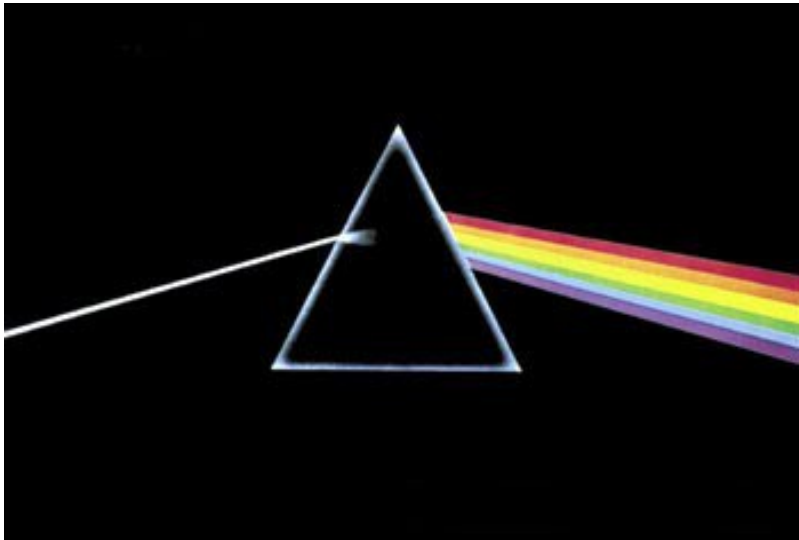
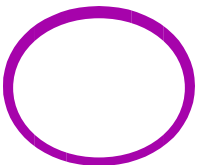


Optical Networks

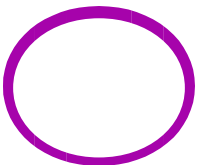


- **CS294-3: Distributed Service Architectures in Converged Networks**
- **George Porter**
- **Tal Lavian**



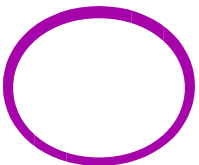
Overview

- Physical technology, devices
- How are optical networks currently deployed?
- Customer-empowered networks
 - New applications, ways of doing business
 - How does this change the "big picture"?
 - How do we do it?
 - What are the challenges? Payoffs?



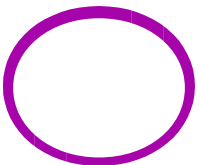
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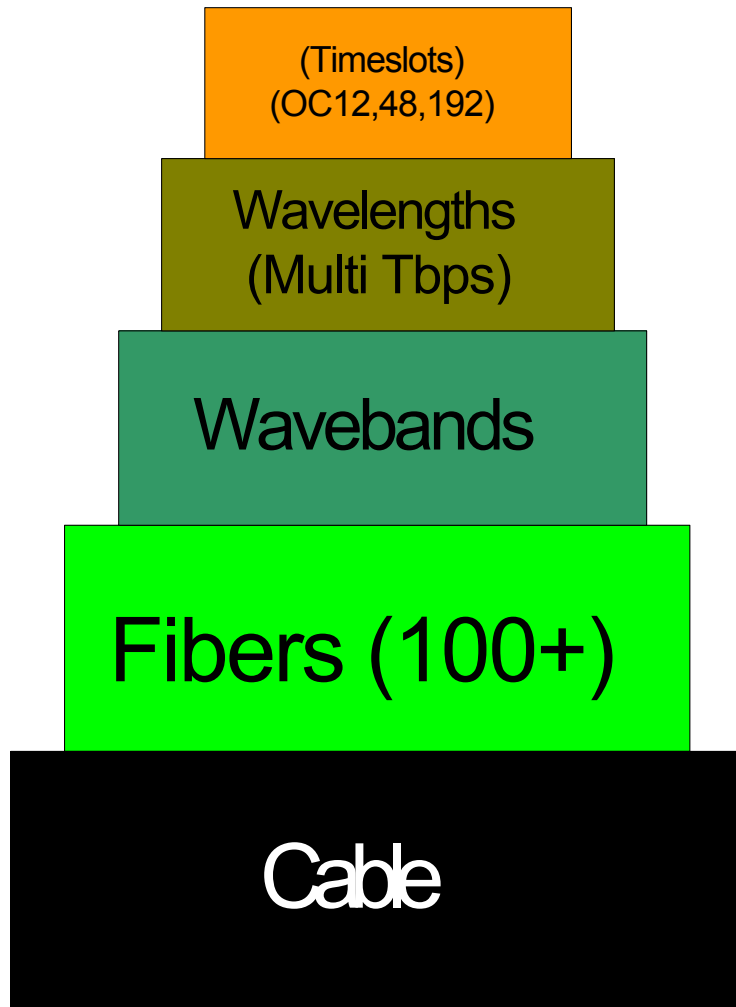


Why optical?

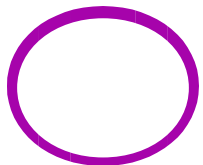
- Handle increase in IP traffic
 - Moore's law doesn't apply here
 - 1984: 50Mbps, 2001: 6.4Tbps
- Reduce cost of transmitting a bit
 - Cost/bit down by 99% in last 5 years
- Enable new applications and services by pushing optics towards the edges



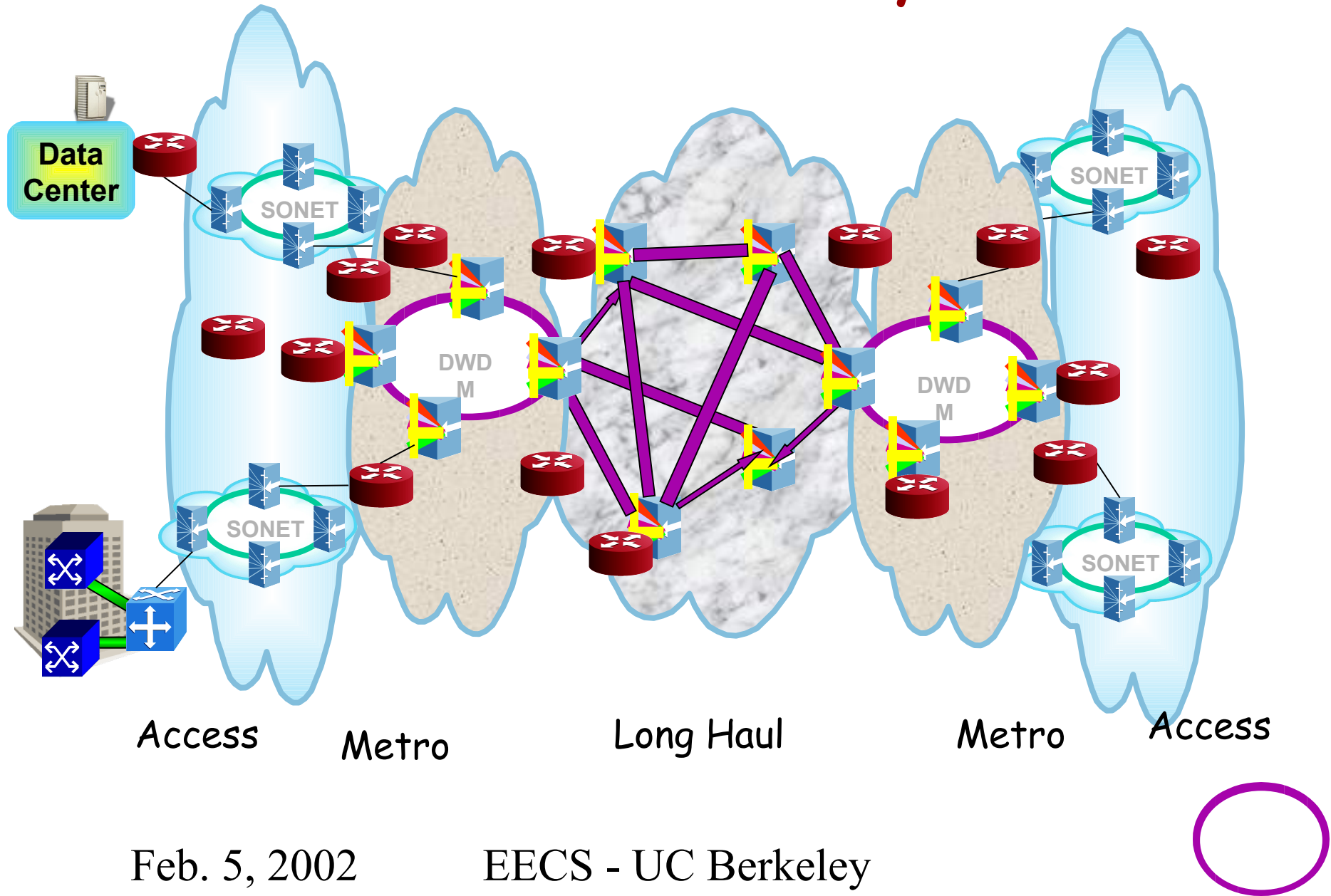
Fiber capabilities/WDM



- Wavelengths can be time-division multiplexed into a series of aggregated connections
- Sets of wavelengths can be spaced into wavebands
- Switching can be done by wavebands or wavelengths
- 1 Cable can do multi terabits/sec



Internet Reality

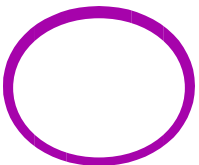


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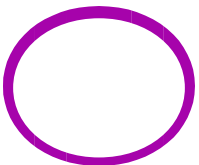
Devices

- Add/Drop multiplexer
- Optical Cross Connect (OXC)
 - Tunable: no need to keep the same wavelength end-to-end
 - Switches lambdas from input to output port
- For “transparent optical network”, wavelengths treated as opaque objects, with routing control brought out-of-band



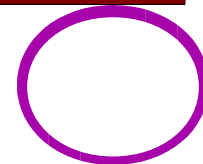
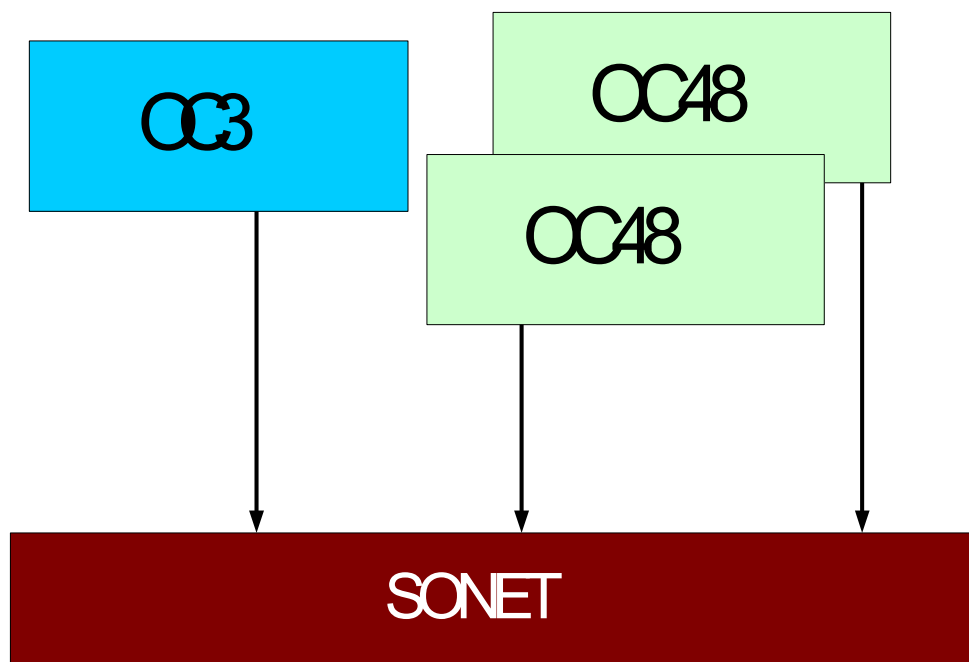
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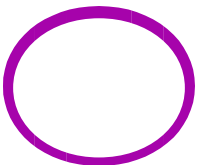
Overview of SONET

- Synchronous Optical Network
- Good for aggregating small flows into a fat pipe
- Electric endpoints, strong protection, troubleshooting functionality



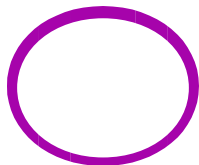
Today's provisioning

- Anywhere between months to minutes
 - Semi-automatic schemes
 - Much like old-style telephone operator
- The fact is there are tons of fibers underground, but they are not organized in a way where you can utilize their full potential



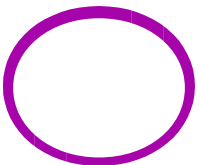
Drive to autoswitched network

- Make the network intelligent
- On-demand bandwidth to the edge of the network
- New applications
 - Disaster Recovery
 - Distributed SAN
 - Data warehousing
 - Backup Bunkers (no more tapes)
 - Big Pipes on Demand
 - Download movies to movie theaters
 - Site replication
 - Optical VPN



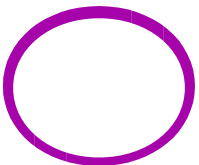
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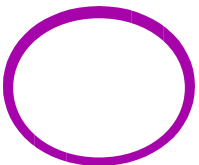
Customer empowered nets

- Huge bandwidth to the enterprise
 - The curb
 - The house
 - The desktop
- End hosts can submit requirements to the network, which can then configure itself to provide that service
- Issues of APIs, costs, QoS



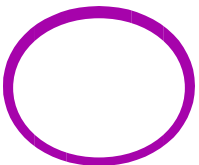
Changing the big picture

- Now the converged network looks different
- Dial-up bandwidth has huge implications
- Pushing bandwidth to the edges of the network
 - Affects service placement, for example

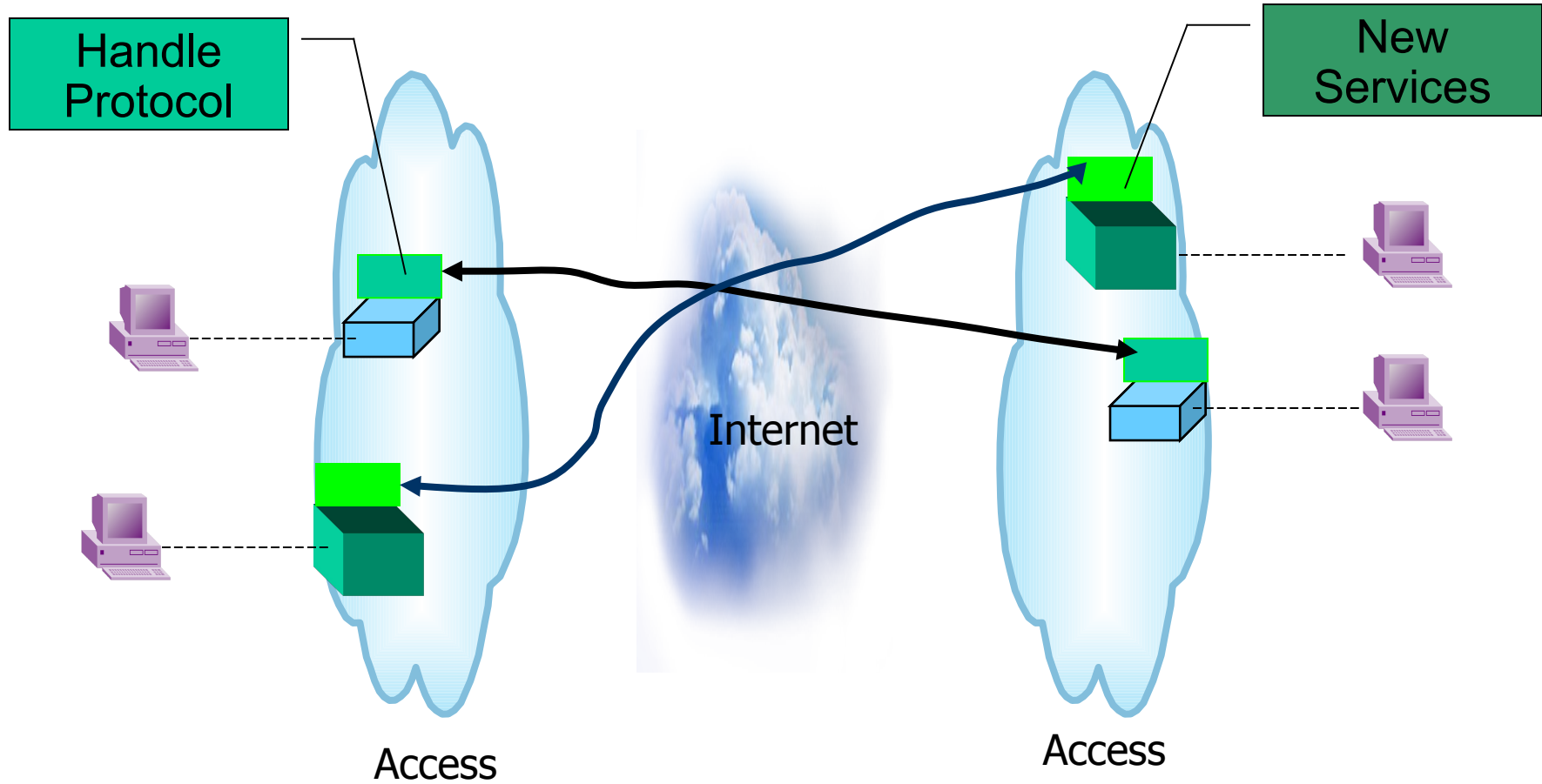


Bandwidth at the edges

- Services placed there (ServicePoP)
- Need to connect services to customers and other services
- Metro networks
 - Use of Ethernet as low cost/flexible mechanism
- Eventually fibers to pcmcia?!

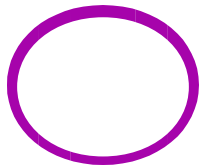


Protocol and Services on Edge Devices

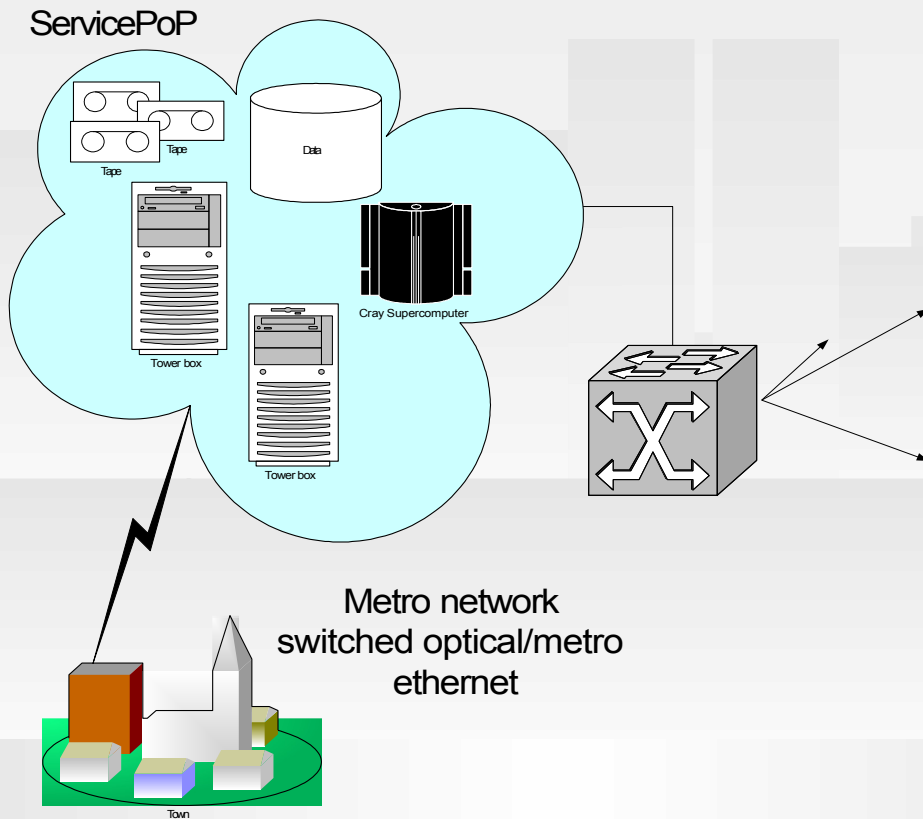


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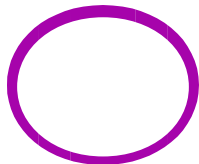
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ServicePoPs

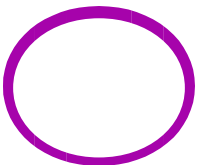


- ServicePoPs act as intermediary between service provider and customer
- Connectivity between ServicePoP and customer more important than provider to customer
- Feature is very fast infrastructure

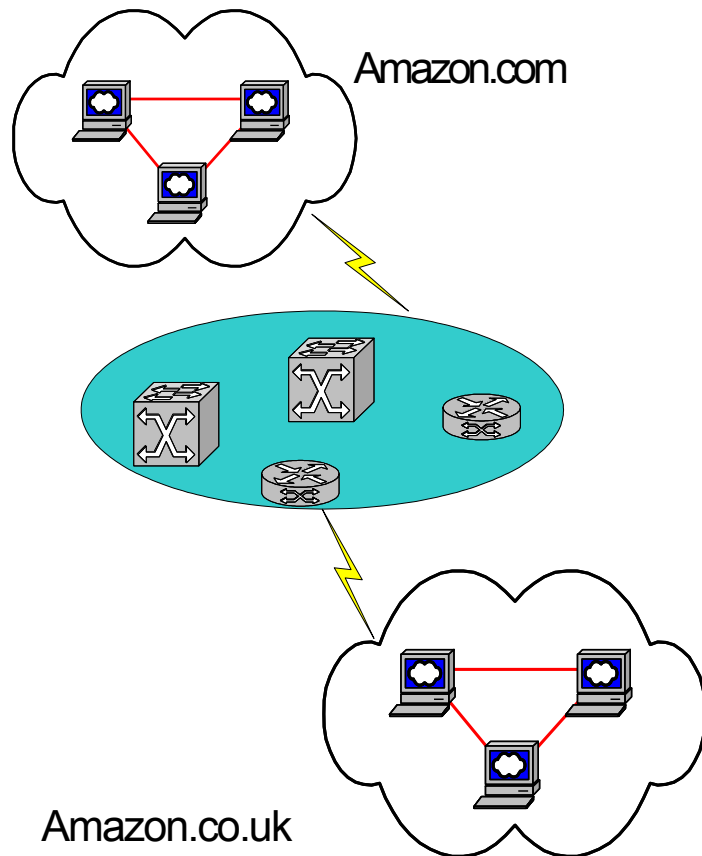


Metro networks

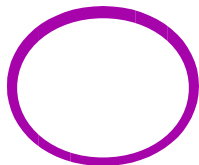
- Interim step: services in servicePoPs
- Tap into fast connections here for enterprises
- Use of Ethernet as protocol to connect the enterprise to the MAN
- Avoid need for last mile for certain applications/services



Amazon.com-vs-Amazon.co.uk

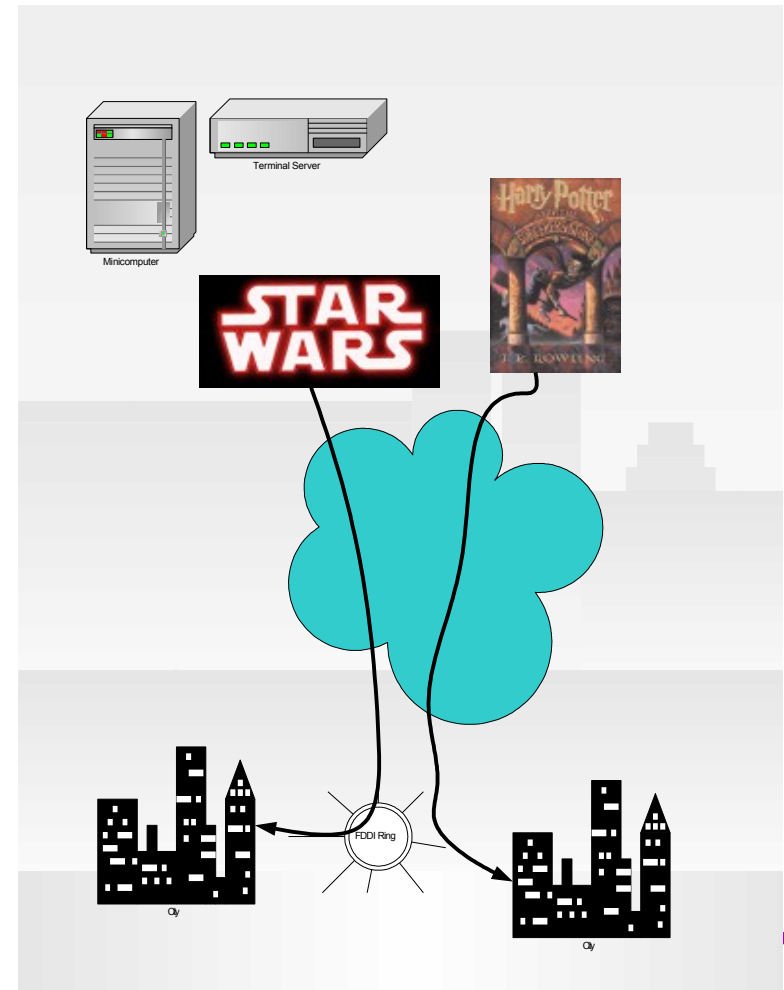


- One site wants to do a software upgrade
- Reserve 100Gbps for outage time
- Send entire database over at outage time, reroute all customer requests to other site
- When outage is over, transfer all data back to original site



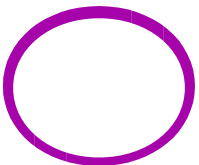
Movie Distribution

- Each movie theater in a large area (SF, New York, Houston) requests 1 hour of bandwidth a week (OC192)
- All movies transferred during this time
- Efficient use of expensive but necessary fat pipe



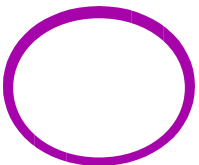
New type of businesses

- Data warehousing: no more mailing tapes
- Have tape vaults with gigabit connectivity
- Data is sent optically to destination, where it is written to magnetic tape



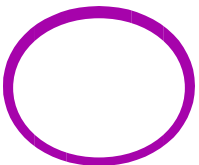
How to do it

- Generalized Multiprotocol Label Switching (GMPLS)
- UNI: user-to-network interface as API to specify requirements, service requests
- NNI: network-to-network interface acts as API between entities for service composition/path formation



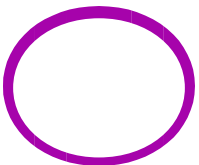
How to do it

- Interdomain?
- Wavelength selection/routing
- Exchange info
 - Connectivity
 - Wavelengths
 - Qos, bandwidth requirements
 - Switching instructions

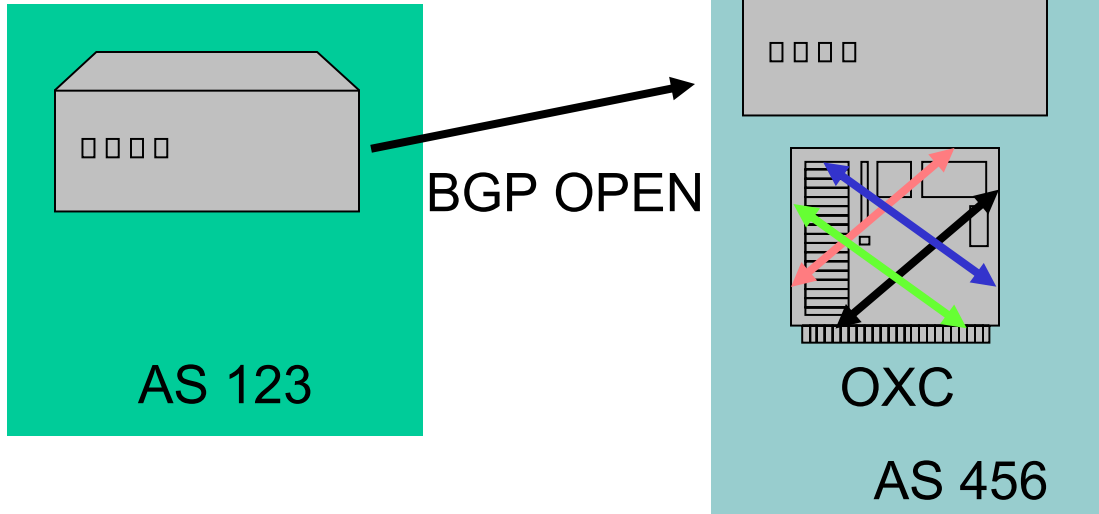


Canarie's approach

- OBGP (Optical BGP)
- Routers spawn "virtual BGP" processes that peers can connect to
- By modifying BGP messages, lightpath information can be traded between ASes



1)

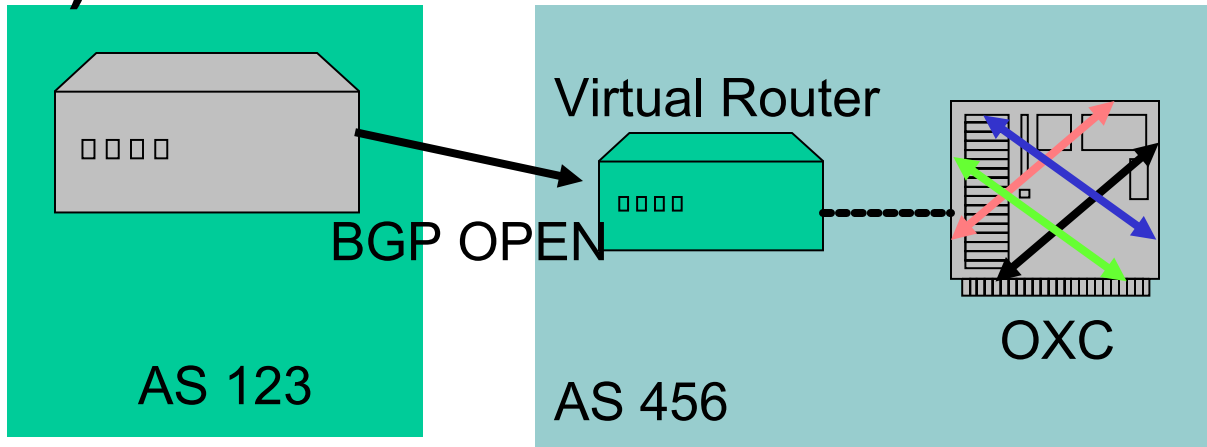


- BGP OPEN message sent to router with information about optical capabilities

- A virtual BGP process is spawned

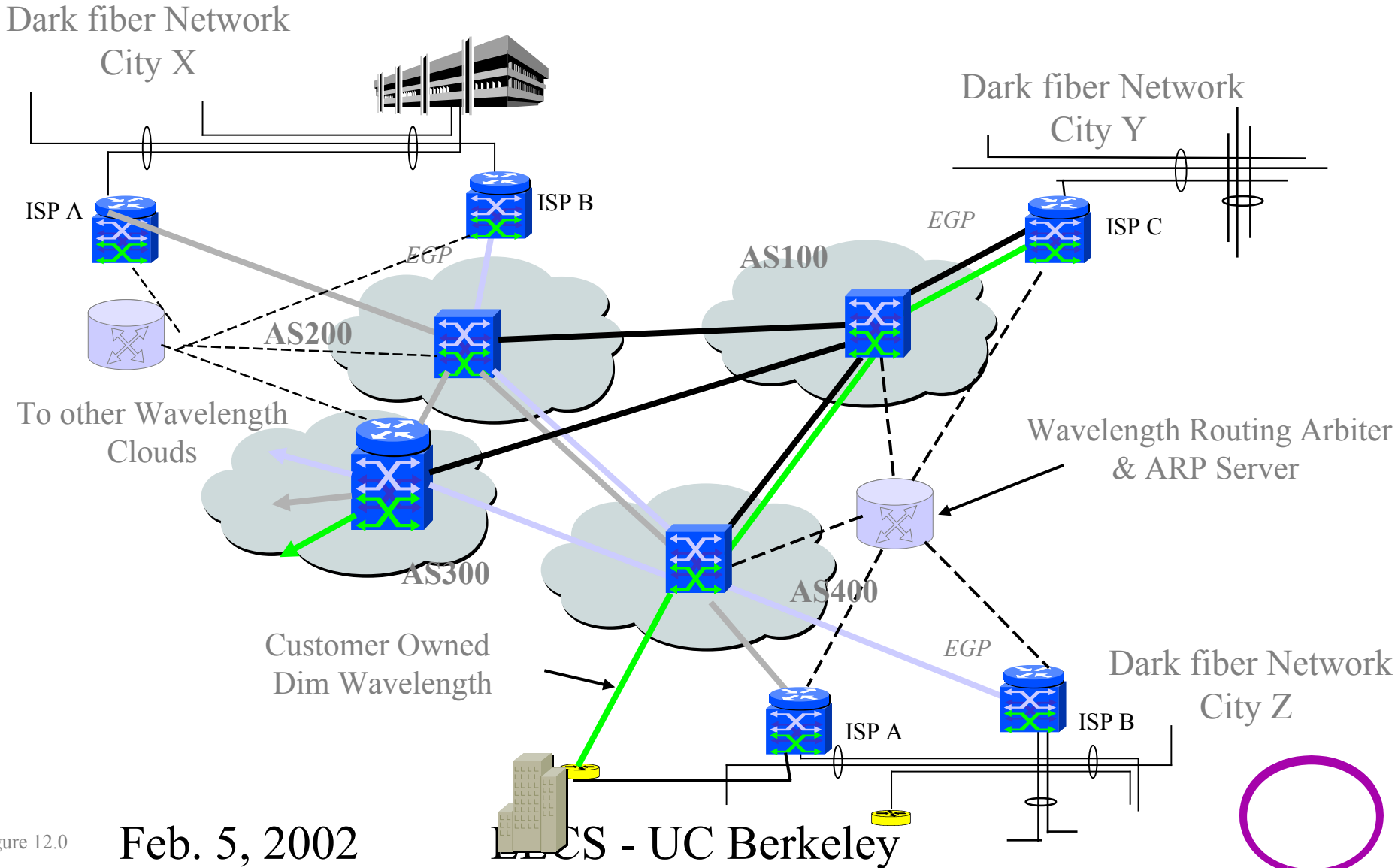
- A BGP session is initiated independently with new BGP process

2)



- The virtual process (running on the router) configures the OXC to switch the proper optical wavelengths

Optical BGP Networks



Dark fiber Network
City X

Dark fiber Network
City Y

Dark fiber Network
City Z

To other Wavelength
Clouds

Customer Owned
Dim Wavelength

Wavelength Routing Arbiter
& ARP Server

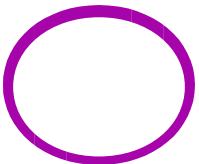
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Figure 12.0

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What is ASON?

- The Automatic Switched Optical Network (ASON) is both a framework and a technology capability.
- As a framework that describes a control and management architecture for an automatic switched optical transport network.
- As a technology, it refers to routing and signalling protocols applied to an optical network which enable dynamic path setup.
- Recently changed names to Automatic Switched Transport Network (G.ASTN)



Optical Network: Today vs. Tomorrow

	Applications	Protection	Topology	Management
Today	<ul style="list-style-type: none"> - DS3 - STS-n - STS-nc - OC-48T, (OC-192T) - 1GE - (134Mb/s) - 140Mb/s - VC-4 - VC-4-nc - NUT - Extra Traffic - Broadcast 	<ul style="list-style-type: none"> - 2F/4F BLSR - Matched Nodes - Head end ring prot. - NUT (non-preemptive unprotected traffic mixed with protected in ring/linear) - Unprotected (extra traffic) - Protection SW time - Clear P =60ms - With ET=160ms - MN = 250ms 	<ul style="list-style-type: none"> - 2F/4F BLSR - Linear - 1+1 - 1:n - Path protection 	<ul style="list-style-type: none"> - Provisioned path connection - Trail management across multiple rings - Multiple product
	<ul style="list-style-type: none"> - VC-4-nv - 10GE - Flexible i/f - Billing method (distance, time, bw, QoS) - Asymetric bw connections - Point-to-multipoint <ul style="list-style-type: none"> - sequential 	<ul style="list-style-type: none"> - Wider range of SLA capability - Path diversity verifiable - Scalable to large NW size 	<ul style="list-style-type: none"> - Mesh - Port connectivity - unconstrained - arbitrary 	<ul style="list-style-type: none"> - Auto discovery of NW configuration - Connection provisioning of paths over unconstrained line topology - No pre-provisioning of connections? - User signaling i/f for connection provisioning - Scalable to very large NW - Fast connection establishment <2s - Resource (bw) management and monitoring
Tomorrow				

Optimized IP application - current driver for transparent NW

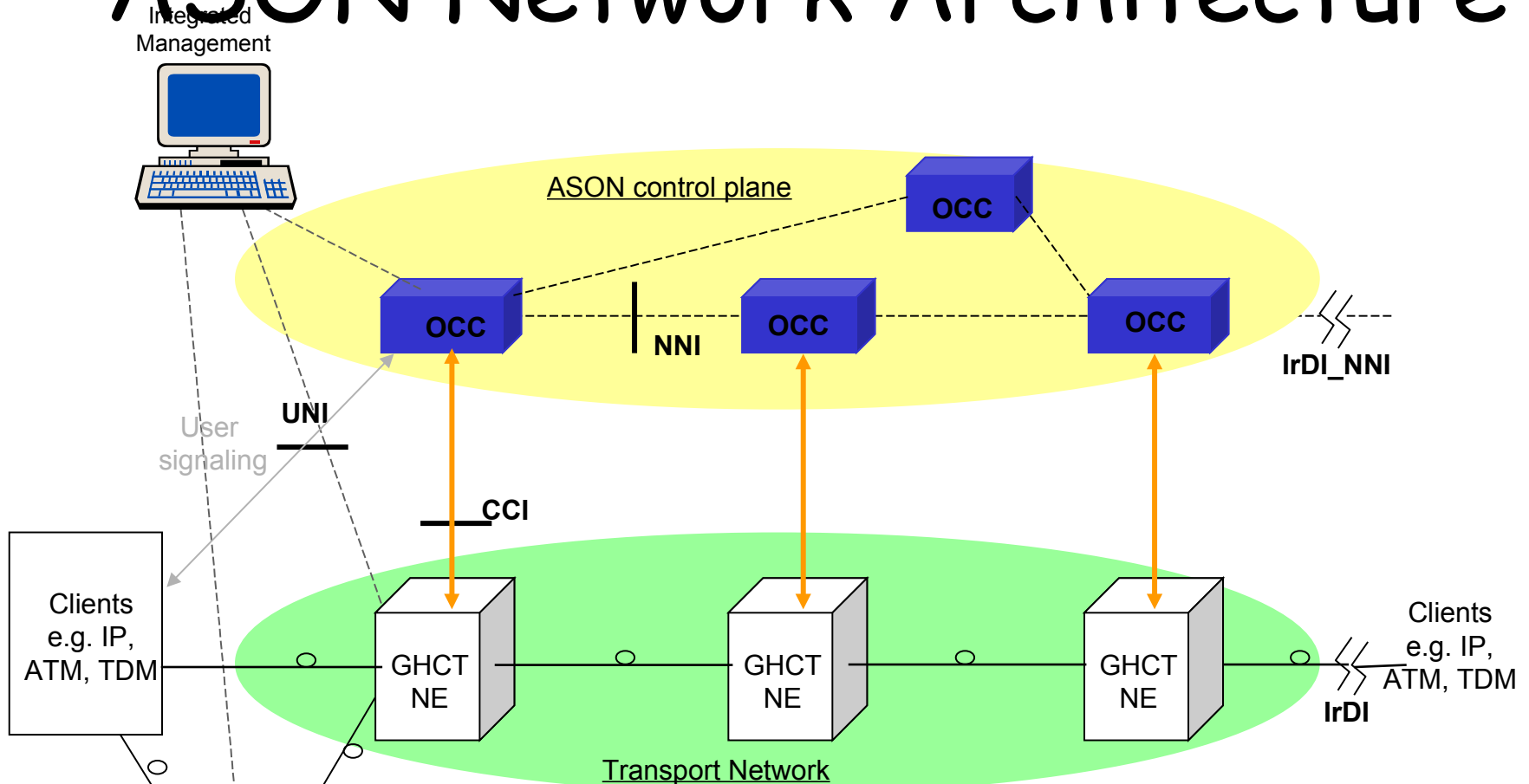
Additional SLA capability

Mesh network

Auto connection & resource mgnt

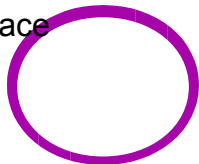
ASON value added

ASON Network Architecture

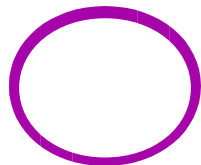
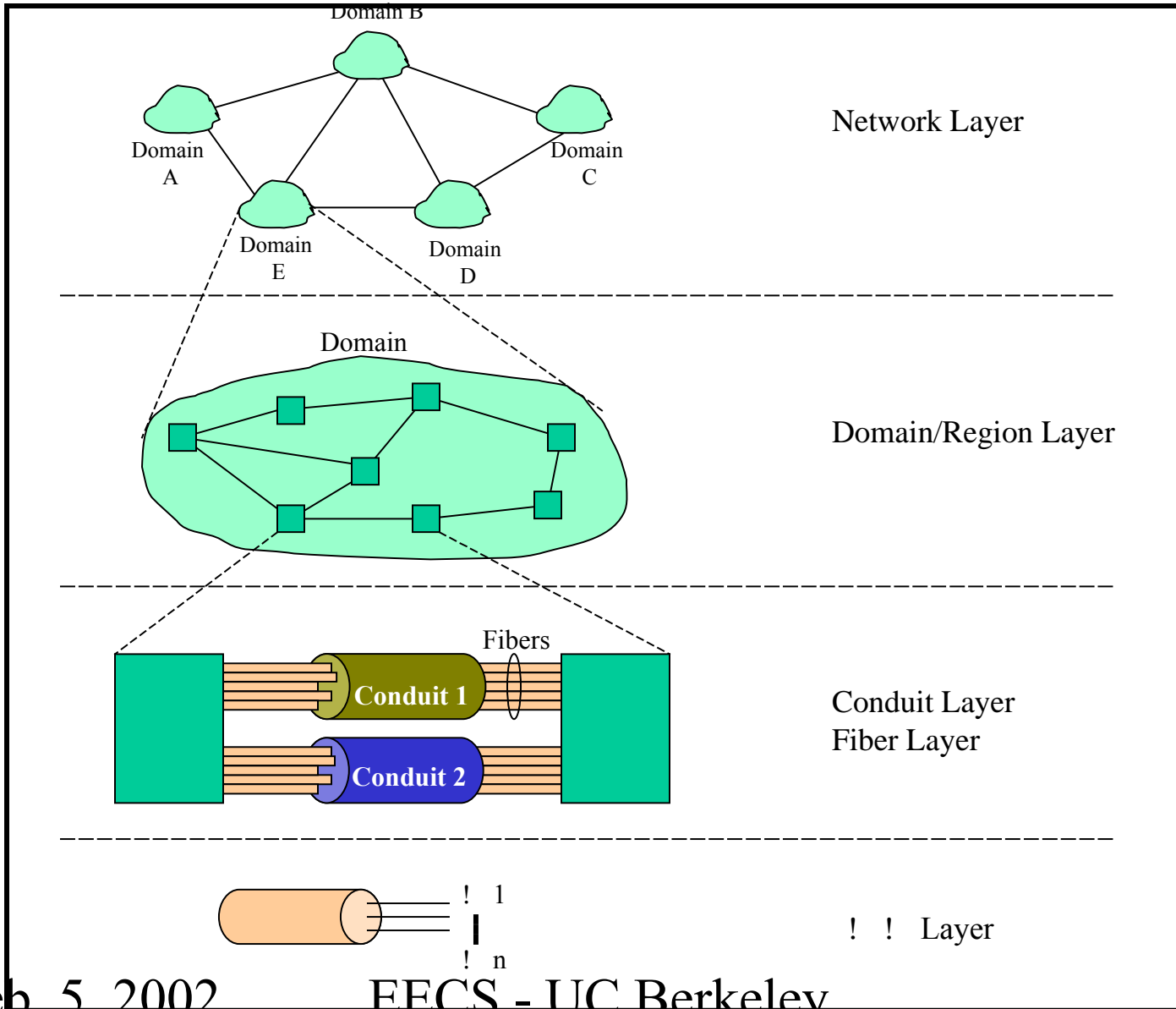


GHCT NE: Global High Capacity transport NE
 ASON: Automatic Switched Optical Network
 OCC: Optical Connection Controller
 IrDI: Inter Domain Interface

Interfaces:
 UNI: User Network Interface
 CCI: Connection Control Interface
 NNI: ASON control Node Node Interface

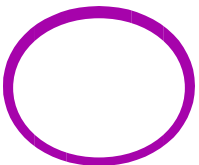


ASON Layer Hierarchy

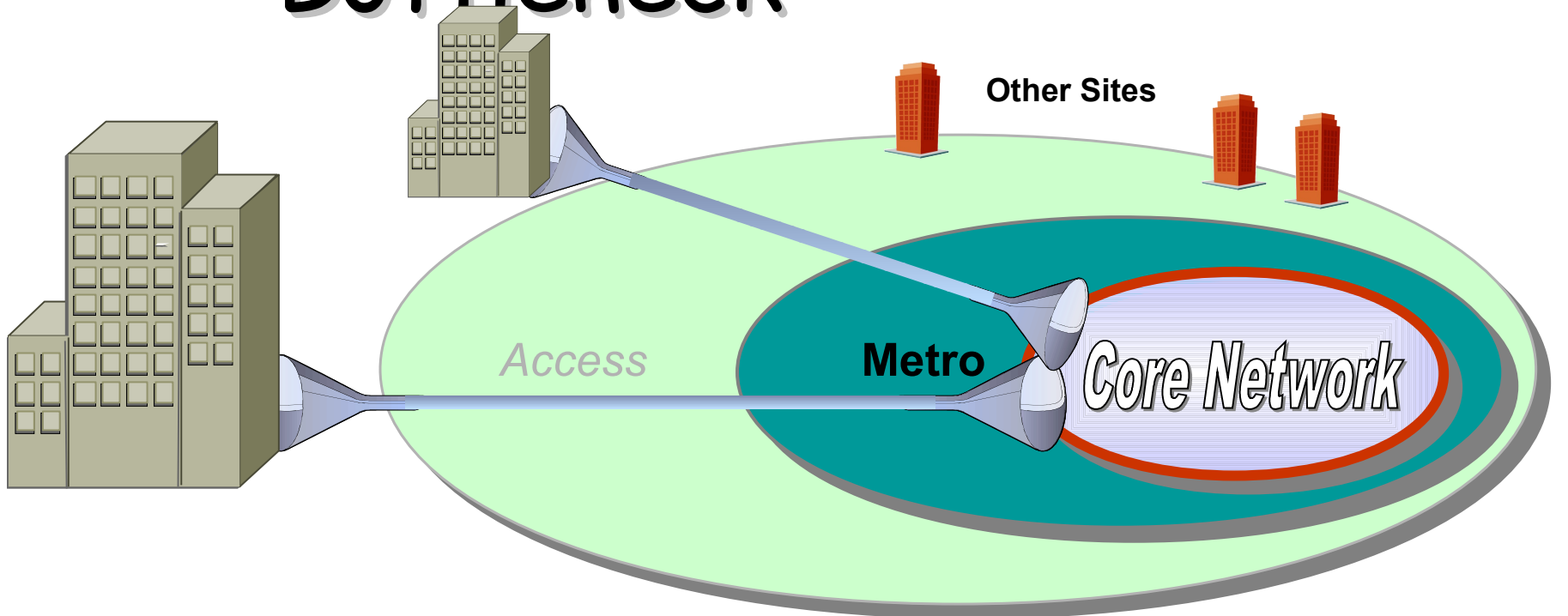


Resilient packet ring (802.17)

- Put lan on top of man
- 50ms protection
-



The Metro Bottleneck



End User

Ethernet LAN

IP/DATA
1GigE

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Access

T1
DS1
DS3

LL/FR/ATM

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Metro

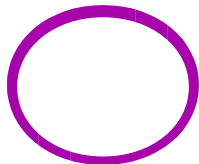
OC-12
OC-48

1Gig+

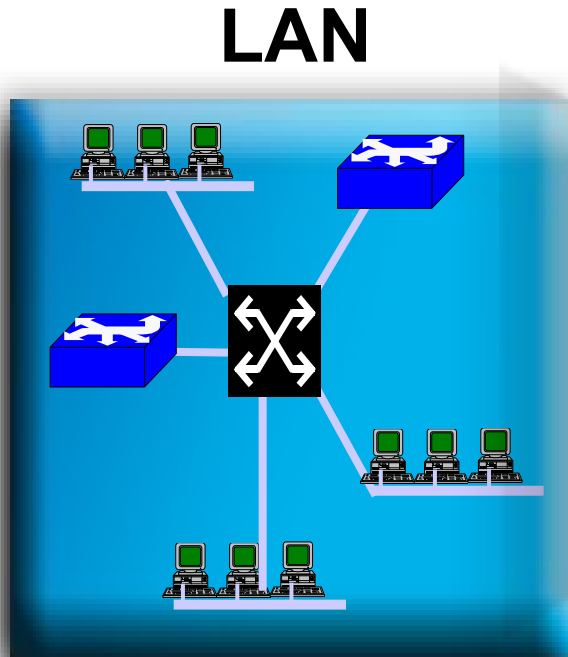
Core

OC-192
DWDM n x !

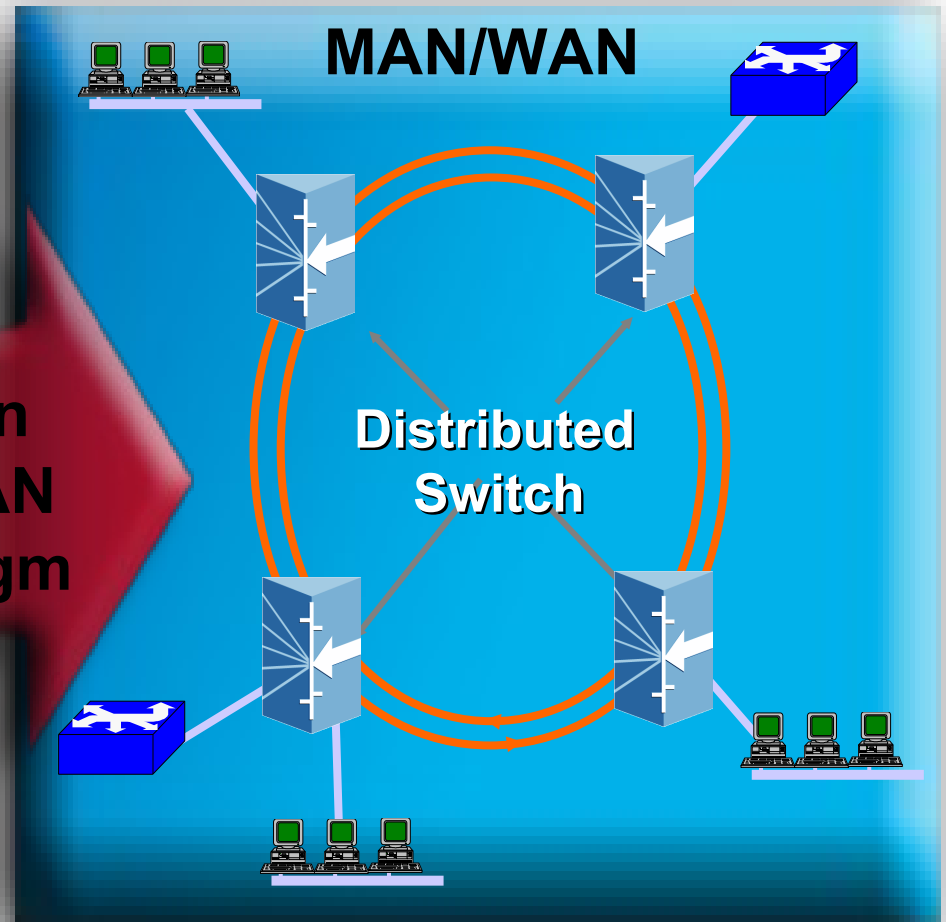
10GigE+



RPR - Expanding the LAN to the MAN/WAN



LAN in the MAN Paradigm



- Low Cost
- Simplicity
- Universality

- Low Cost
- Simplicity
- Universality

+

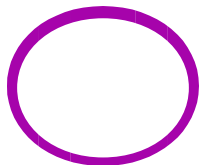
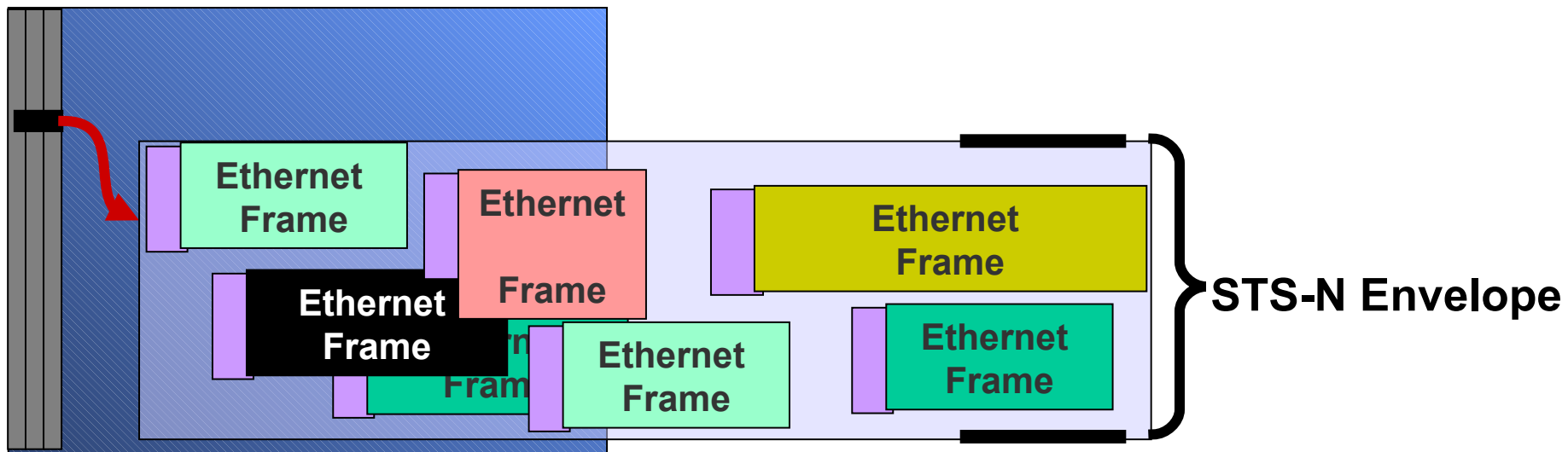
- Scalability
- Reach
- Robustness

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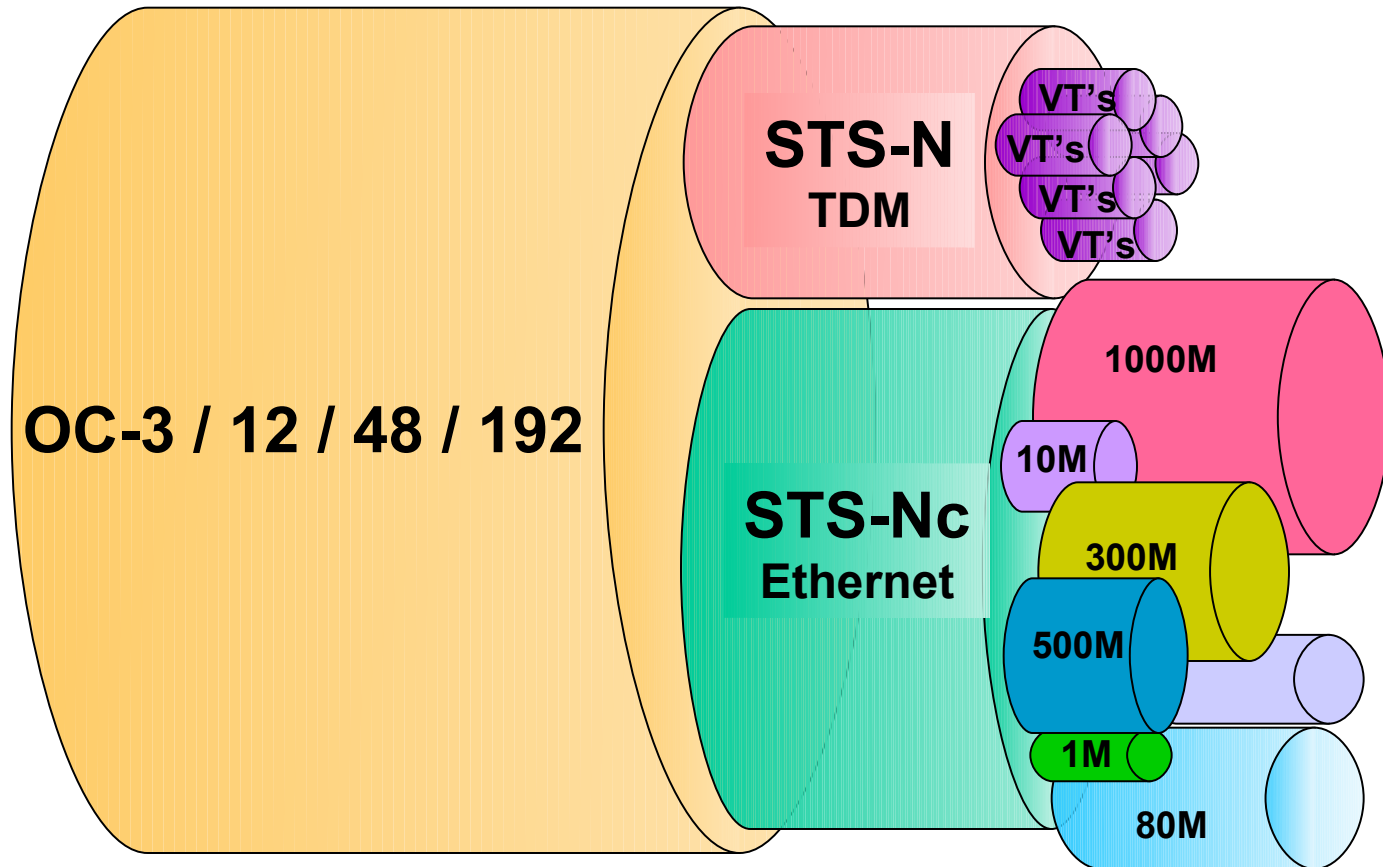
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What is RPR?

Ethernet networking on Optics (STS-Nc)

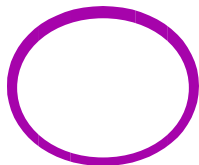


Scalable Bandwidth and Services

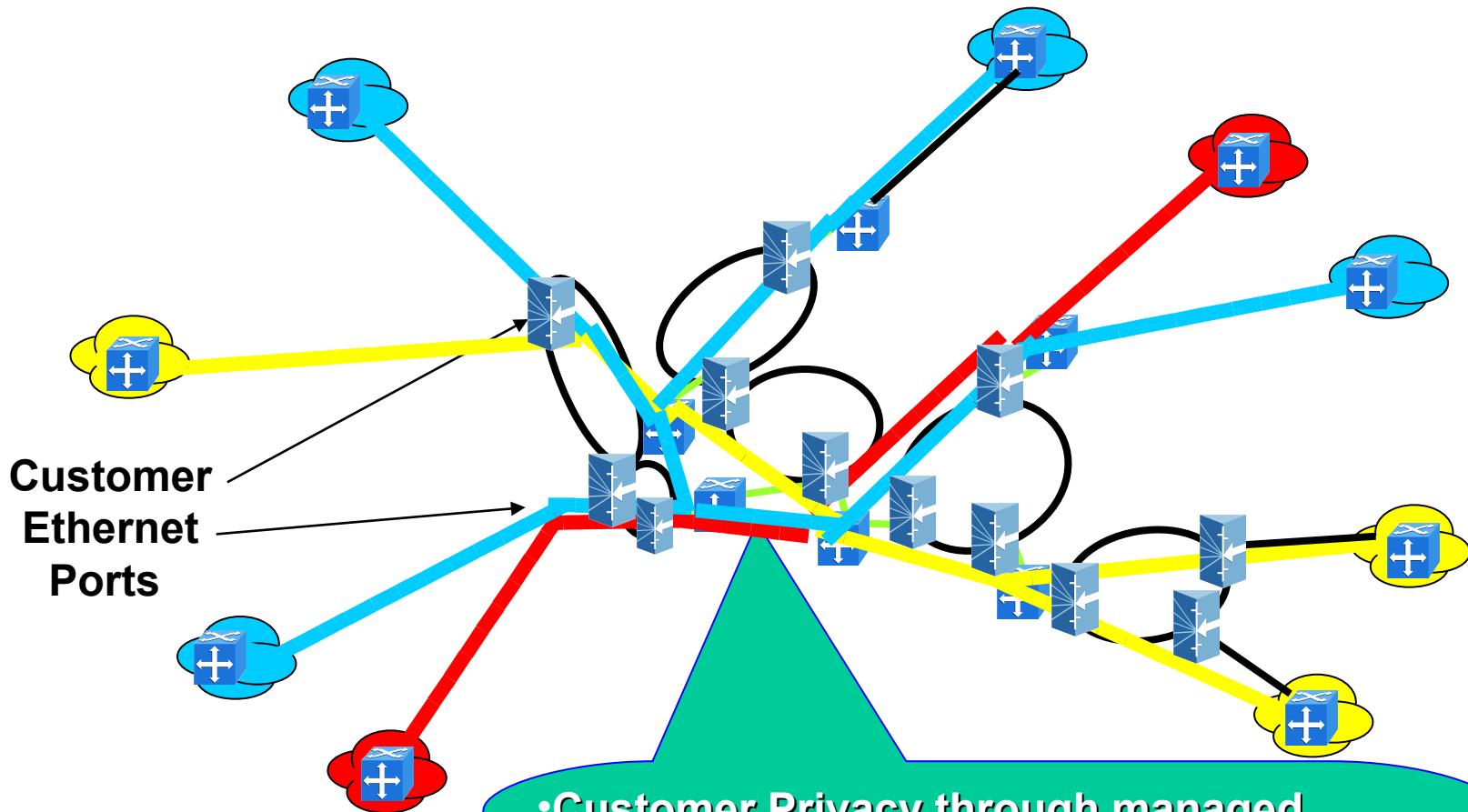


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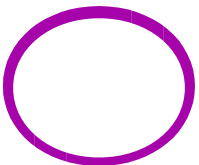
Network & Customer Management



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Move to optical

- The key is to find a way to use the infrastructure that we have available in an efficient manner
- What services are available? What can we do?
- Challenges?



The Future is Bright

- **There is a light in the end of the tunnel**

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