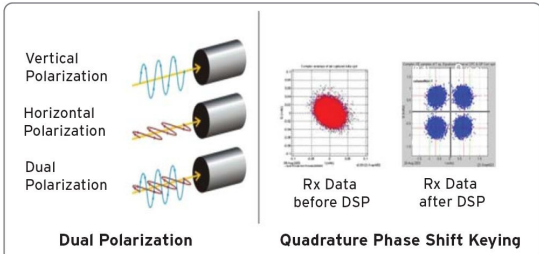
- STM-256 and OTU-3 defined for many years
  - Uses basic NRZ signal at 40 Gbaud psec
- Practical Issues reduce optical effectiveness at long range
  - ¼ light per bit -> 6 dB (~ 30km) reduction in distance
  - 16 times less tolerant to Chromatic Dispersion – very hard to tune CD compensation
- Proprietary line codings work better (DPSK etc)– but are not interoperable, single vendor lock-in
- Currently \$40G optics > 4 x \$10G optics


Upgrade MAY require additional amplifier/regenerator sites  
 Unless very short of wavelengths, consider not bothering with  
 40G long-haul yet



## Long Haul 100G

- New line coding developed by Nortel – DP-QPSK – adopted by OIF (Optical Interworking Forum)
- ~112 Gbps from 25 - 28 Gbaud per sec carriers
- Works through existing 50 GHz DWDM equipment
- More robust than 40Gbps NRZ
- Some pre-release trials occurring (Verizon, Telstra, others), OTU4 completion late 2010 after 100GbE finalised as client payload





## Caution!

**1G -> 10G:**

- Ethernet & SDH similar bitstream format
- Easy to convert “gray” to DWDM – swap optical module frequency (swap SFPs)

**40G -> 100G:**

- Ethernet frame very different from OTN frame
- Incompatible cabling, frequencies, connectors



## Lambda Services

aka Wavelength Services, Optical Channels, Lightpaths

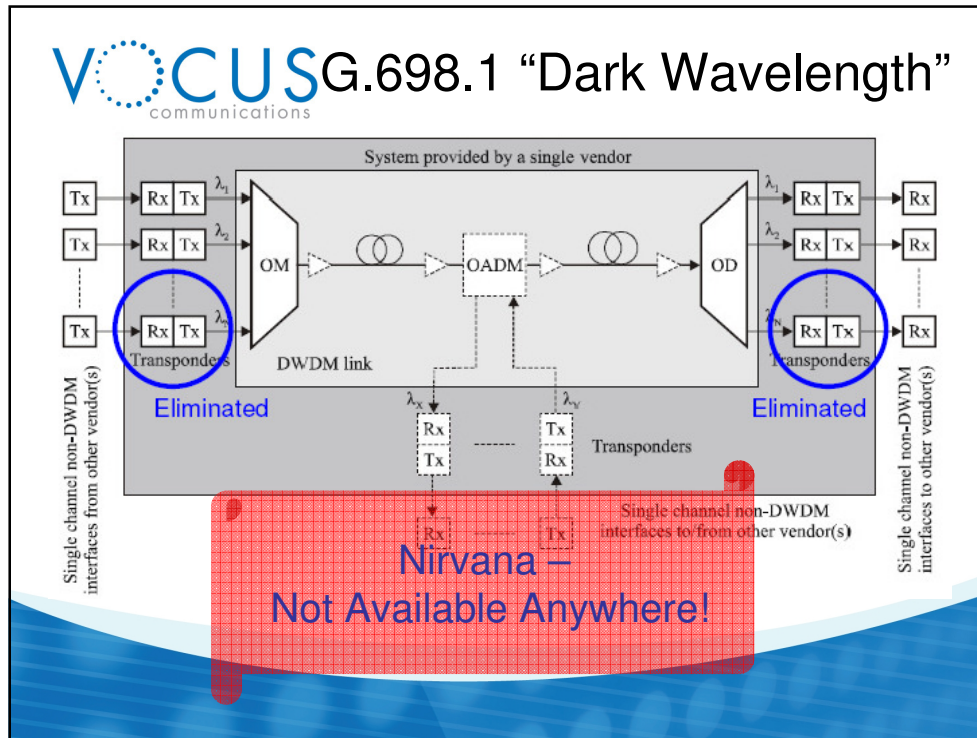
The logo for VOCUS communications, featuring the word "VOCUS" in a blue, sans-serif font with a dotted circle around the "O", and the word "communications" in a smaller, lowercase font below it.

## 'ideal' Lambda Service

- Network provider nominates the frequencies/wavelength(s)
- Customer Access is coloured DWDM (one or more wavelengths per physical fibre pair)
- Client Transponder sets the speed (up to a limit)
- Independent of signal framing

BUT distance limited, no provider regenerators.



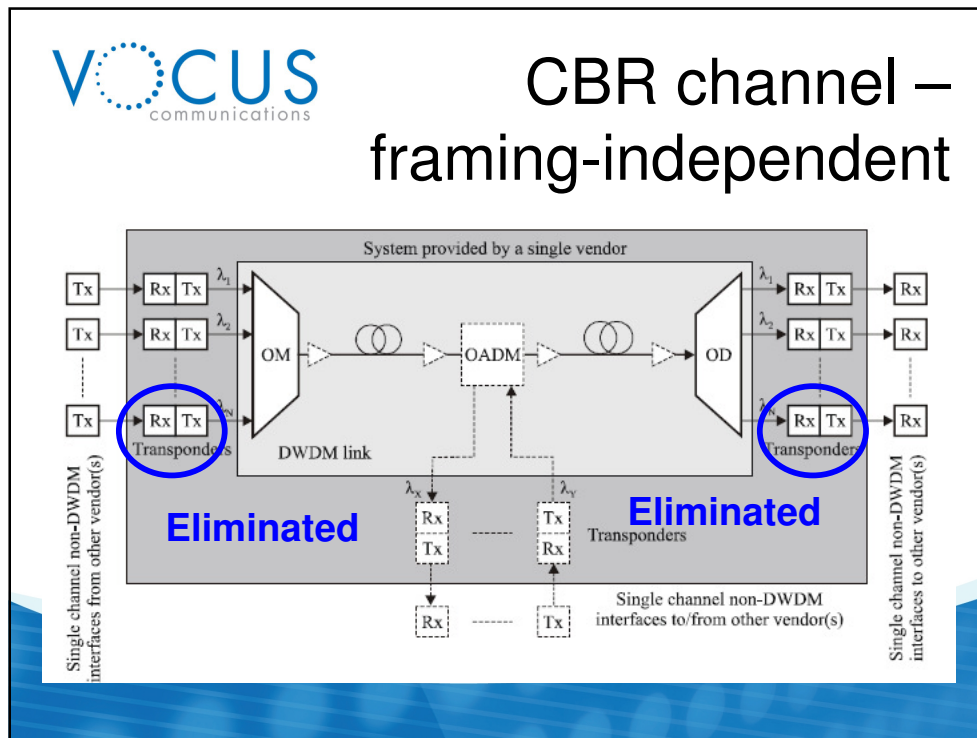


**VOCUS Lambda Brochureware**  
communications

**Lambda-Based Services**

offers point-to-point, high-capacity 10-gigabit Ethernet LAN-PHY or OC-192 lambdas between any two nodes on the infrastructure. The service is a full-production, unprotected point-to-point wavelength.

- Speed is constrained to 10gbps
- Protocol Framing is constrained
- Only a 'lambda' while the underlying network runs 10Gbps optical channels – when upgraded to 40gbps, customer still gets only 10G



**VOCUS** communications

## Quick Survey

- 20 Providers for Lambda or Wavelength connections USA/Europe (none in Aus)
- 12 provide 'protocol independent' 2.5G and/or 10G channels
- 1 allows coloured access (2.5G only)
- 0 true 'dark wavelengths'



Thankyou

Questions?

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