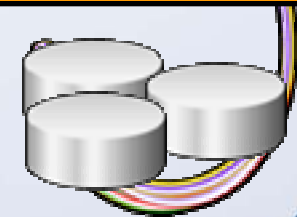


Optical Networking for the Enterprise



Storage and Networking @ Light Speed



By Al Lounsbury, P.Eng.
Nortel Networks, Optical Enterprise
al.lounsbury@nortelnetworks.com

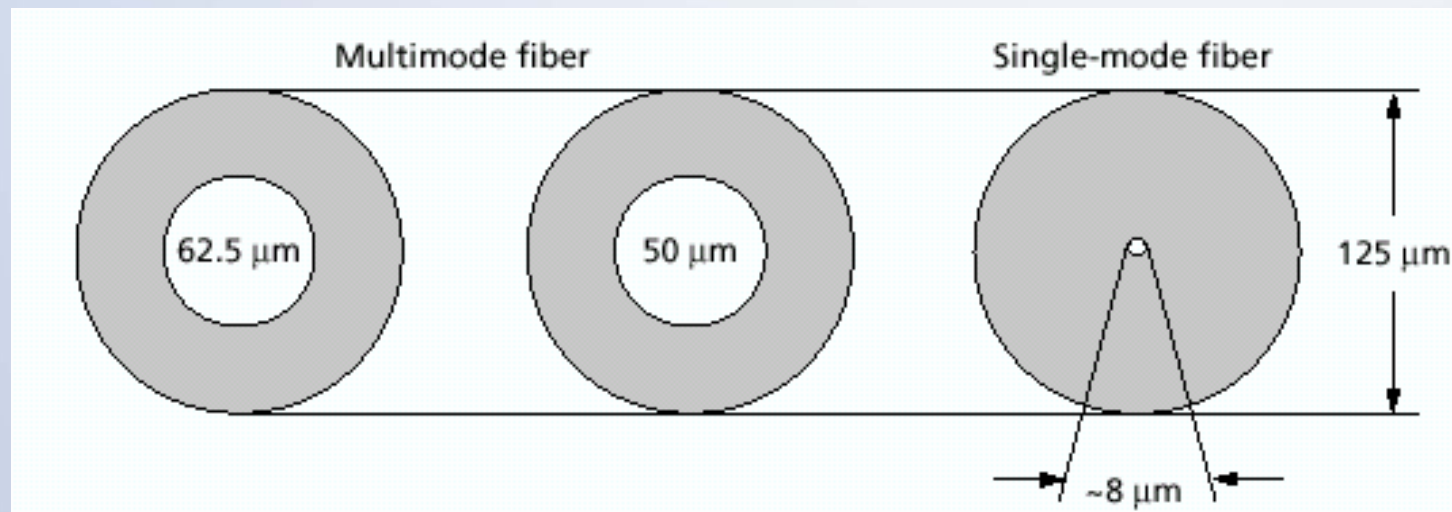
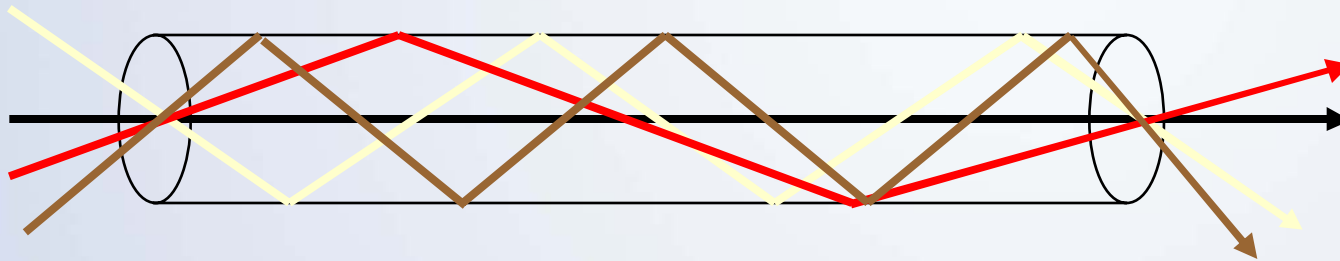
Agenda

- **Optical Fiber**
 - Types of Fiber
 - Attenuation and Dispersion
- **Wavelength Division Multiplexing (WDM)**
- **SONET**
 - Next Gen SONET Technologies
- **Optical Networking Applications**
 - Convergence with SONET
 - Convergence with WDM
- **Summary**

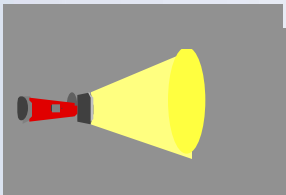
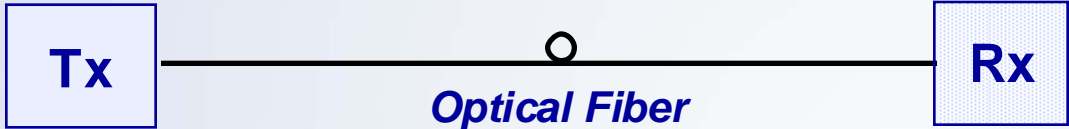
Types of Optical Fiber

- **General Description**

- Multi Mode Fiber (used for short distances e.g. LANs)
 - Several paths/modes for light to travel in fiber
- Single Mode Fiber (used for longer distances, DWDM)

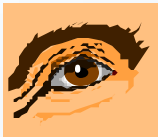


Attenuation



**Power of the
optical signal
sent**

ATTENUATION



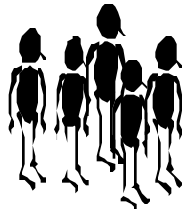
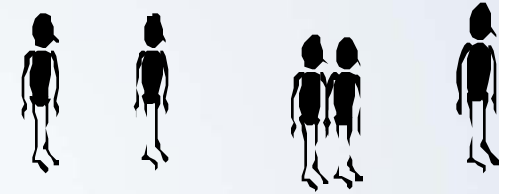
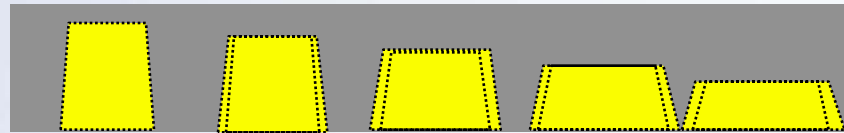
**Sensitivity of
the receiver**

**ATTENUATION
comes from fiber,
connectors,
splices, etc**

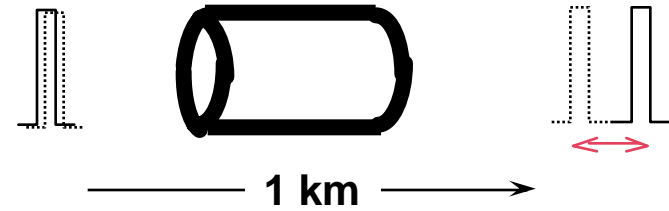
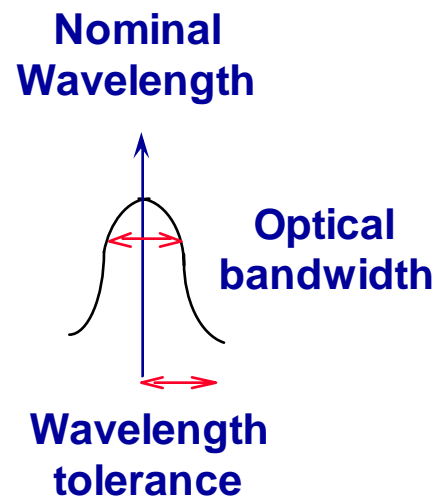
A fiber has a '**loss**' which represents the power used to travel a certain distance (typically < 0.25 dB per km)

However, sending more power is not necessarily the solution to greater span length (due to fibre non linearities)

Dispersion



The optical signal sent at a nominal frequency is in fact made of several wavelengths (frequency components)

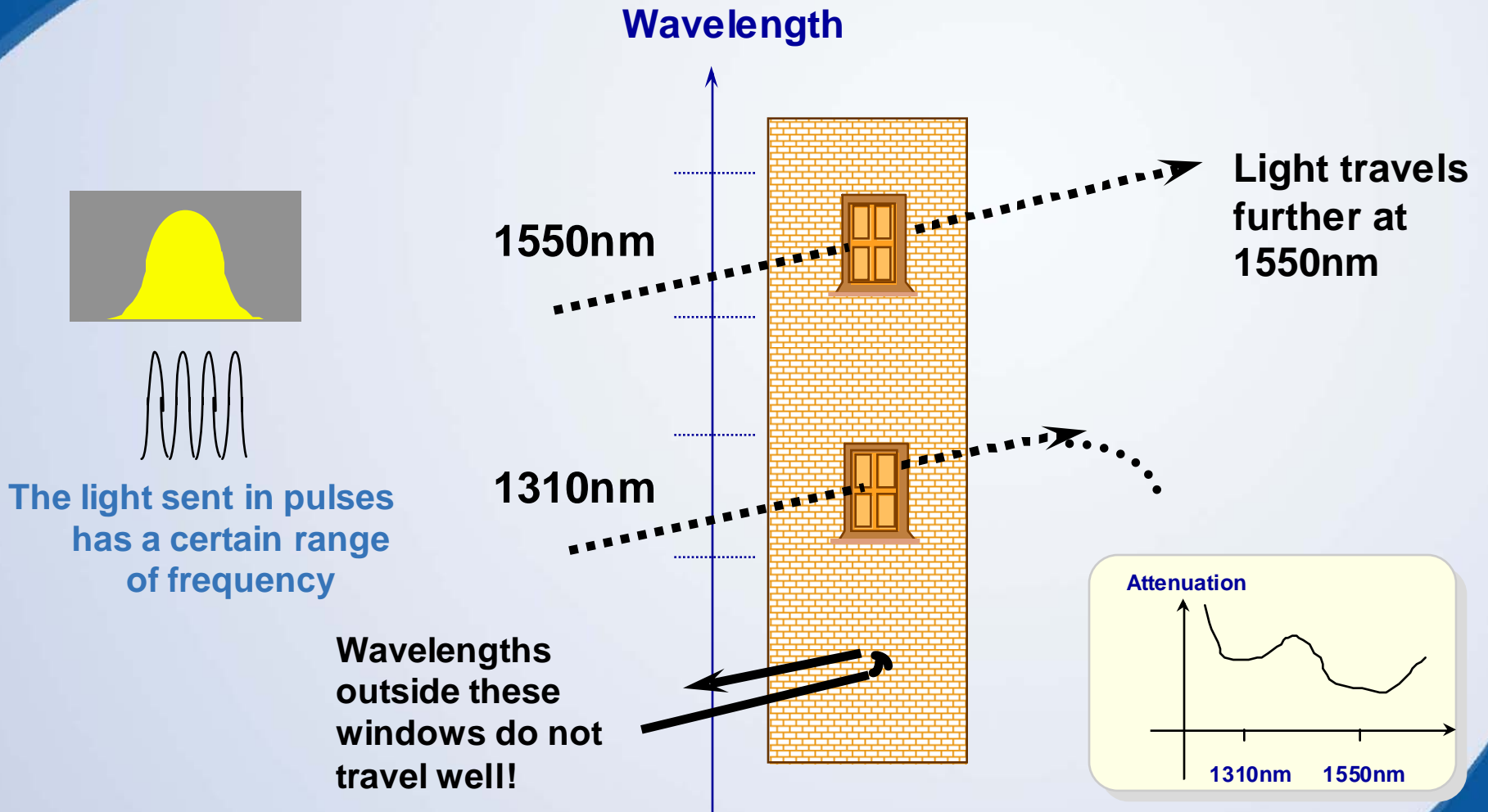


Dispersion causes a light pulse to spread (i.e. lose its shape) because all frequency components experience different delays

Dispersion is in time per wavelength per km

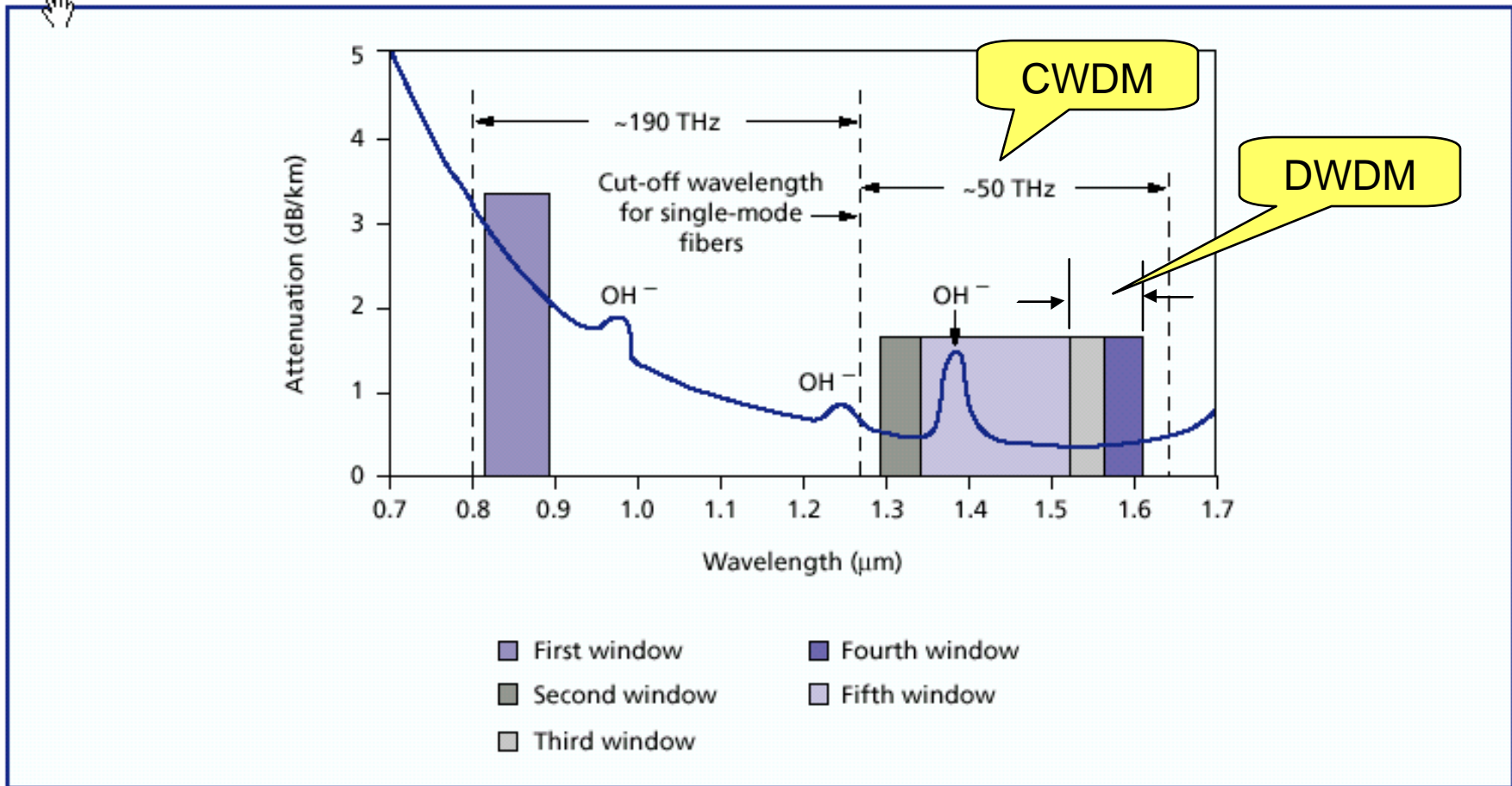
Fibers have certain dispersion characteristics

Fiber dispersion characteristics



Silica characteristics give minimum fibre attenuation in 2 windows

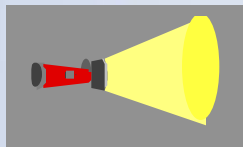
Attenuation of a Typical Optical Fiber



Challenges in Optical Transmission

Attenuation & Dispersion

How far the light goes depends on several parameters:
attenuation, dispersion and fiber non linearities



→ Distance



Perfect Pulse

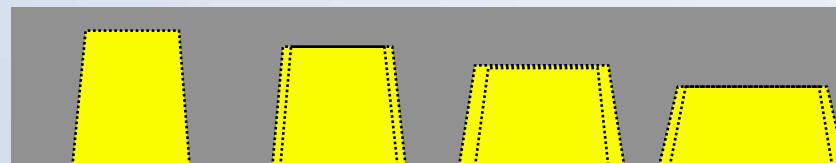
Attenuation fixed by:

- ✓ Fiber Type
- ✓ Amplification
- ✓ Regeneration

Attenuation



Attenuation
+
dispersion

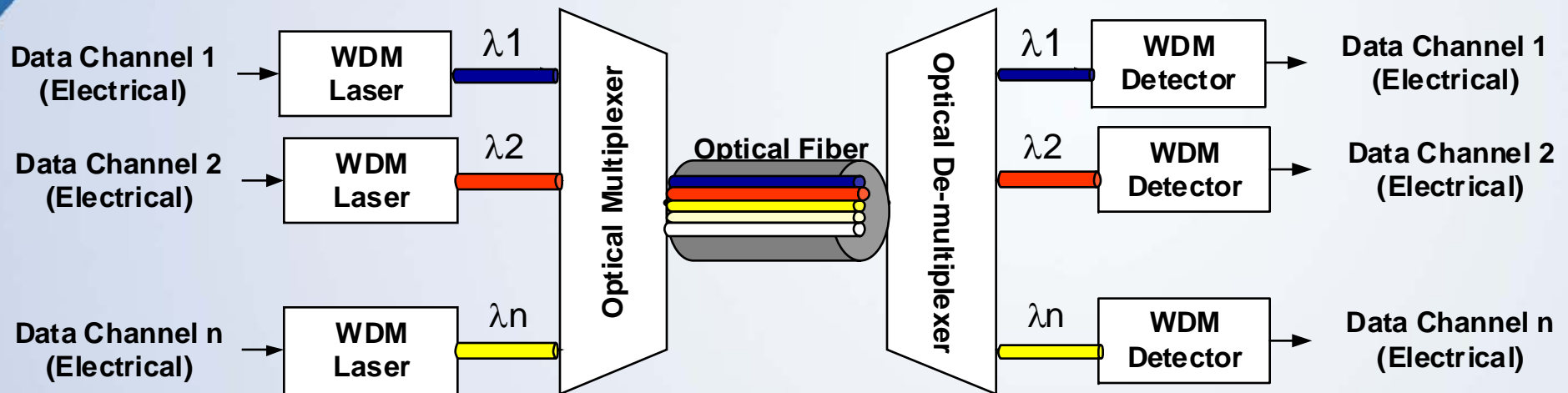


Dispersion fixed by:

- ✓ Fiber Type
- ✓ Regeneration

Light transmission is limited by attenuation and dispersion

What is Wave Division Multiplexing (WDM) ?

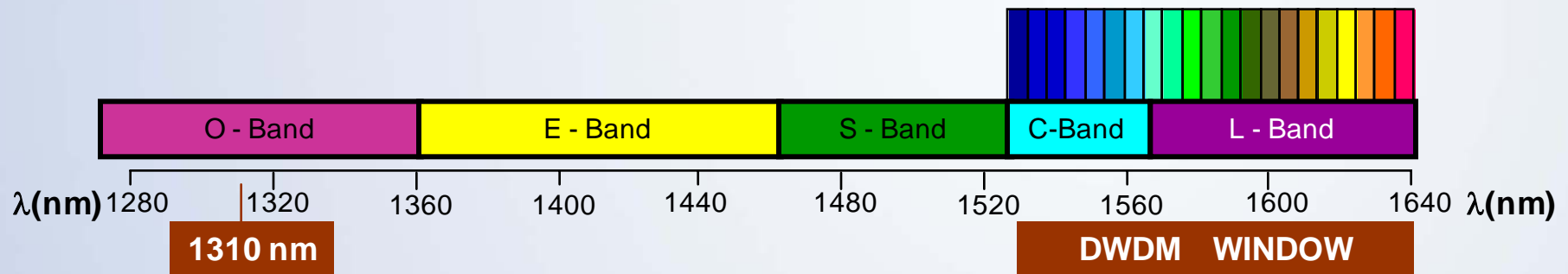


- Wave Division Multiplexing is a fiber-optic transmission technique that employs light wavelengths to transmit data
- An “optical funnel” for any signal (Bit rate/protocol) onto one fiber using different colors of light (λ 's) for each signal
- There is no protocol translation or taxation as a result

DWDM and CWDM

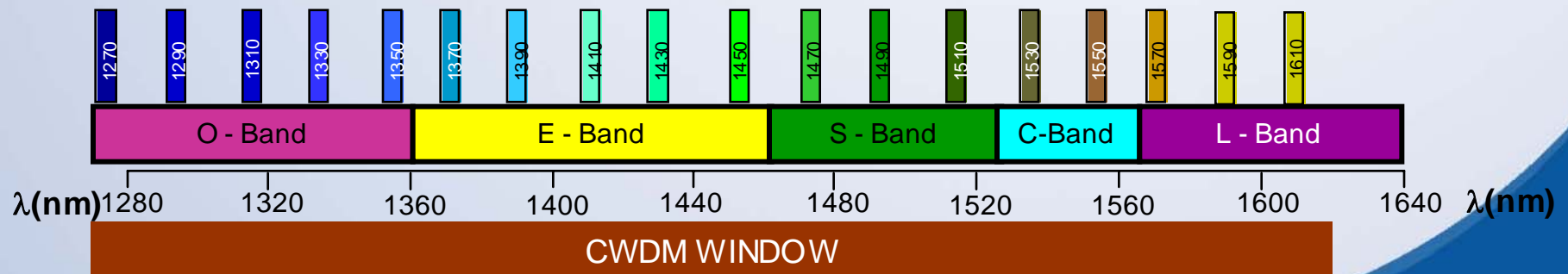
DWDM – Dense Wave Division Multiplexing

- For High Bandwidth applications
- Squeezes many channels into Optical Spectrum
- Characterized by a tight channel spacing (typically 50 – 200 GHz) in the C and L bands

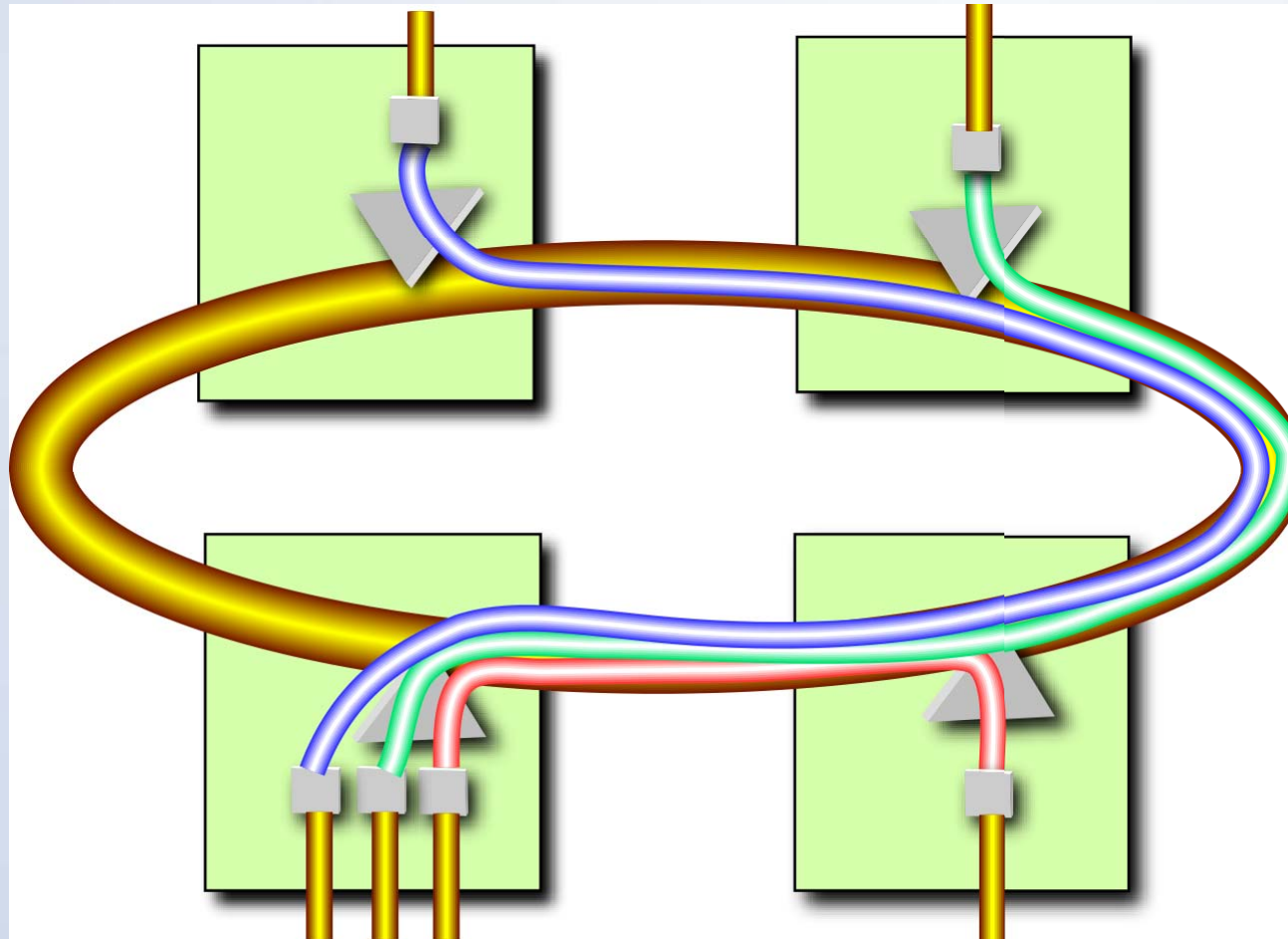


CWDM – Course Wave Division Multiplexing

- For lower channel count applications
- Lower cost than DWDM with same resiliency and protection
- Characterized by a wide channel spacing (20 nm) over a wide optical spectrum (1270 – 1610 nm)



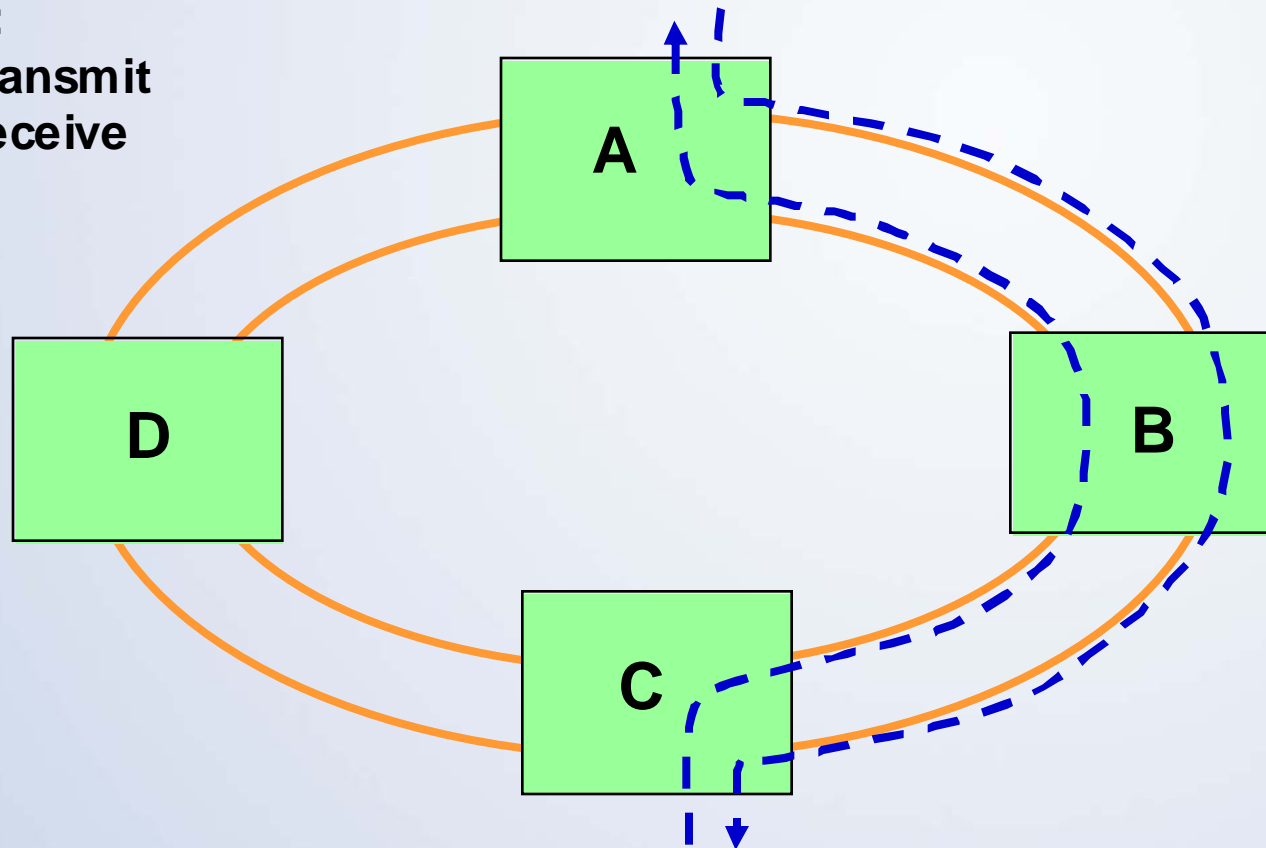
Basic Ring C/DWDM Functionality



Transports optical signals from one location to another

Signal Flow

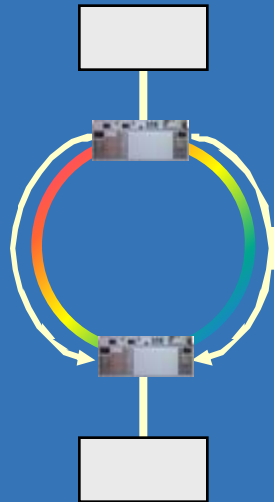
- 2 fibers:
- one Transmit
- one Receive



Transmit and receive are the same wavelength but run on separate fibers

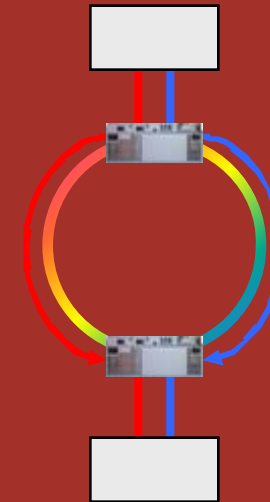
Optical Protection Strategies

Protected 1+1 Dedicated Optical Paths



High availability for client signals without built-in protection, eg. Fibre Channel, ESCON

Unprotected Dual Diverse Optical Paths



For client networks with built-in protection/restoration mechanisms, eg. Ethernet S-MLT

Provisionable on a per-service, per-wavelength basis

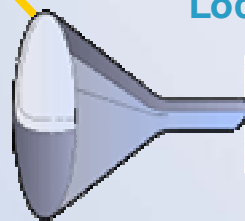
C/DWDM Value Proposition

Scalable Platform:
Delivering a comprehensive set
of services and applications

Simple Architecture:
Reducing the Enterprise Total
Cost of Ownership (TCO)

Secure System:
Service assurance for mission
critical data and applications

Fast Ethernet
GbE
10 GE
ESCON
FICON
Fibre Channel
FDDI
SONET/SDH
ETR/CLO
ISC/ISC3
ATM
D1 Video
DV6000



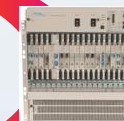
Location A



Location B



Location C

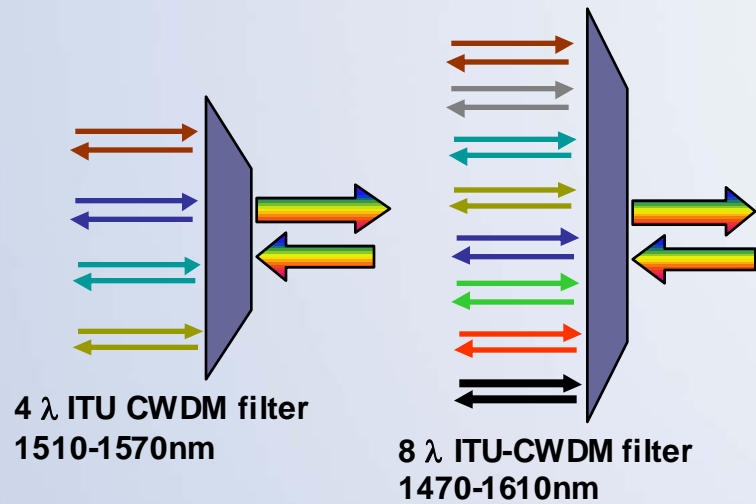


Location D

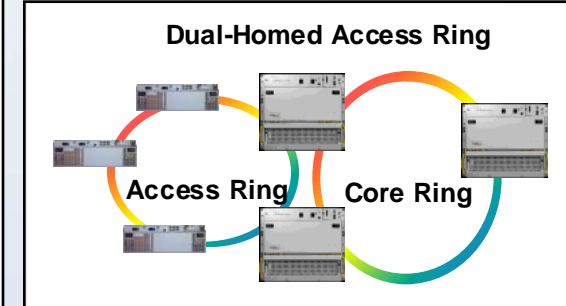
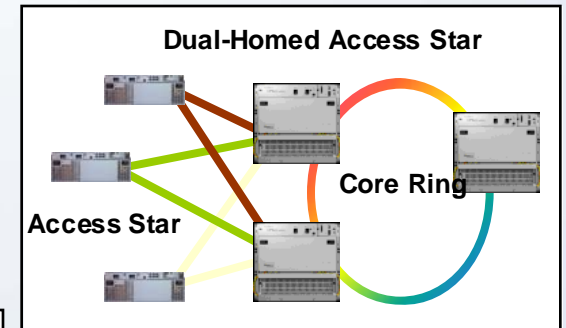
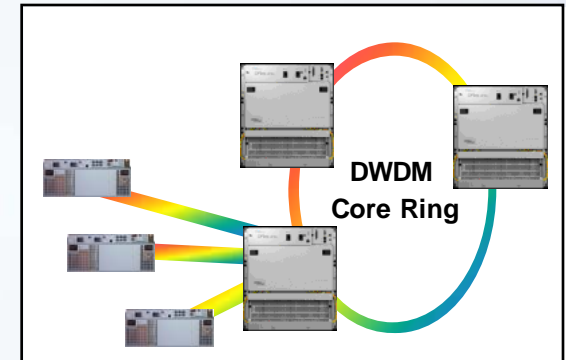
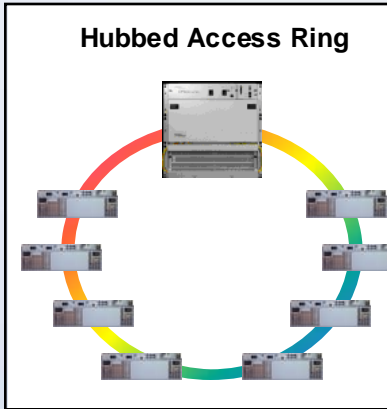
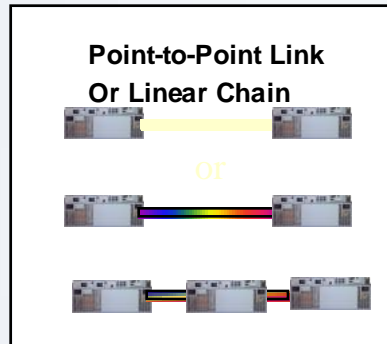


***A Complete Transport Infrastructure Delivering Any
Protocol & Any Bit-Rate Between Any End-Points***

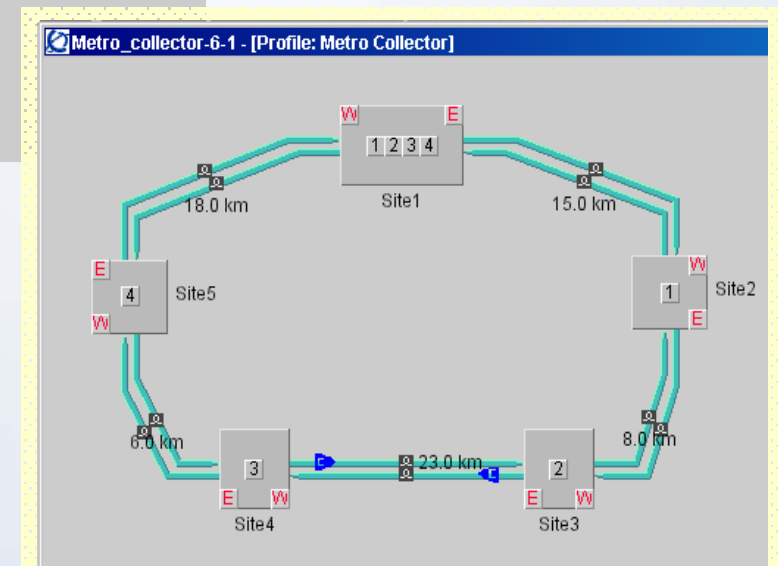
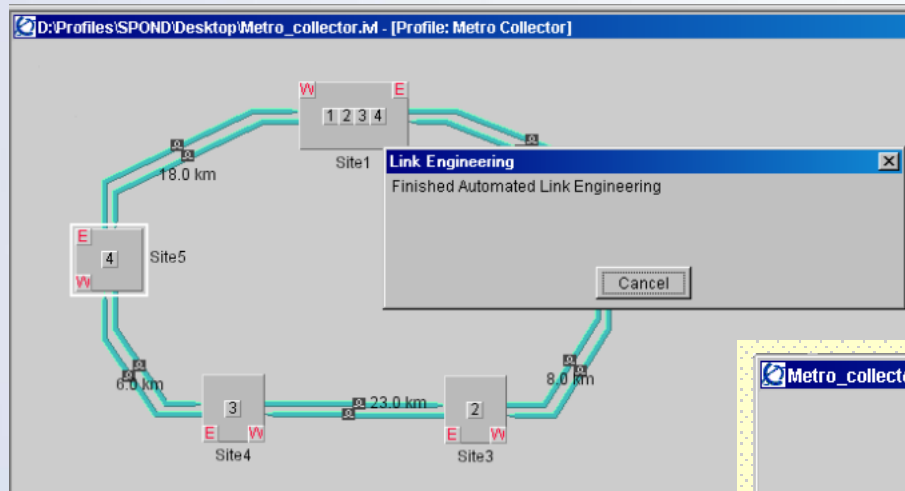
CWDM Solutions



ITU-T G.694.2 Compliant
Reach up to 80 km



WDM Network Modeling Tools

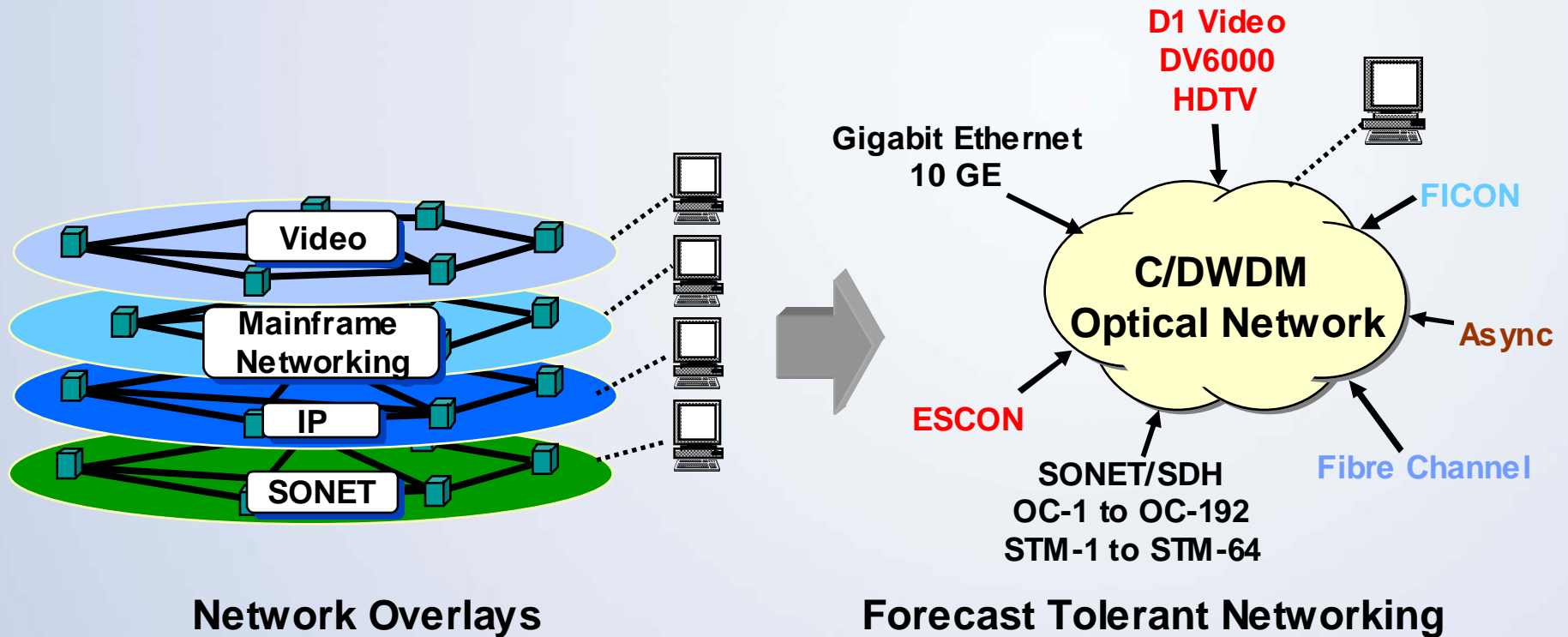


Automatic Link Engineering

- Automatic placement of amplifiers, regenerators and equalization components
- Ability to modify automatic placement and validate solution
- Ability to model both greenfield designs and system expansions

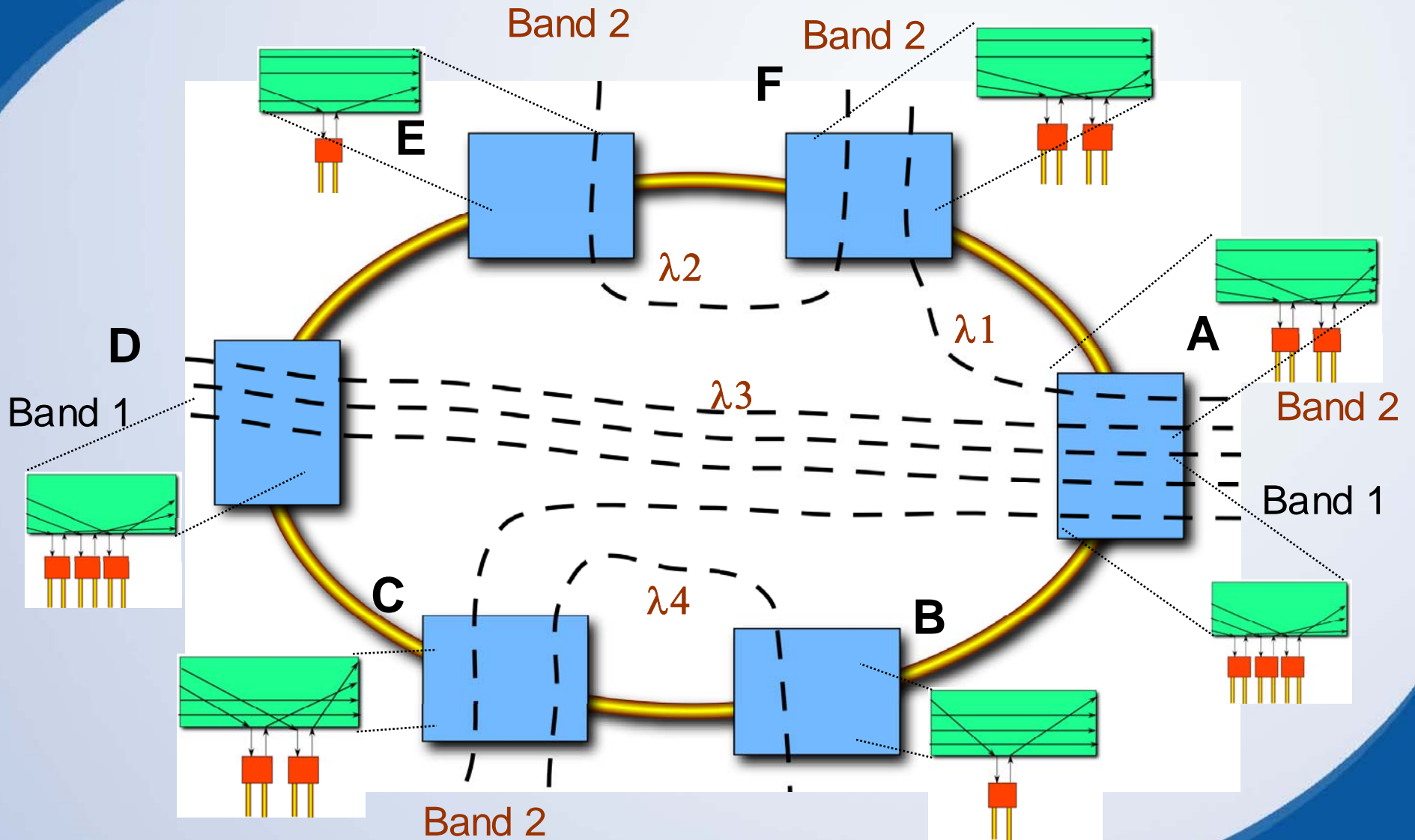
Network Convergence

WDM Technology

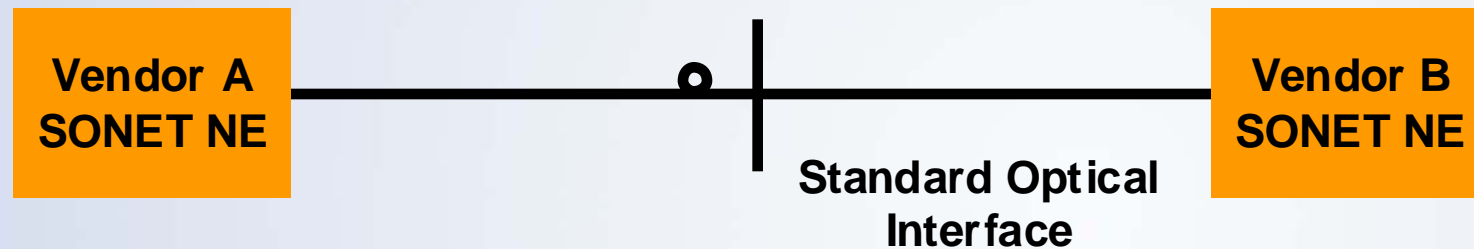


Simple - Flexible - Cost effective - Easy to operate & grow

A DWDM Solution

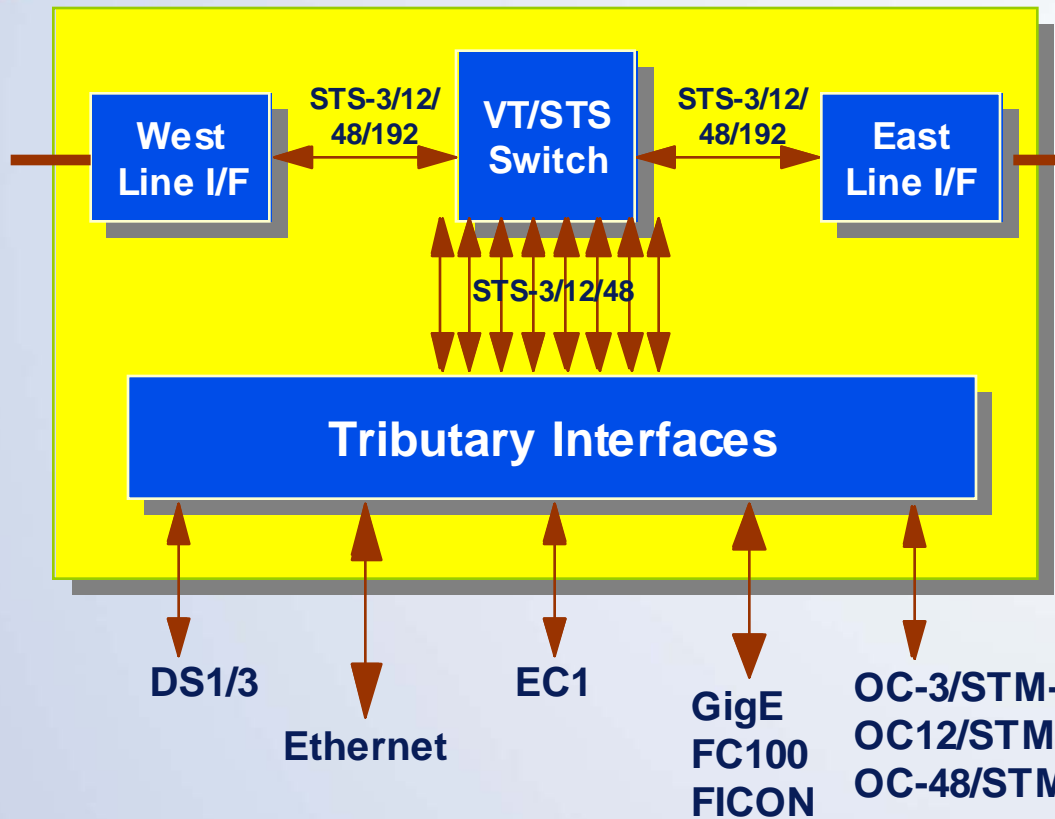


What Is SONET?



- Synchronous Optical and Electrical Interface for Multi-Vendor (e.g. SONET)
- Synchronous frame structure for multiplexed digital traffic
- Set of building blocks to allow easy growth of bandwidth
- Standards based survival rings
- Enhanced set of messages and protected overhead channels for operational control and management of network
- With GFP, storage, video and data applications can be readily transported across the existing pervasive SONET infrastructure

NG SONET Nodal Architecture



OC-3/STM-1/STM-0
 OC12/STM-4
 OC-48/STM-16
 OC-192/STM-64

- Fully nonblocking cross-connections
- Total payload access
- Minimal engineering rules

SDH/SONET Hierarchy

Optical Signals	Bit (Line) Rate
STS-1, OC-1 / STM-0	51.84 Mb/s (VC-3)
STS-3, OC-3 / STM-1	155 Mb/s (VC-4)
STS-12, OC-12 / STM-4	622 Mb/s
STS-48, OC48 / STM-16	2.5 Gb/s
STS-192, OC-192 / STM-64	10 Gb/s
Electrical Signals	Bit (Line) Rate
DS-0	64 kb/s
DS-1	1.544 Mb/s (VT1.5)
DS-2	6.3 Mb/s
DS-3	44.736 Mb/s

Why SONET?

Benefits over the previous transmission technology

Network and Service Management

- End-to-end management
- Standard management channel

Improved protection

Network simplification

- Access signal from the largest multiplexed signal

Network optimization

- Distributed bandwidth management

Standardization

Pervasive

Multi-vendor networks

Rapid creation and deployment of high value connectivity

Survivable networks:

10 msec detect
50 msec protect

Reduced operating cost

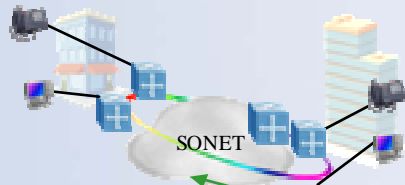
Improved Network utilization

Multi-Protocol with GFP/RPR

The Question “Is SONET Fading?”

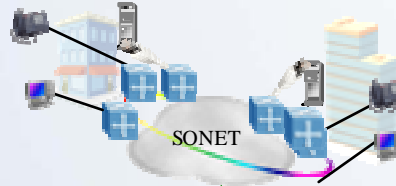
Legacy SONET

- Multi-box TDM based
- Single Service
- Costly Reliability



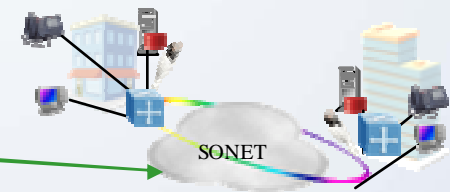
Metro Ethernet

- Multi-box – TDM & Ethernet
- Best effort Ethernet MANs
- New Builds



Any Applications over Next Gen SONET

- Multi-Service Broadband (GFP)
- Carrier Grade Ethernet
- Lowest TCO



WW: \$38.93B from 2000-2002!*

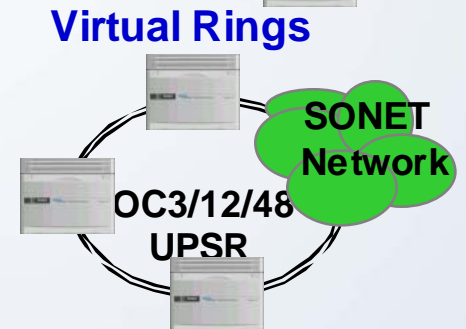
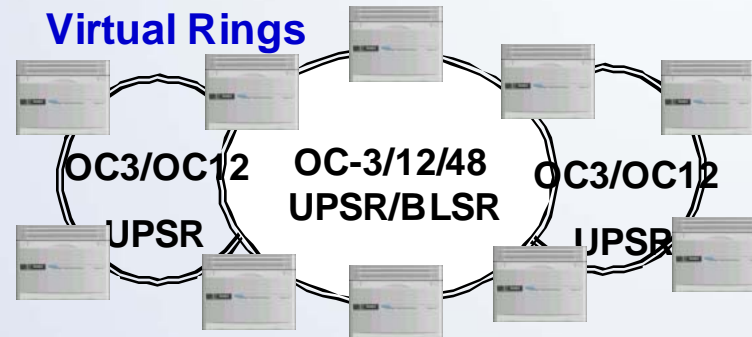
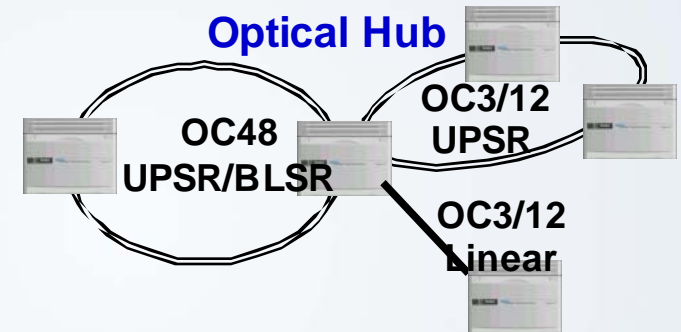
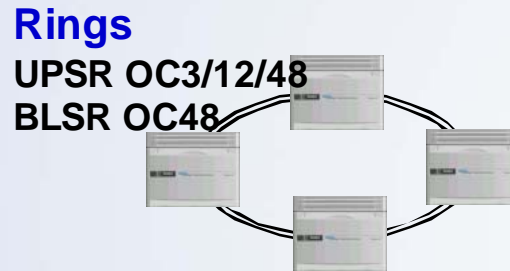
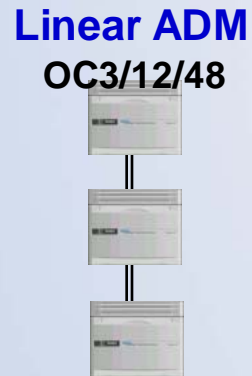
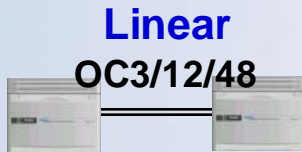


*\$US revenue numbers are from RHK and include all SONET/SDH equipment deployed in that year

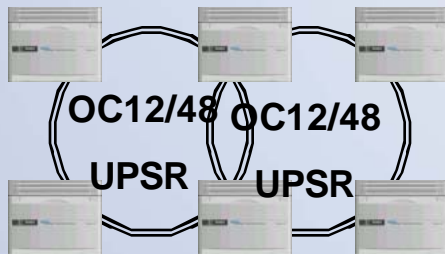
The Answer

No. Leveraging a greater than \$39B installed base of SONET with Next-Generation SONET is an excellent enabler of all Enterprise Applications.

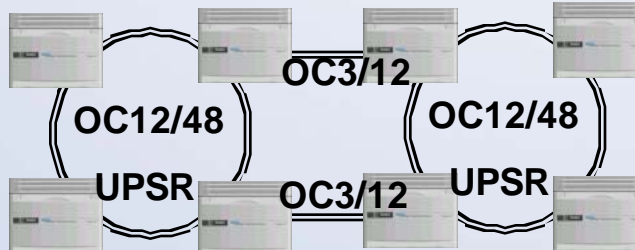
Flexible Networking Options



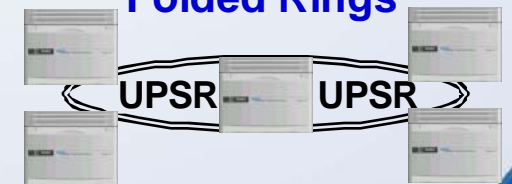
Dual Homed Subtending Rings



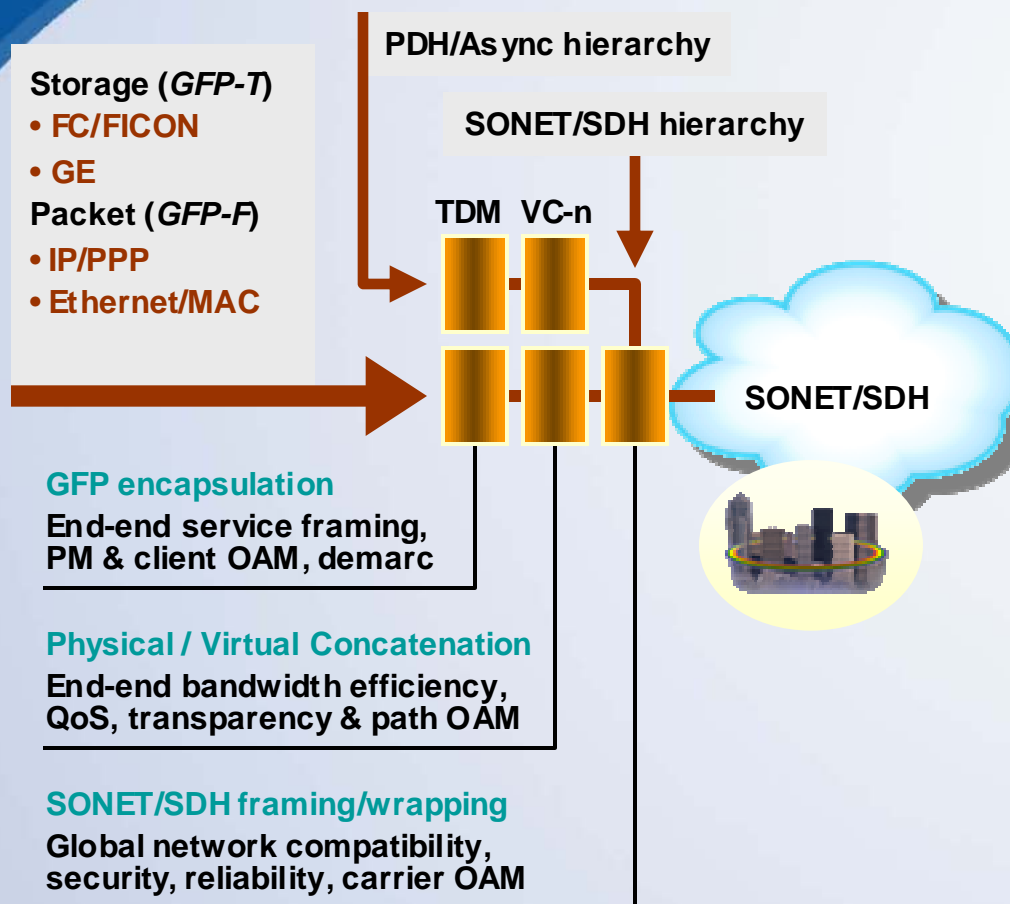
Matched Nodes



Folded Rings



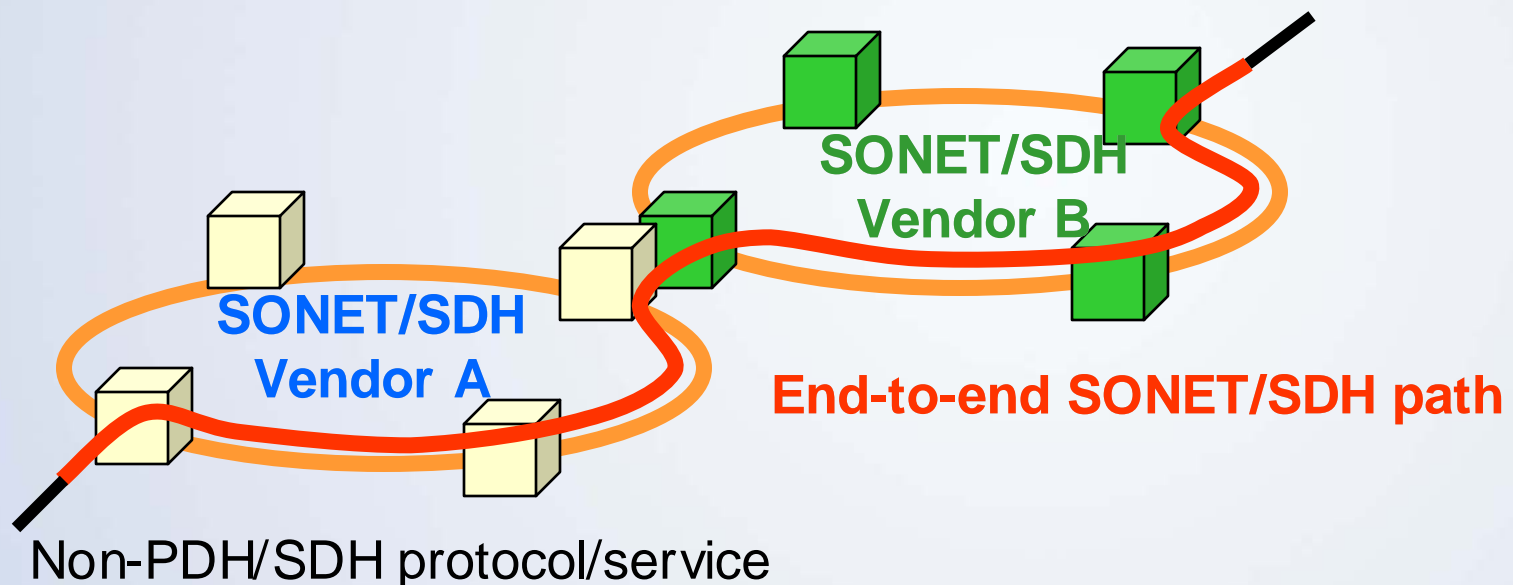
GFP – Generic Framing Procedure



ITU-T G.7041

- **Simple multiservice adaptation**
- **Robust & uniform packet transport**
- **Interoperable global ITU-T standard**
 - Mapping to SONET, SDH & OTN
- **Efficient network resource utilization**
 - Low GFP overhead
 - “Rightsizing” - No over-provisioning with Virtual Concatenation.
- **TDM QoS, latency & jitter performance**
 - Transparent mode, minimal buffering
- **L2 independent**
 - Supports RPR, other L2 protocols
- **Enables network consolidation**
 - Converges next-generation services with existing infrastructure investment

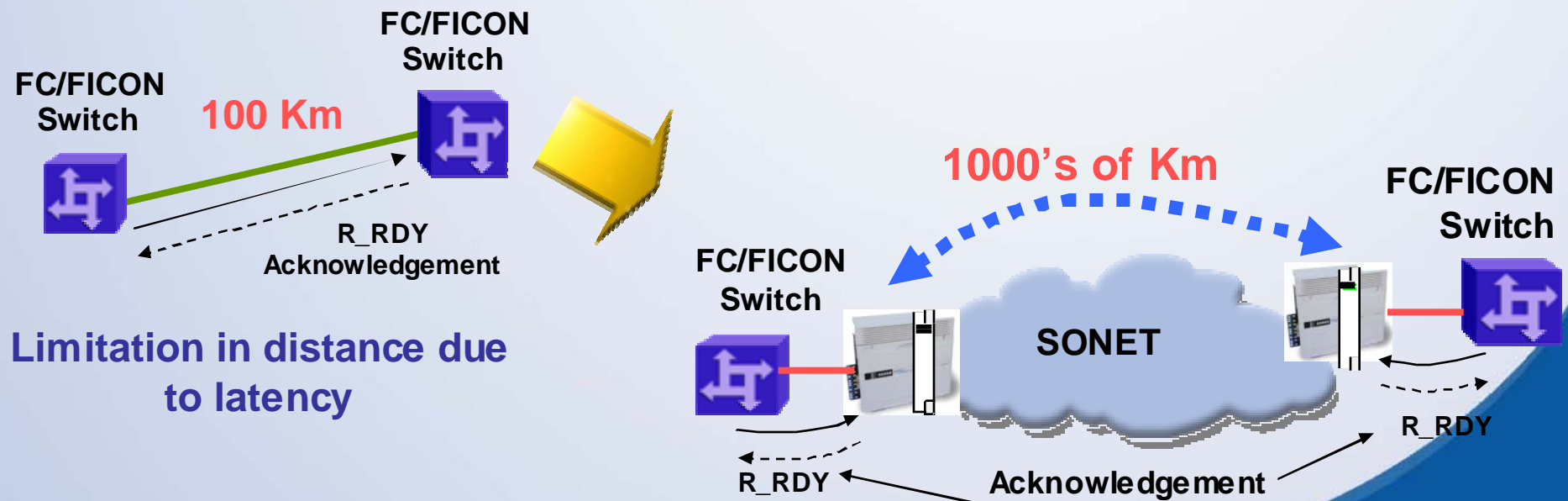
GFP: “Real Inter-Working”



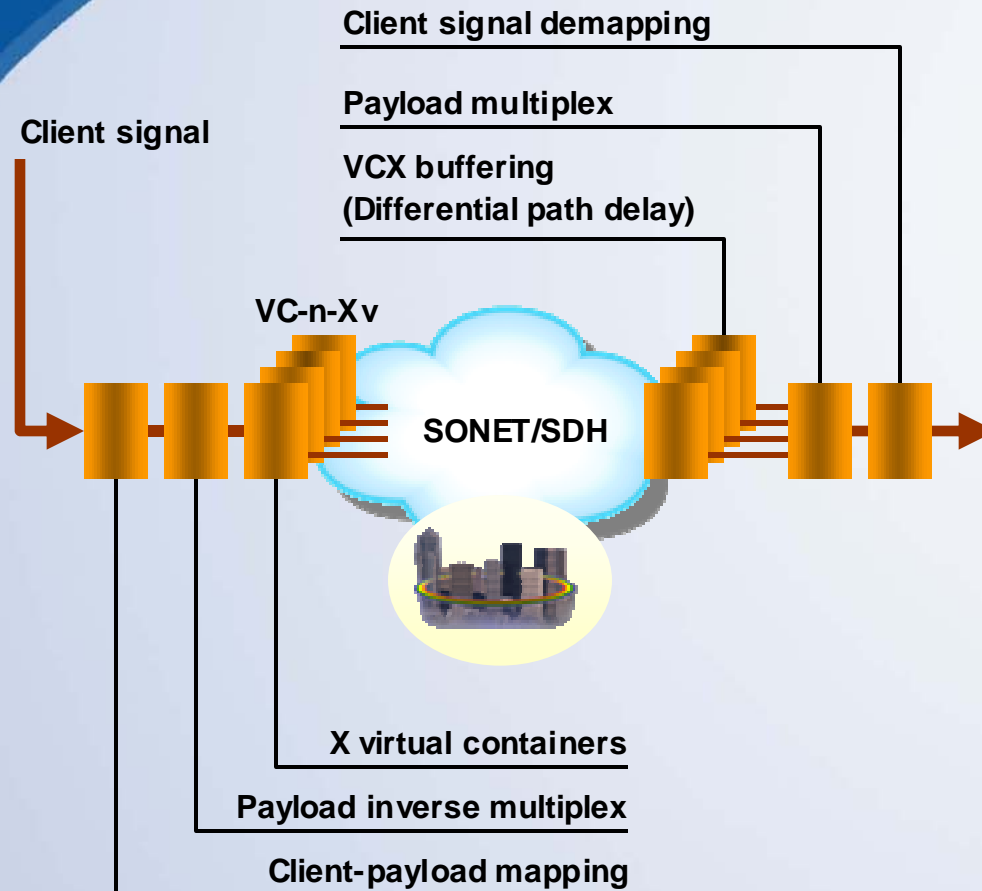
- The Generic Framing Procedure (GFP) provides a standard mapping/framing technique for Layer 1/2 signals into SONET/SDH/OTN
- Standardization enables unambiguous implementation across multi-vendor and legacy SONET/SDH networks with full QoS!

Fibre Channel/FICON Over Distance

- The new FC/FICON/GigE Mapper Enterprises to extend the reach of FC/FICON services up to 1000s of Km to meet various DR/BC requirements
- Achieved via the implementation of Flow Control and Buffer-to-Buffer Credits (BBC)



VCAT – Virtual Concatenation

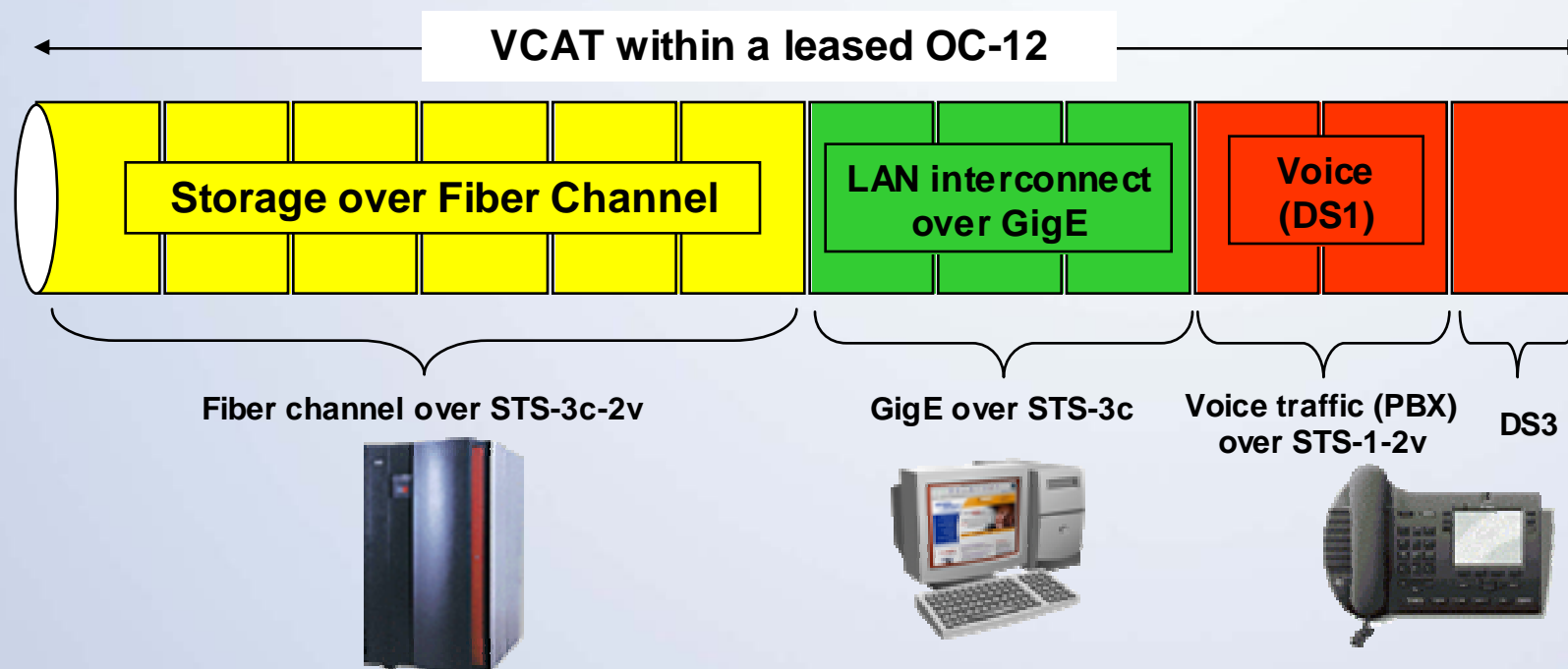


ITU-T G.707

- **Interoperable global ITU-T standard**
 - Mapping to SDH, SONET structures
 - Compatible with existing global network
- **Efficient network resource utilisation**
 - “Right-sized” bandwidth channels
 - Reduction in over-provisioning
 - End-end efficiency for packet services
- **Flexible provisioning of multiservices**
 - Increases SONET/SDH granularity
 - Uses existing service management
- **TDM QoS, jitter performance**
 - Deterministic QoS for all services
- **New soft protection schemes**
 - LCAS (ITU-T G.7042) provides automatic signalling capability

Benefits of VCAT

- Enterprise customers can maximize their return on investment by combining multiple traffic types on the same leased bandwidth while ensuring maximum bandwidth efficiency

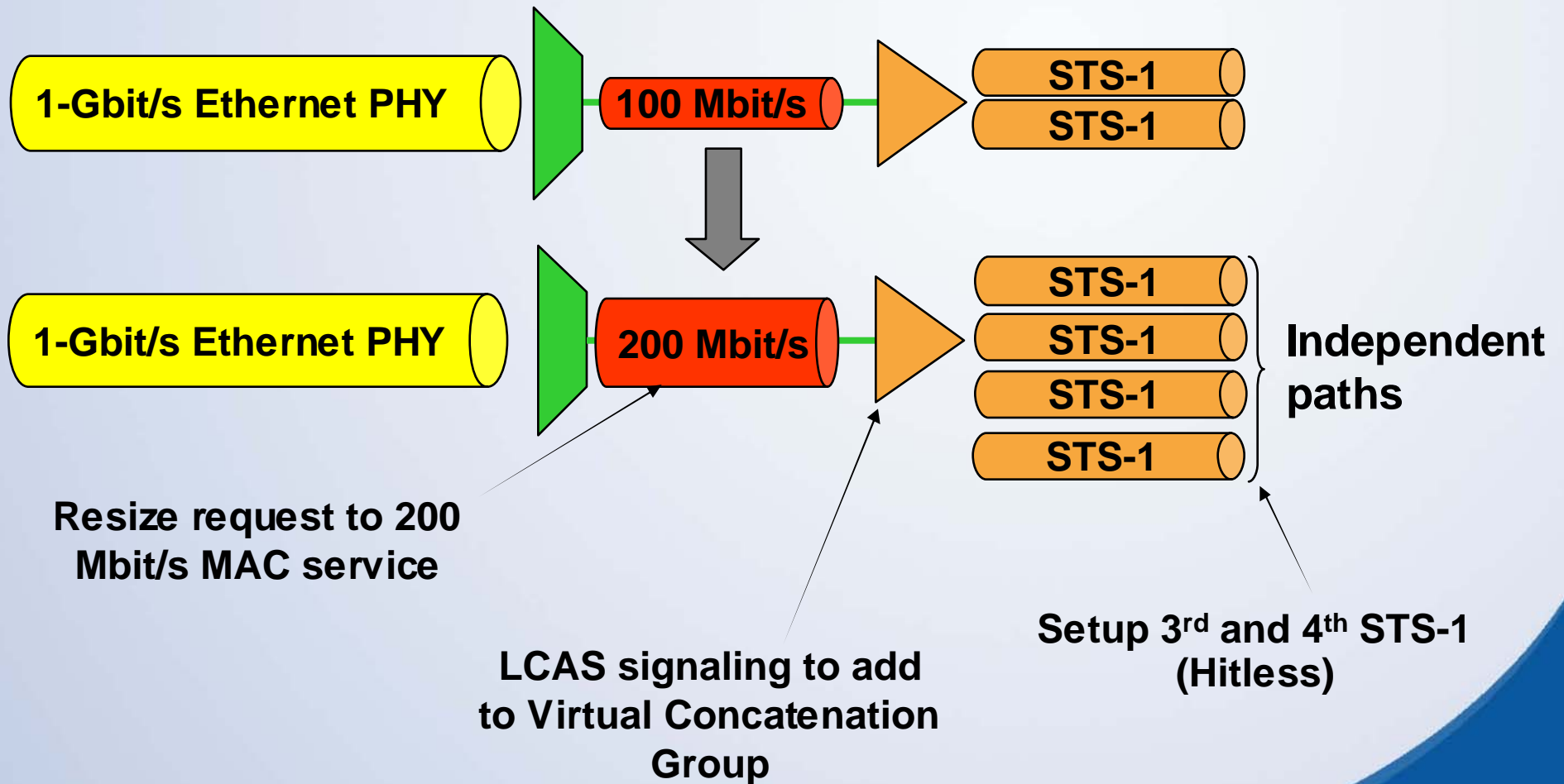


LCAS – Link Capacity Adjustment Scheme

- **The NMS/OSS can efficiently offer dynamically-allocated bandwidth**
- **Hitless increase or decrease in capacity of a VCAT Link (or Virtual Concatenated Group, VCG) by adding/removing STSs**
- **Provides a soft protection & load-sharing mechanism**
 - Automatically decreases the link capacity if an STS path experiences a failure
 - Automatically increases the link capacity when the network fault is repaired
- **Provides an extra level of network and service resiliency**
 - Facilitates support of Service Level Agreements, especially in the area of network and service restoration
 - Hitless bandwidth expansion and contraction reduces service interruptions in the event of network failure
 - Eases network operations and maintenance actions

Enabling dynamic provisioning for Enterprise Services

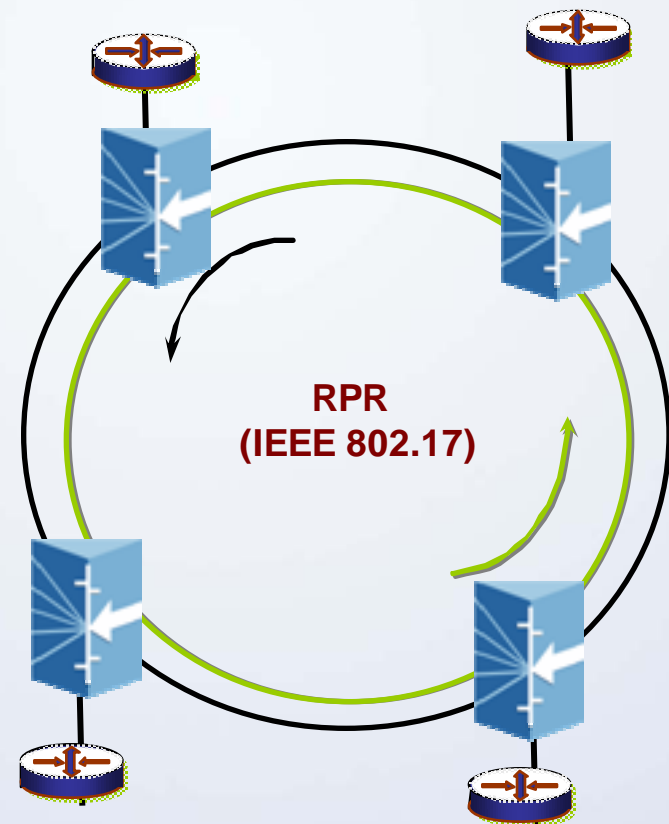
VCAT + GFP + LCAS Example



Next Gen Technology

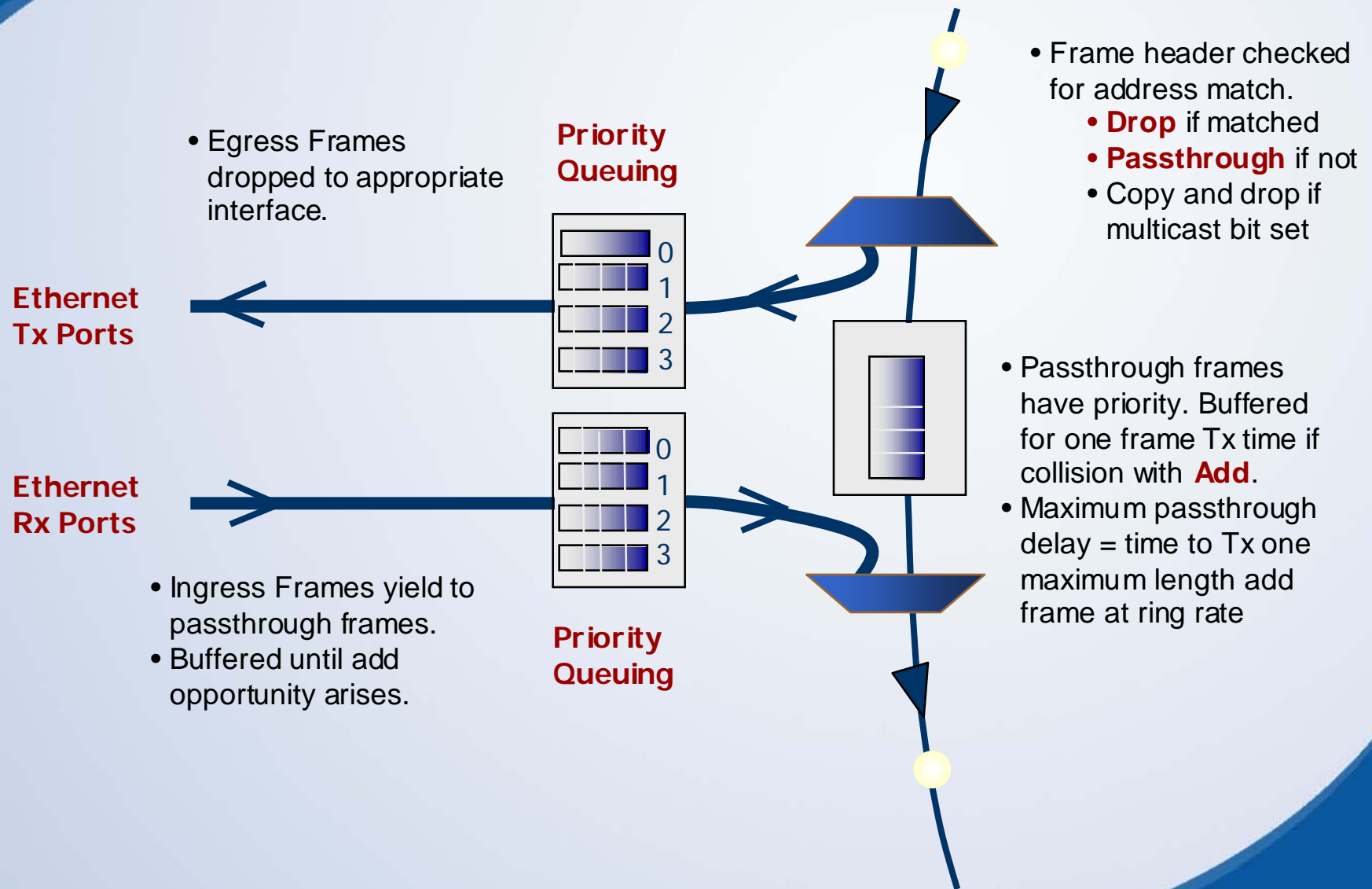
Resilient Packet Ring (RPR)

- **Ring MAC Protocol**
 - Packet Add/Drop/Pass through
 - Efficient Multicast/Broadcast
- **Class of Service**
 - Multi-service support
 - Transparent to end-service
- **Spatial Reuse**
 - Effective Use of Bandwidth
- **Ring Protection**
 - Fast and reliable layer 2 protection
- **Topology Discovery**
 - Connectionless route discovery
- **Control Access Protocol**
 - Ensures fair access to ring BW



Maximizing Ethernet WAN Bandwidth for New Applications

Ring MAC Protocol

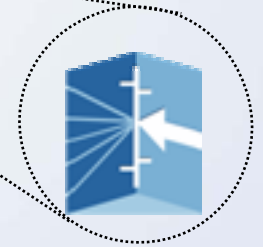
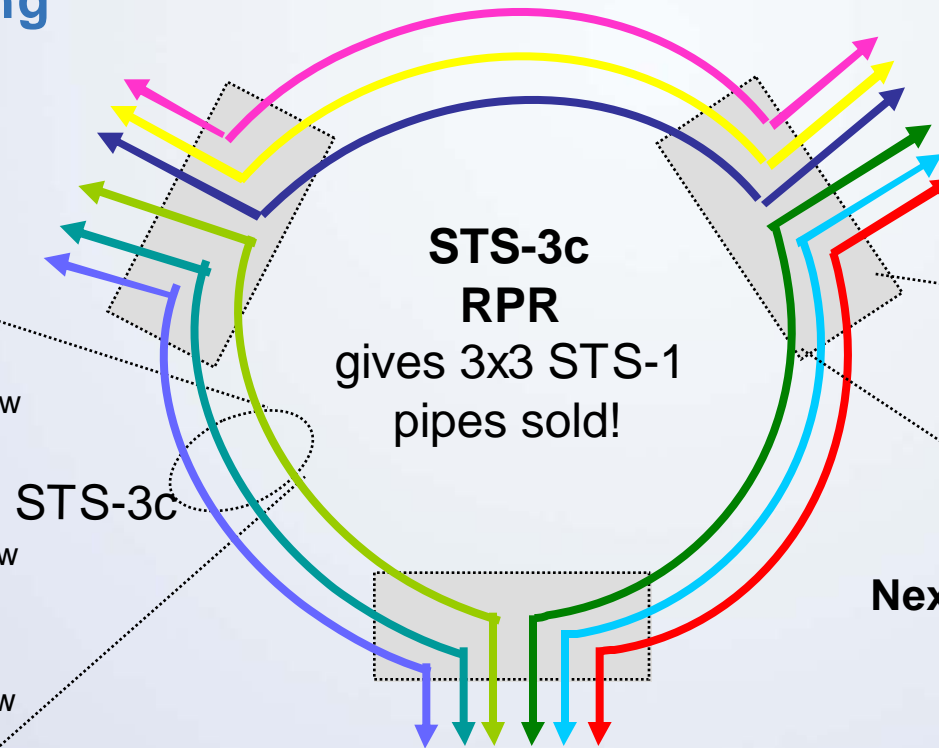
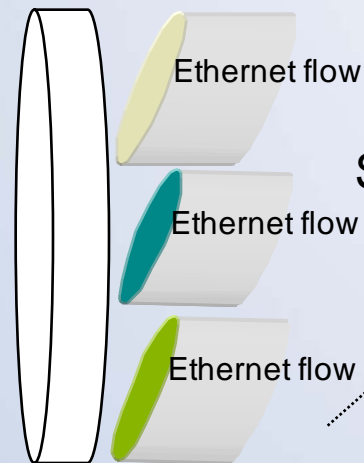


RPR Systems

Bandwidth best use with

- Statistical multiplexing
- Spatial reuse
- Shortest path

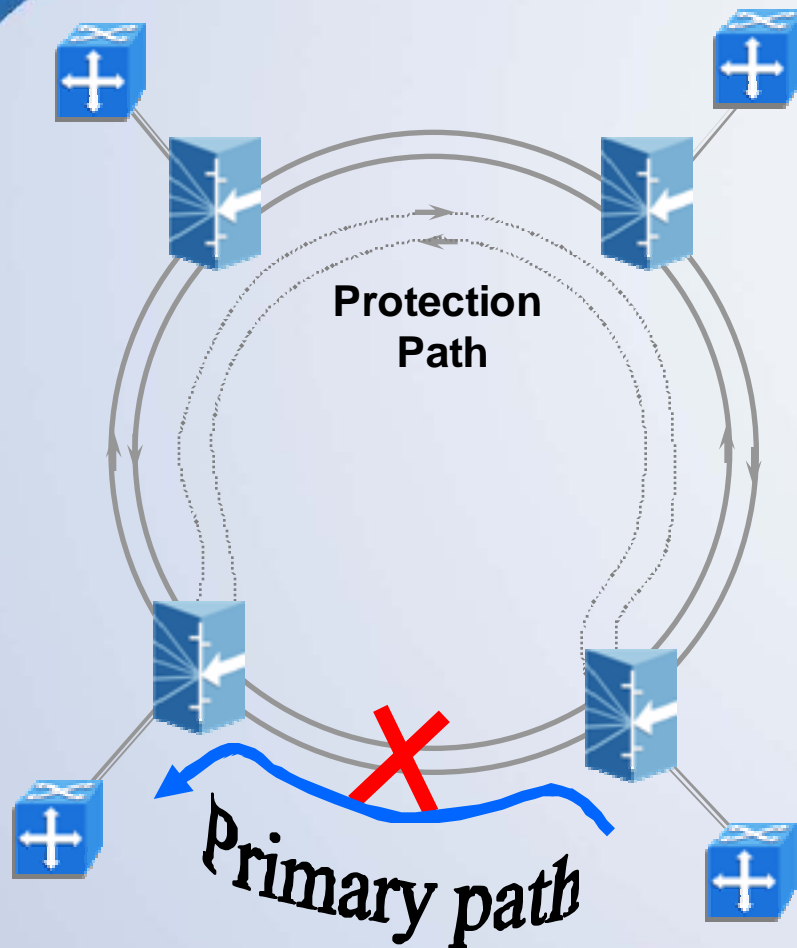
3 distinct flows share the bandwidth



Next Gen SONET Platform

Resilient Packet Ring (RPR) brings the advantage of statistical muxing

RPR – Best use of Bandwidth

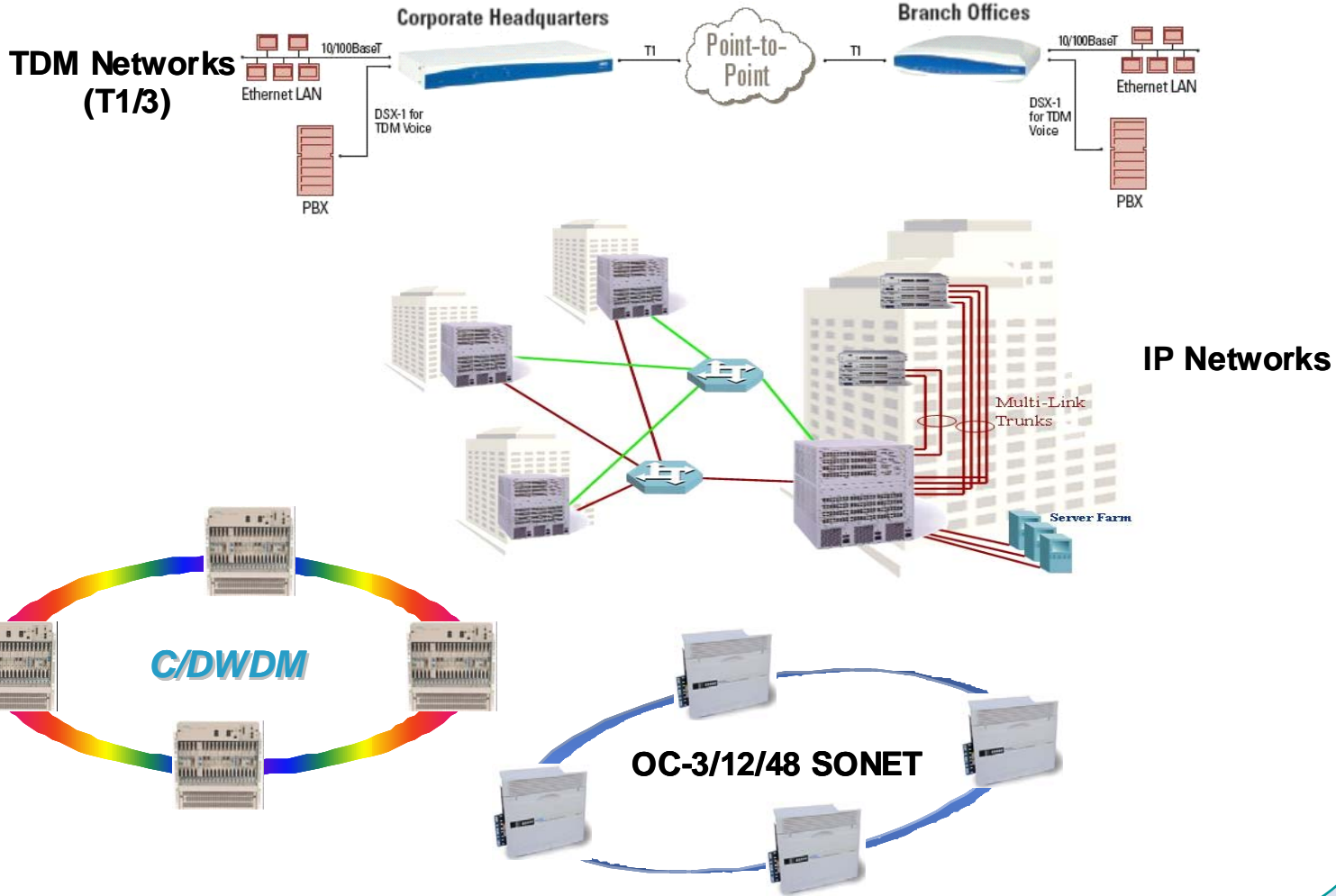


- **Protection at Ethernet layer**
 - Unprotected circuits established in SONET
- **Best use of bandwidth**
 - No dedicated protection bandwidth
- **Simple set-up**
 - Primary and Secondary Paths automatically discovered by Topology Discovery Algorithm

***Fast Intelligent L2 Protection Switching
L3 won't see the protection switch!***

**OPTICAL NETWORKING
ENABLING
CONVERGENCE APPLICATIONS**

WAN Network Types

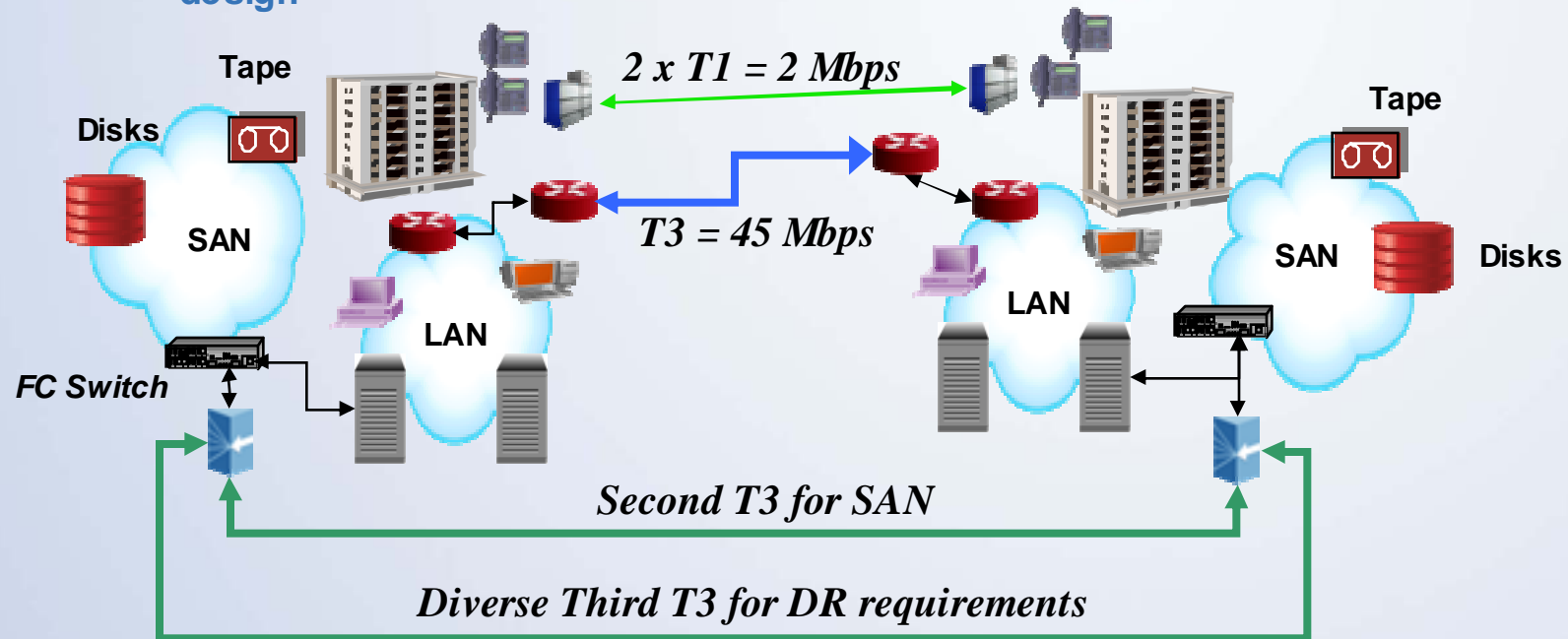


WAN Network Comparison

Application Requirement	Traditional Private Line, ATM & FR	IP WAN Network	WDM Network	SONET/SDH Network
Economics for Long Haul Distances	GOOD	GOOD	POOR	GOOD
Performance Characteristics (Latency, Jitter)	FAIR	POOR	GOOD	GOOD
Throughput	LOW Due to Adaptation	POOR Unpredictable	Full Rate FC-100 FC-200	Scalable by N x 50 Mbps
Economics for High Channel Counts / High Bandwidth	POOR	POOR	GOOD	POOR
Economics for Low Channel Counts / Low Bandwidth	POOR	AVERAGE	FAIR /w CWDM	GOOD
Performance Monitoring / SLA Statistics	GOOD	POOR	AVERAGE	GOOD
Flexibility to Provision and Scale	POOR	POOR	GOOD	GOOD
Protection and Restoration (<50 msec)	YES	NO	YES	YES
Infrastructure Security	GOOD	POOR	GOOD	GOOD
Available Now	YES	YES	YES	YES

Optical Networks – Enabling Convergence

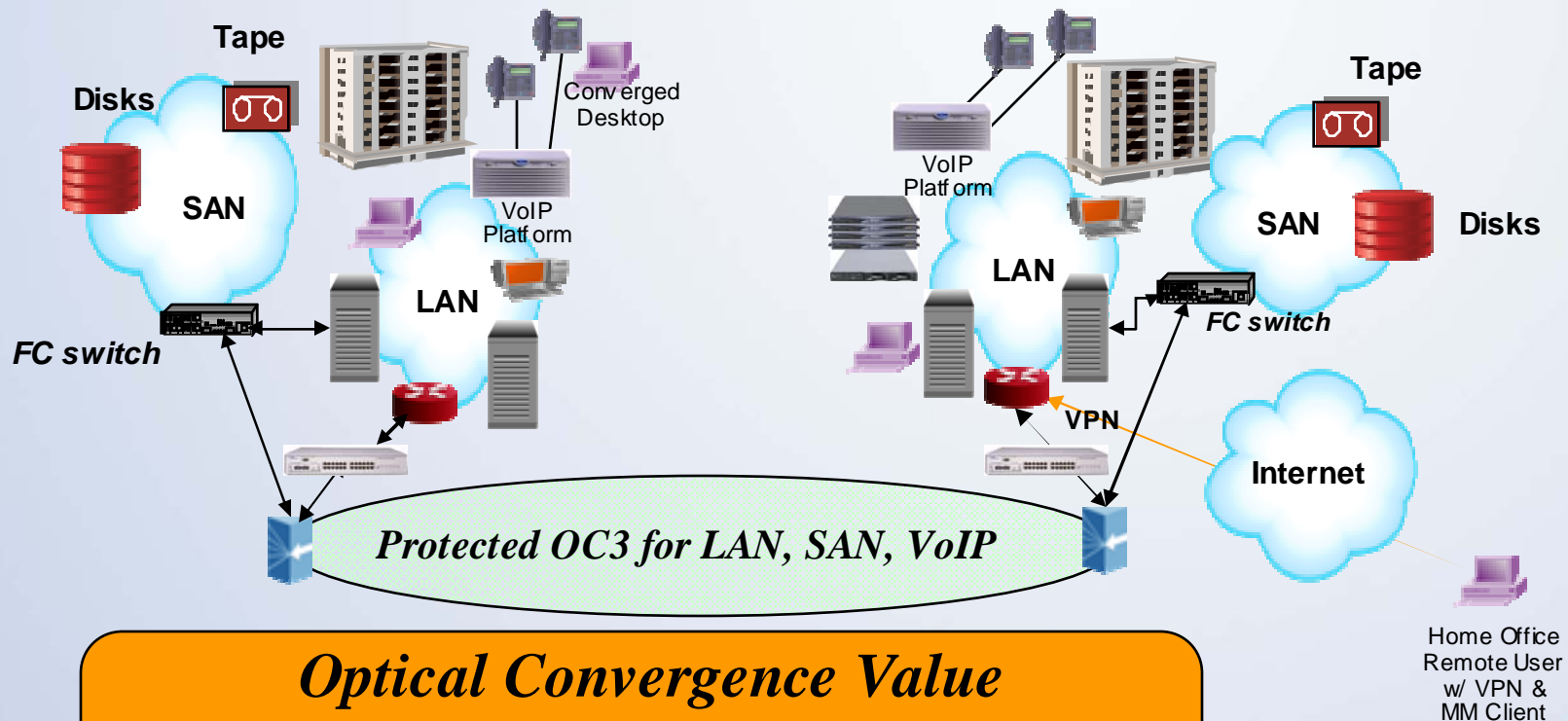
- **Present Mode of Operation**
 - WAN links are becoming exhausted and bandwidth constrained
 - Disaster Recovery regulations and business concerns driving SAN extension with remote data centers
 - SAN and LAN and Voice traffic remains completely independent of each other by design



Metro T3 = \$3,200/month, T1 = \$390/month
Voice + LAN + SAN connectivity = \$7,180/month (92 Mbps)
Voice + LAN + SAN Diverse = \$10,300/month

Optical Networks – Enabling Convergence

- **Future Converged Mode of Operation**
 - Voice TDM network converged over IP network
 - Disaster Recovery regulations and business concerns are now addressed with remote data center
 - SAN, LAN and Voice traffic remain completely independent of each and can be re-allocated as required with no need for service provider to be involved



Optical Convergence Value

- ***68% more bandwidth (155 Mbps vs 92 Mbps)***
- ***37% cost savings (\$6,500 vs \$10,300 diverse)***
- ***Ability to allocate BW between SAN and LAN***

Optical Networks – Enabling Convergence

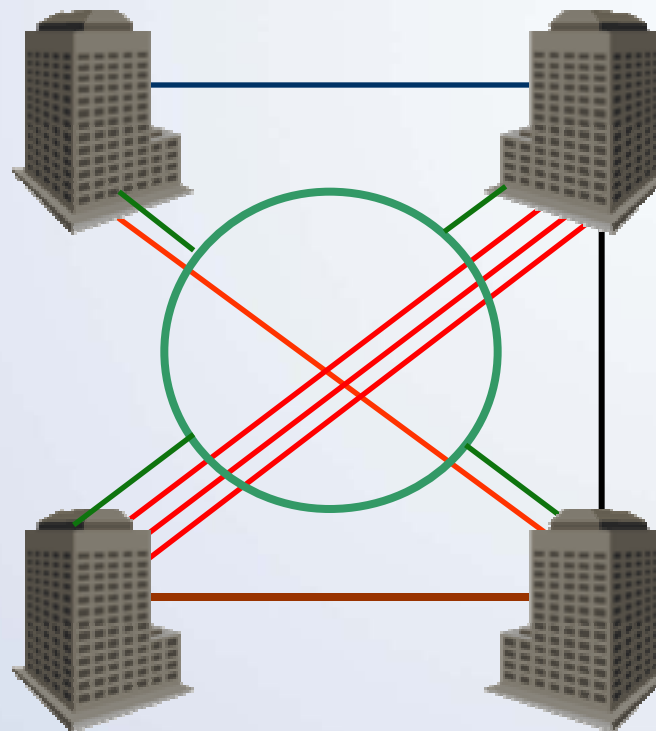
T1 Link:

- Low Bandwidth
- Limited Protocol Support
- Limited Reliability
- Expensive

PPP WDM:

- ESCON and FC Storage Extensions

Existing Network



Legacy SONET:

- Stable/Proven
- Limited Bandwidth
- Not Scalable
- Limited Protocol Support
- Expensive

LAN Extension:

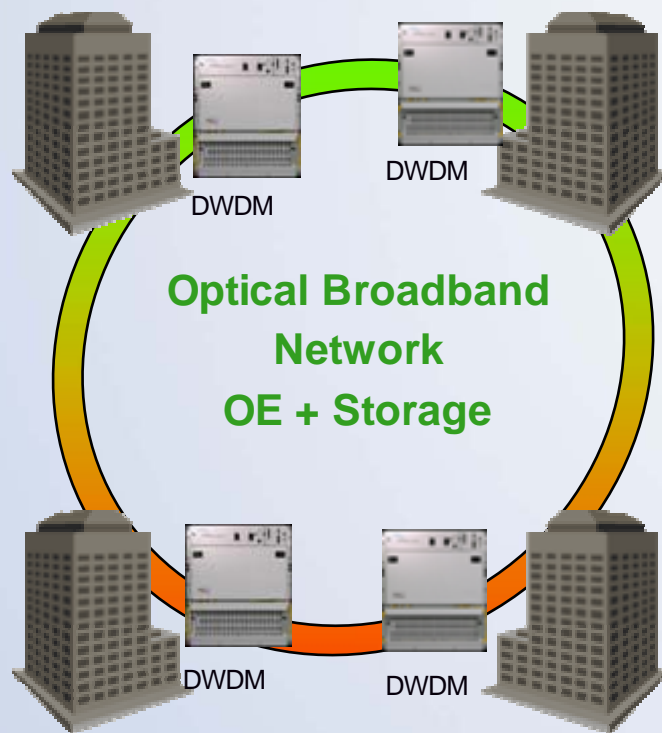
- High Bandwidth
- Limited Protocol Support
- Limited Reliability/QoS
- Expensive

ATM:

- High Bandwidth
- Limited Protocol Support
- Good QoS
- Expensive

Complex, Unreliable and Expensive \$135 / Mb transported!

Optical Networks – Enabling Convergence



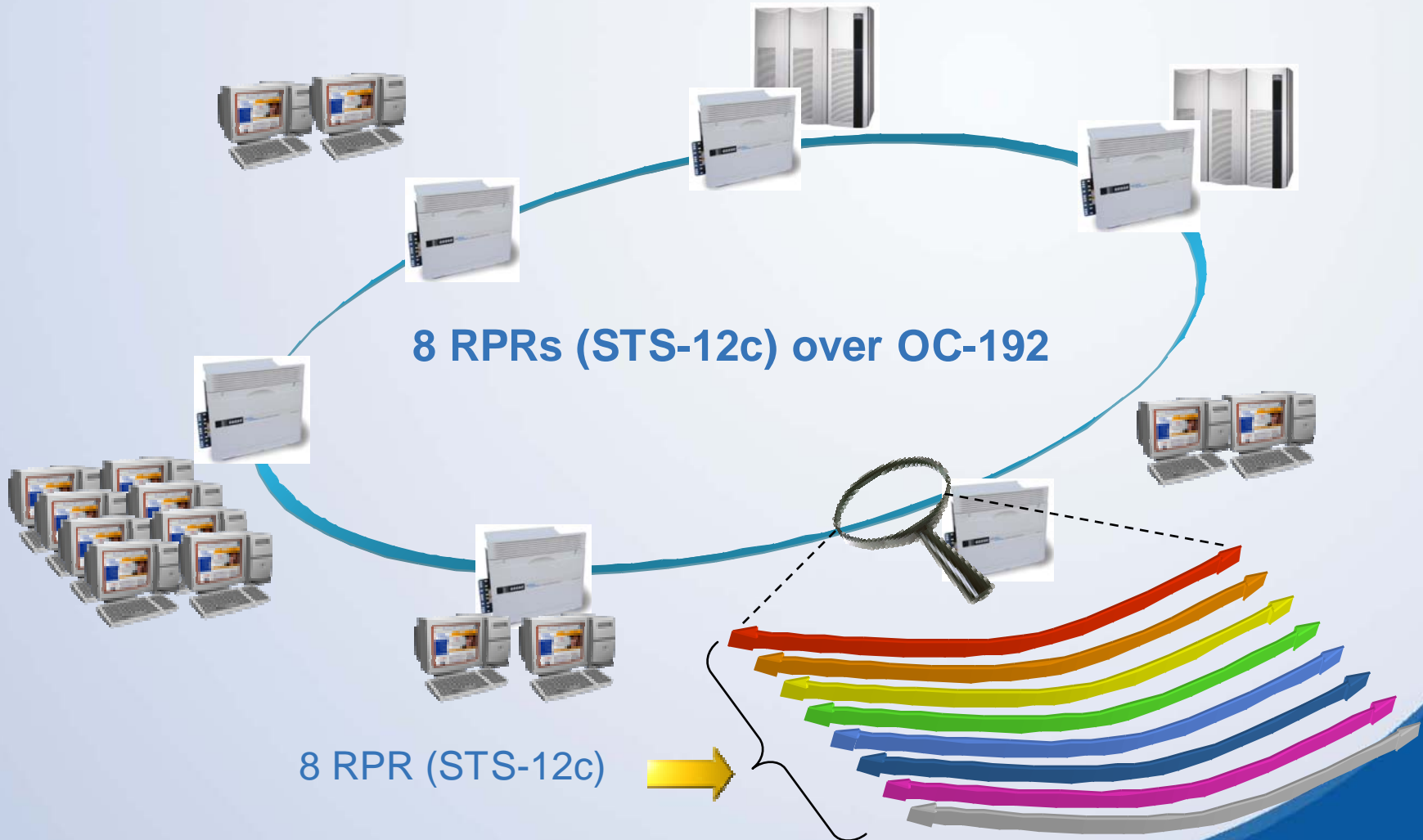
The Solution

DWDM Converged Solution

- Carrier Grade Resiliency
- Bit rate and Protocol Independent (All native protocols preserved, not converted/translated!)
- Scalable and Future Proof
- New Applications
- Quantifiable ROI

A Simple, Secure, & Scalable Solution – \$10 / Mb Transported – 93% savings!

High-bandwidth Ethernet Backbone (8 RPRs over OC-192)



Next Gen Optical Enterprise Myths and Realities

“Optical is hard, because...”	“The reality is ...”
“Acquiring dark fiber - if available is challenging at best”	“Optical Enterprise solutions enable Next-Gen Enterprise services over <i>existing</i> pervasive OC-n SONET network”
“Optical solutions are too complex”	“SONET/SDH solutions are simple and many vendors offer pre-packaged solutions”
“Our optical solutions require expensive Engineering and Installation”	“SONET/SDH solutions require little engineering and advanced WDM modeling tools make WDM network engineering simple”
“I can’t afford \$30k / month for high end optical solutions”	“Simply lease normal SONET OC3/12 pipes and get a Converged Voice, Storage and Data solution.”

Simple, Secure and Scalable

Summary

- **Optical Networking within the Enterprise is simpler than learning IPv6**
- **Optical Networks provide maximum flexibility and future proofing**
- **Optical Networking enables Network Convergence without any compromises**
 - Multiple protocols and applications can be transported over the same network
 - Each protocol and application maintains 100% isolation from each other
- **Traditional SONET systems for TDM and voice applications have evolved into Next Gen SONET systems capable of delivering any application with full QoS across multiple carriers**
 - SONET systems are pervasive and can be readily leveraged
- **WDM Modeling tools have evolved to enable the Enterprise to design and engineer multi-site networks**

Thank You

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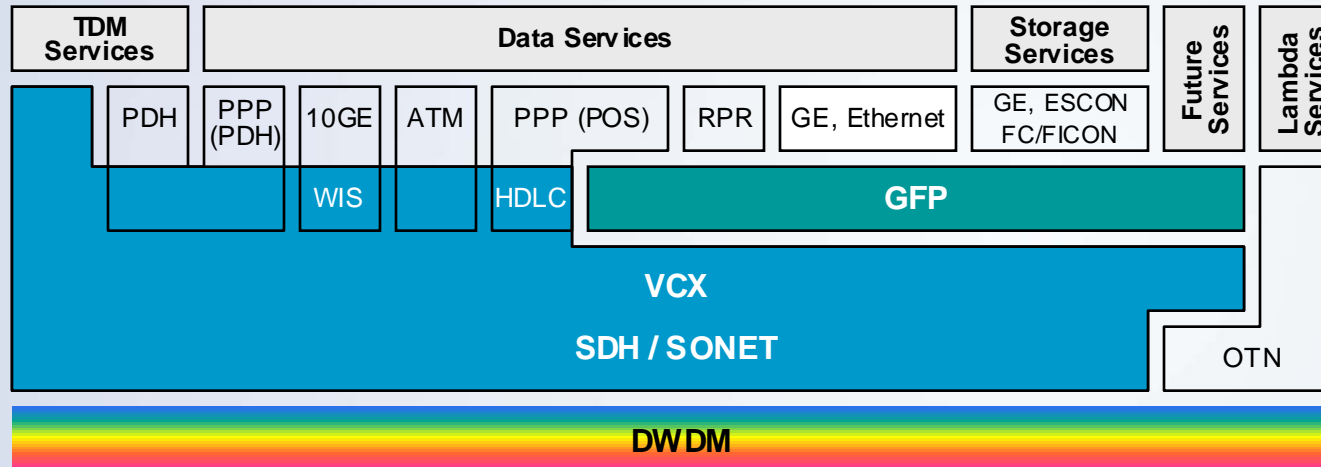
Acronyms

- **SONET – Synchronous Optical NETwork**
- **SDH – Synchronous Digital Hierarchy**
- **ITU – International Telecommunications Union**
- **TDM – Time Division Multiplexing**
- **BLSR – Bidirectional Line Switched Ring**
- **UPSR – Unidirectional Path Switched Ring**
- **DWDM – Dense Wave Division Multiplexing**
- **STS- Synchronous Transport Signal**
- **STM – Synchronous Transport Module**
- **ITU-T International Telecommunications Union – Telecommunications Standardization Sector**
- **OC – Optical Carrier**

Additional Information Sources

- **One Network Enterprise Site**
 - <http://www.nortelnetworks.com/solutions/enterprise/index.html>
- **Optical Storage Web Site**
 - <http://www.nortelnetworks.com/solutions/osc/index.html>
- **Optical Ethernet Web Site**
 - <http://nortelnetworks.com/oe>
- **Success Stories**
 - <http://www.nortelnetworks.com/corporate/success/marketing.html#metro>
- **Optical Enterprise Convergence Tutorial**
 - <http://www.microsoft.com/office/powerpoint/producer/prodinfo/demos.msp>

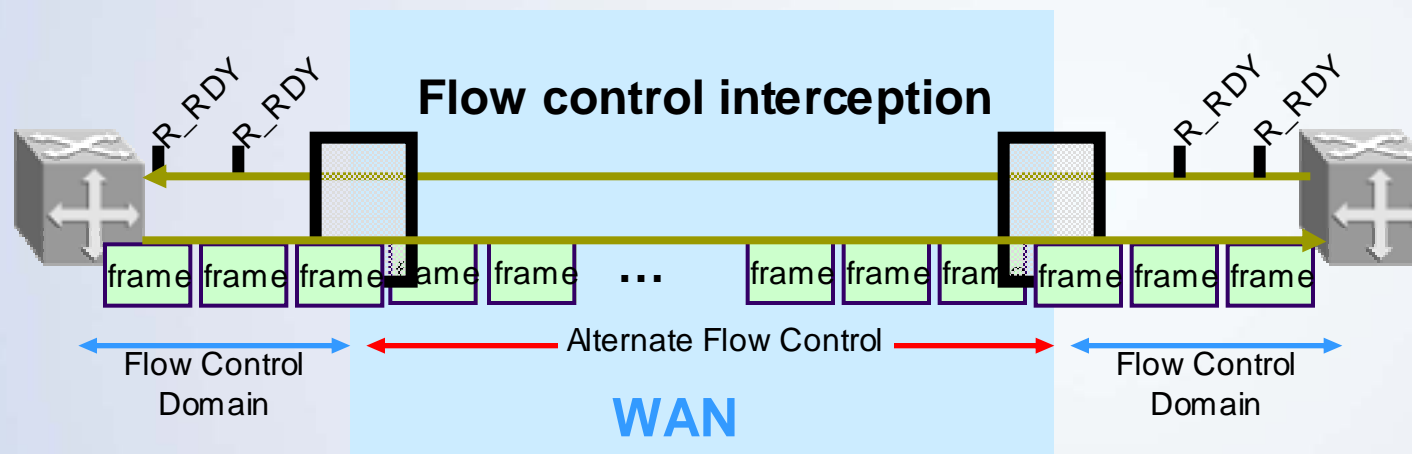
Extending Utility of SONET/SDH



- **Encapsulate & demarcate all services for common management**
 - GFP – Generic Framing Procedure (ITU-T Rec. G.7041)
 - Uniform mapping of packet, storage & future services to global transport network
- **Maximise network efficiency & resource utilisation**
 - VCX – Virtual Concatenation of SONET/SDH
 - Flexible provisioning of dynamic multiservices with LCAS (ITU-T Rec. G.7042)

Extending SONET/SDH to support new Enterprise Services

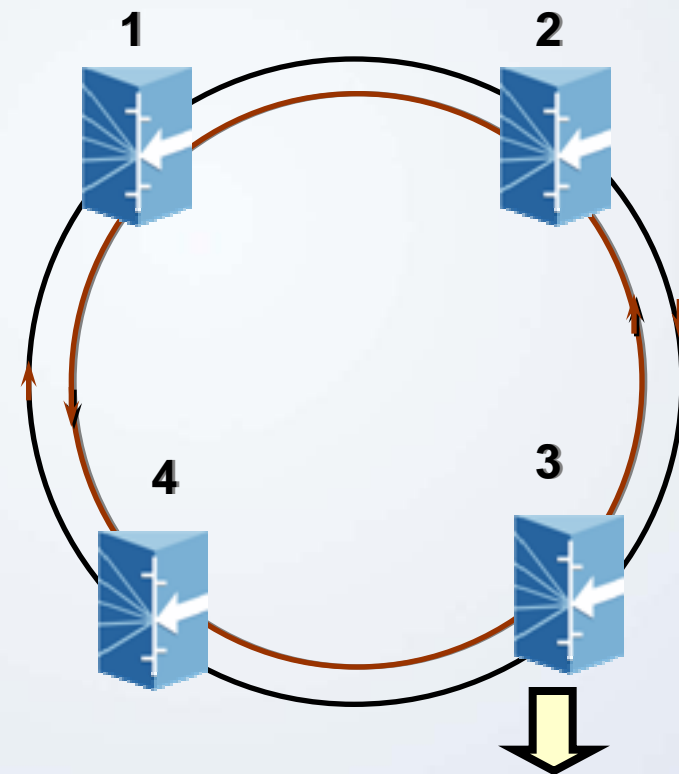
Extended reach over Transparent GFP Solution to Latency Effect



- **Allows the extension of the reach beyond 2 kms / Buffer Credit**
- **Allows to map client into:**
 - **Full rate SONET/SDH:**
 - WAN rates: STS24c, STS3c-6v
 - distances up to 100s of kilometers
 - **Sub rate SONET/SDH**
 - WAN rates: STS3c, STS12c, STS3c-nv (n=1..6)
 - distances up to 1000s of kilometers
- **GFP/CAT enable mixing traffic streams (GigE/FC/FICON)**

Topology Discovery Protocol

- Initiated anytime ring node map changes
 - New node inserted
 - Node removed
- Database constructed that indicates number of hops to a given node in either direction
- Primary path selected based on fewest number of hops



Node	East	West	Primary	Secondary
1	2	2	E	W
2	1	3	E	W
3	-	-	-	-
4	3	1	W	E