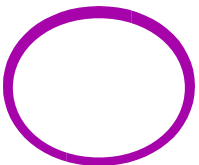


# Optical Networks

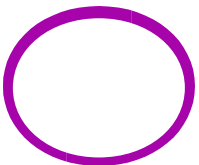


- **CS294-3: Distributed Service Architectures in Converged Networks**
- **George Porter**
- **Tal Lavian**



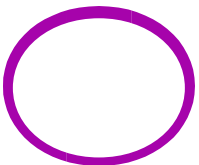
# Overview

- 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?



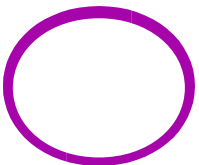
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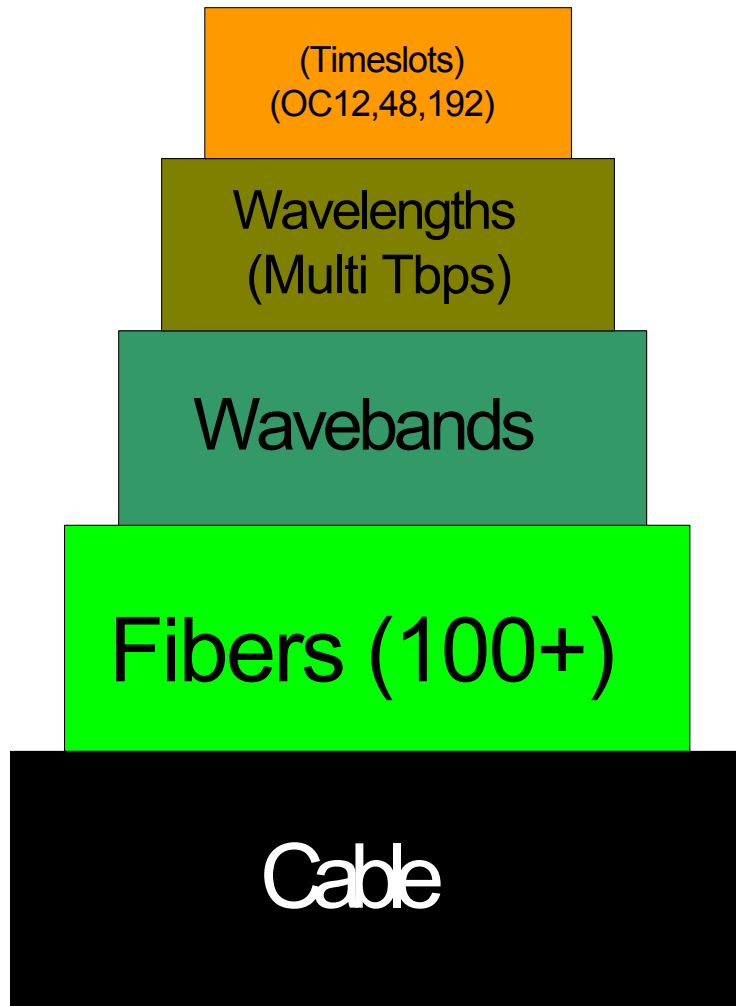


# Why optical?

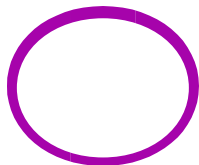
- Handle increase in IP traffic
  - Moore's law doesn't apply here
  - 1984: 50Mbps, 2001: 6.4Tbps
- Reduce cost of transmitting a bit
  - Cost/bit down by 99% in last 5 years
- Enable new applications and services by pushing optics towards the edges



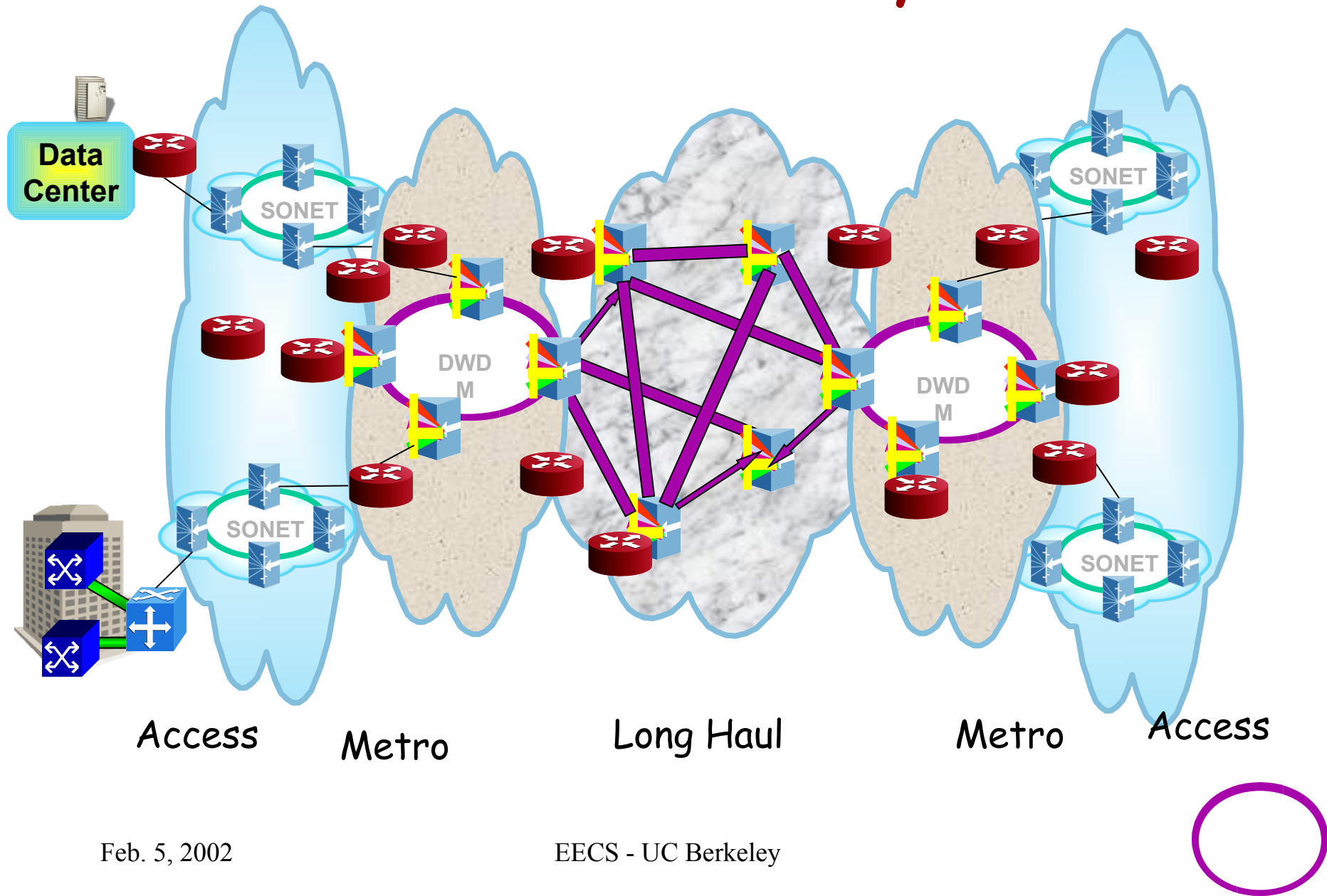
# Fiber capabilities/WDM



- 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

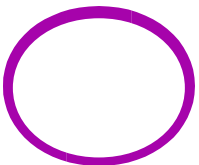


# Internet Reality



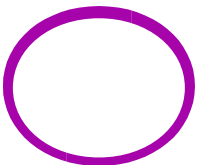
# Devices

- 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



# Overview

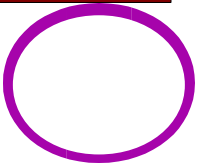
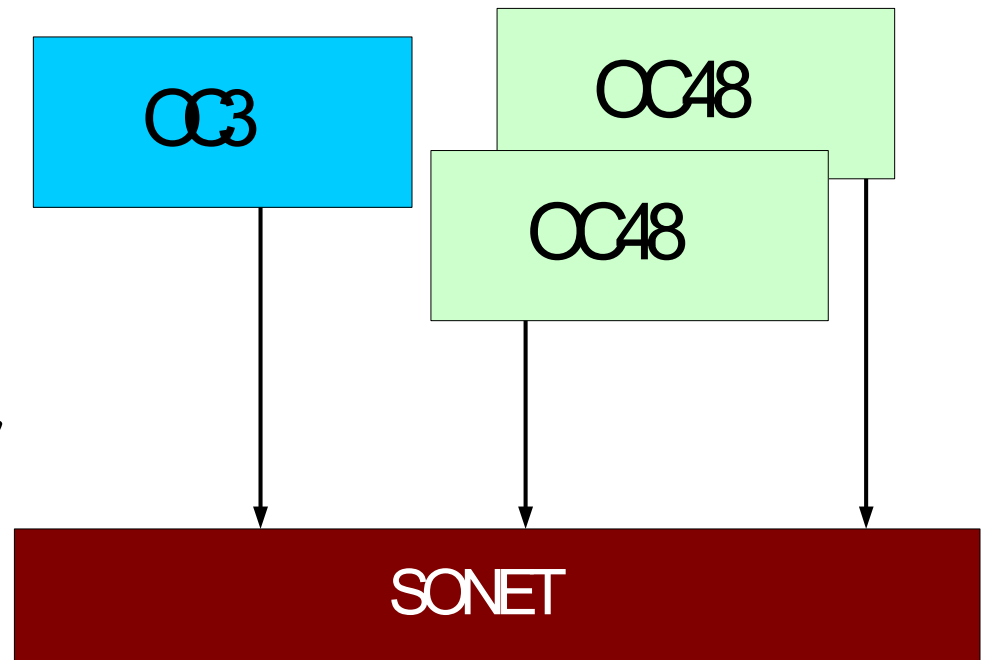
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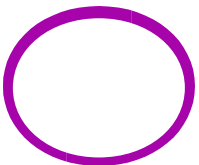
# Overview of SONET

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



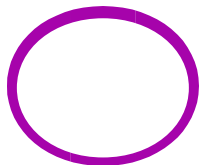
# Today's provisioning

- 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



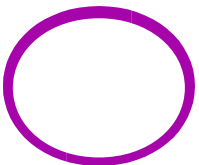
# Drive to autoswitched network

- 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
  - Grid Computing



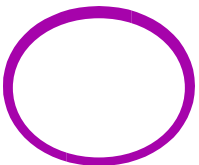
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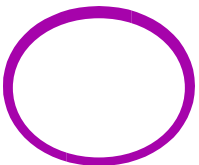
# Customer empowered nets

- 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



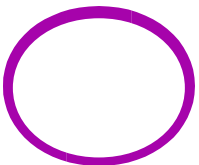
# Changing the big picture

- 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

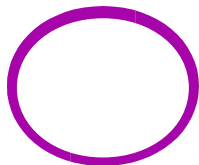
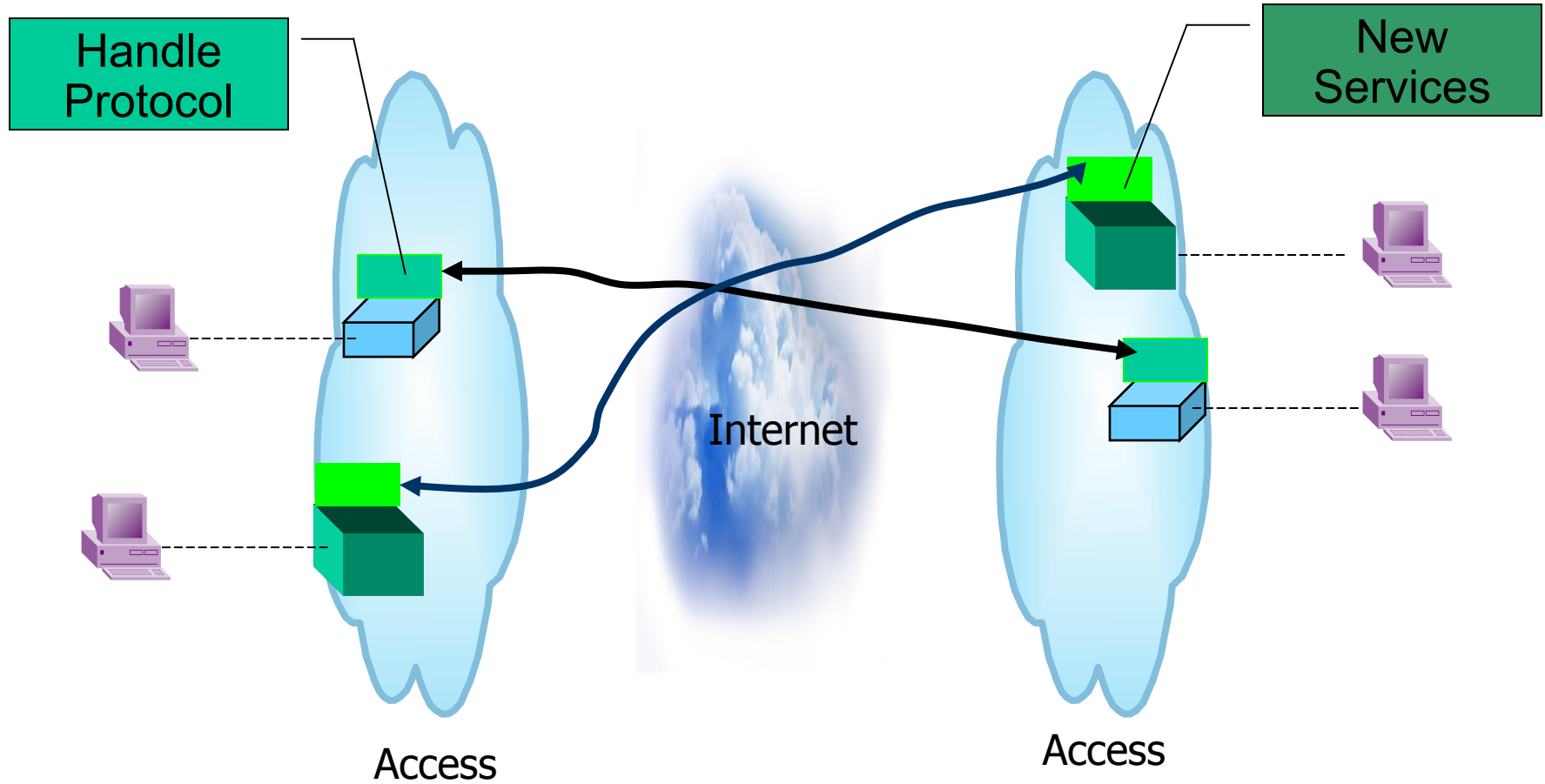


# Bandwidth at the edges

- 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?!

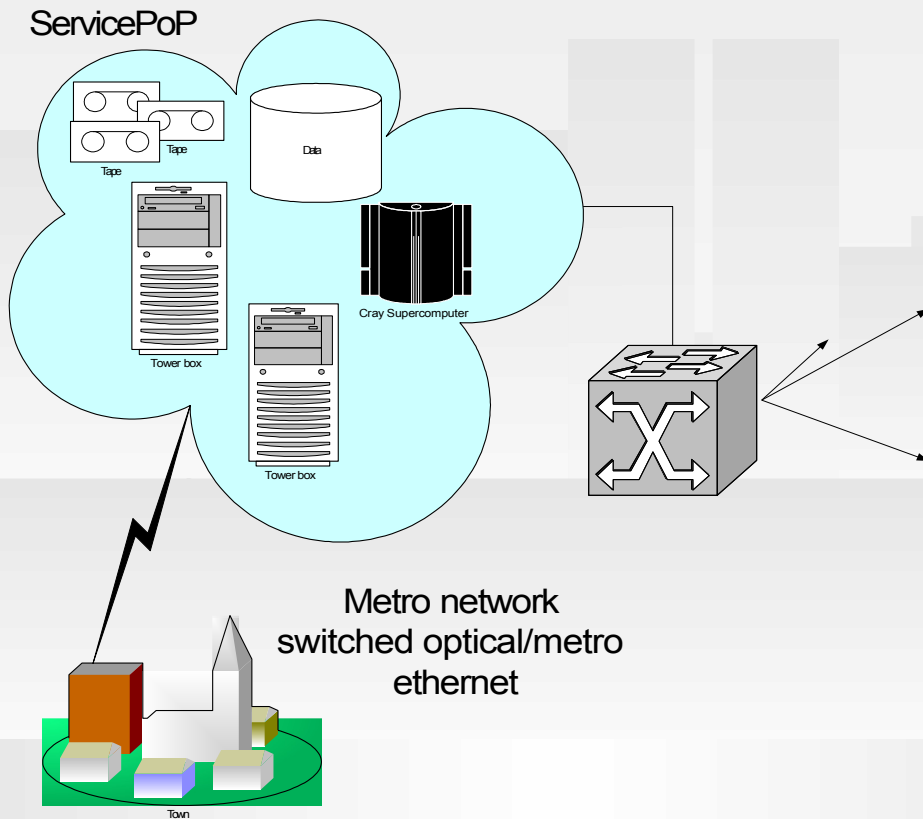


# Protocol and Services on Edge Devices

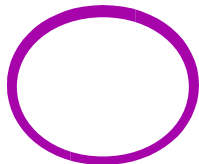




# ServicePoPs

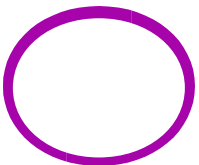


- ServicePoPs act as intermediary between service provider and customer
- Connectivity between ServicePoP and customer more important than provider to customer
- Feature is very fast infrastructure

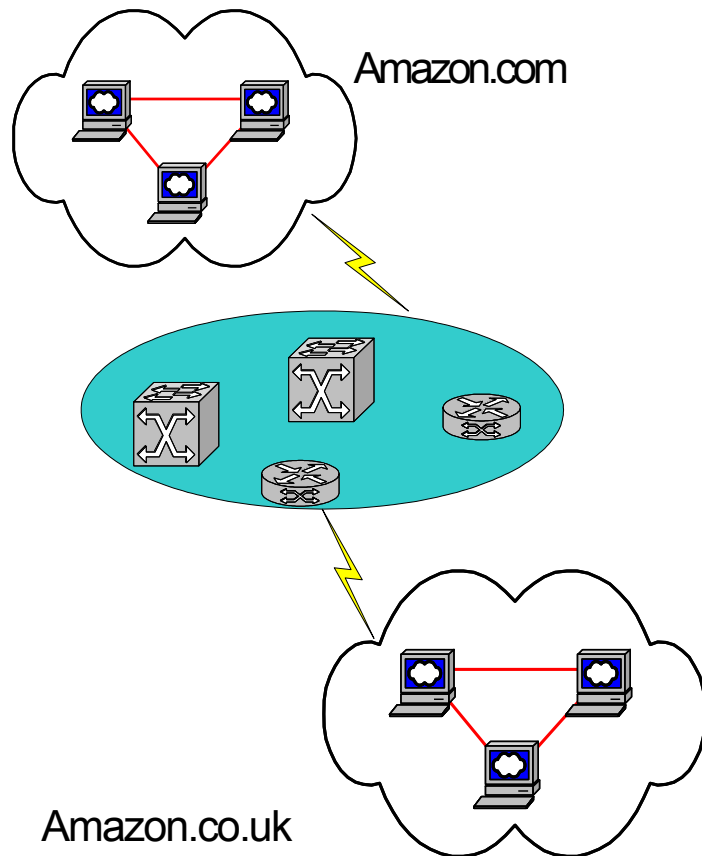


# Metro networks

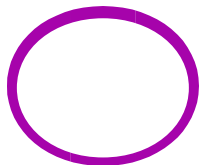
- Interim step: services in servicePoPs
- Tap into fast connections here for enterprises
- Use of Ethernet as protocol to connect the enterprise to the MAN
- Avoid need for last mile for certain applications/services



# Amazon.com-vs-Amazon.co.uk

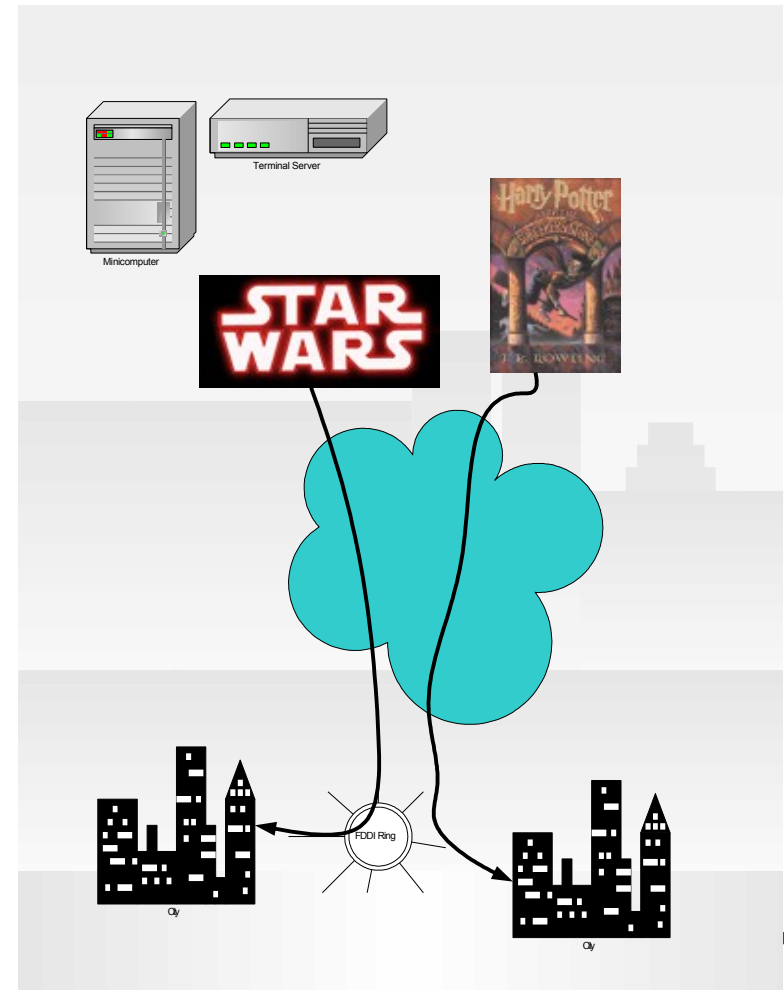


- One site wants to do a software upgrade
- Reserve 100Gbps for outage time
- Send entire database over at outage time, reroute all customer requests to other site
- When outage is over, transfer all data back to original site



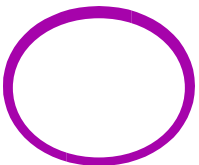
# Movie Distribution

- 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



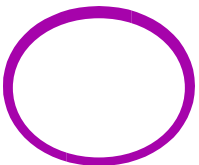
# New type of businesses

- 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



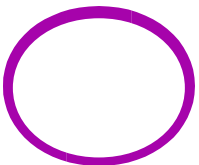
# How to do it

- 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



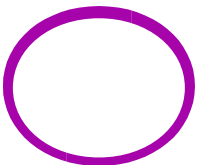
# How to do it

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



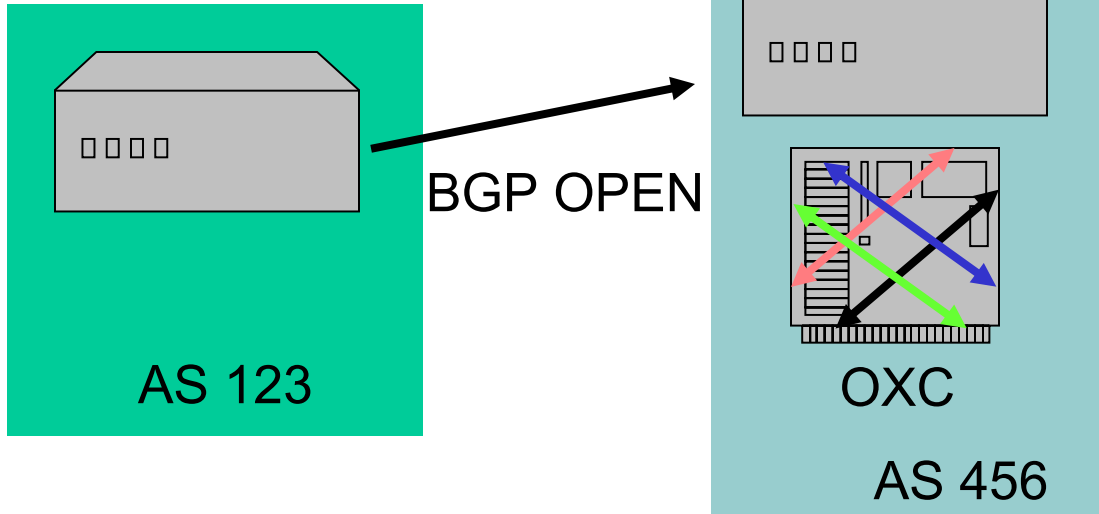
# Canarie's approach

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



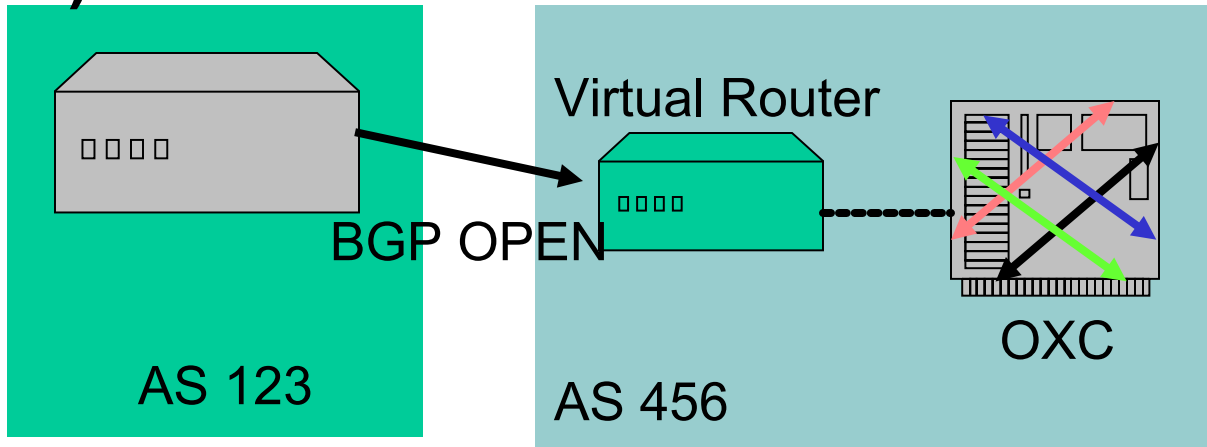


1)



- 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

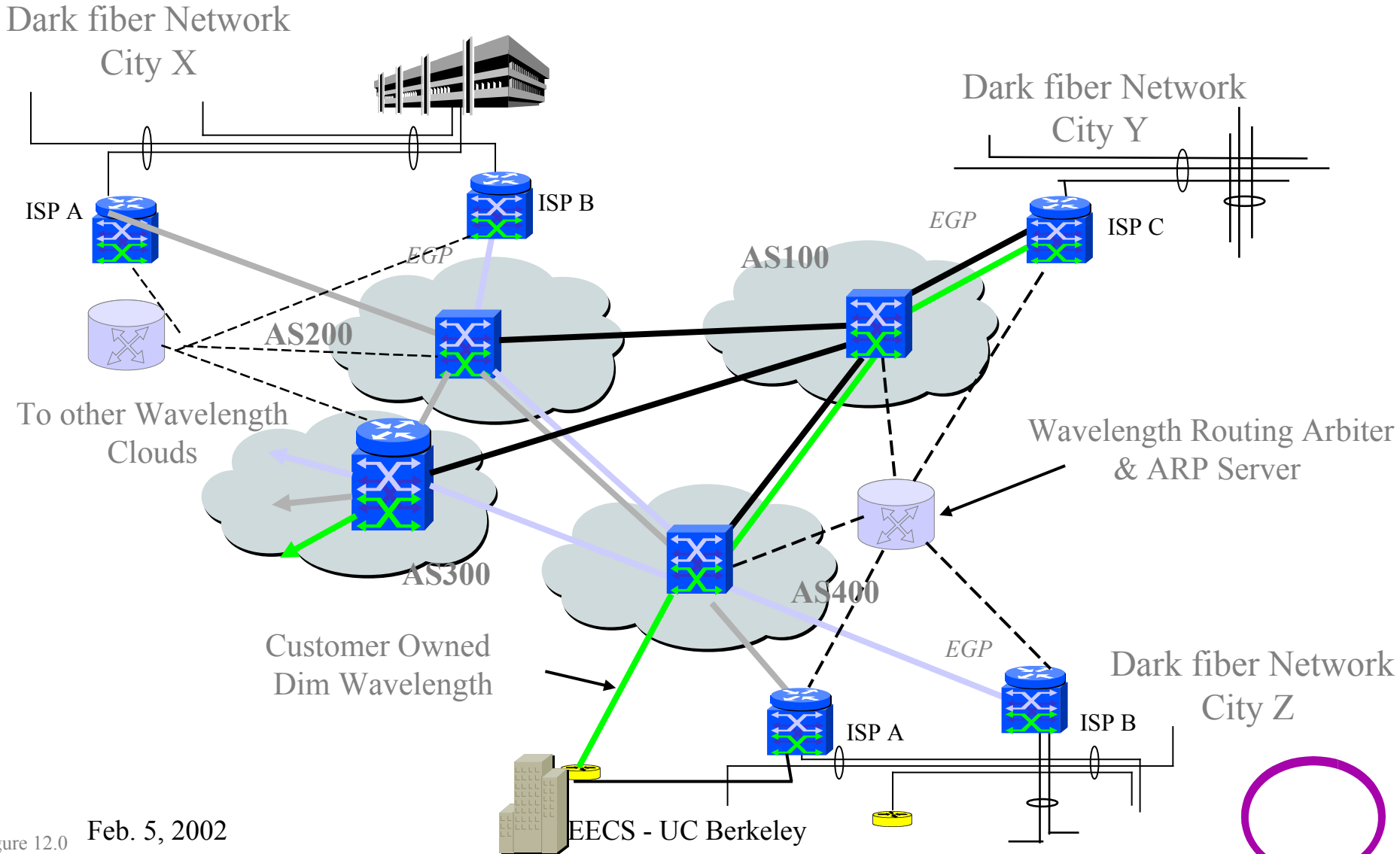
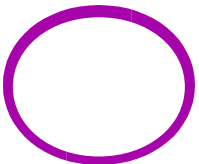


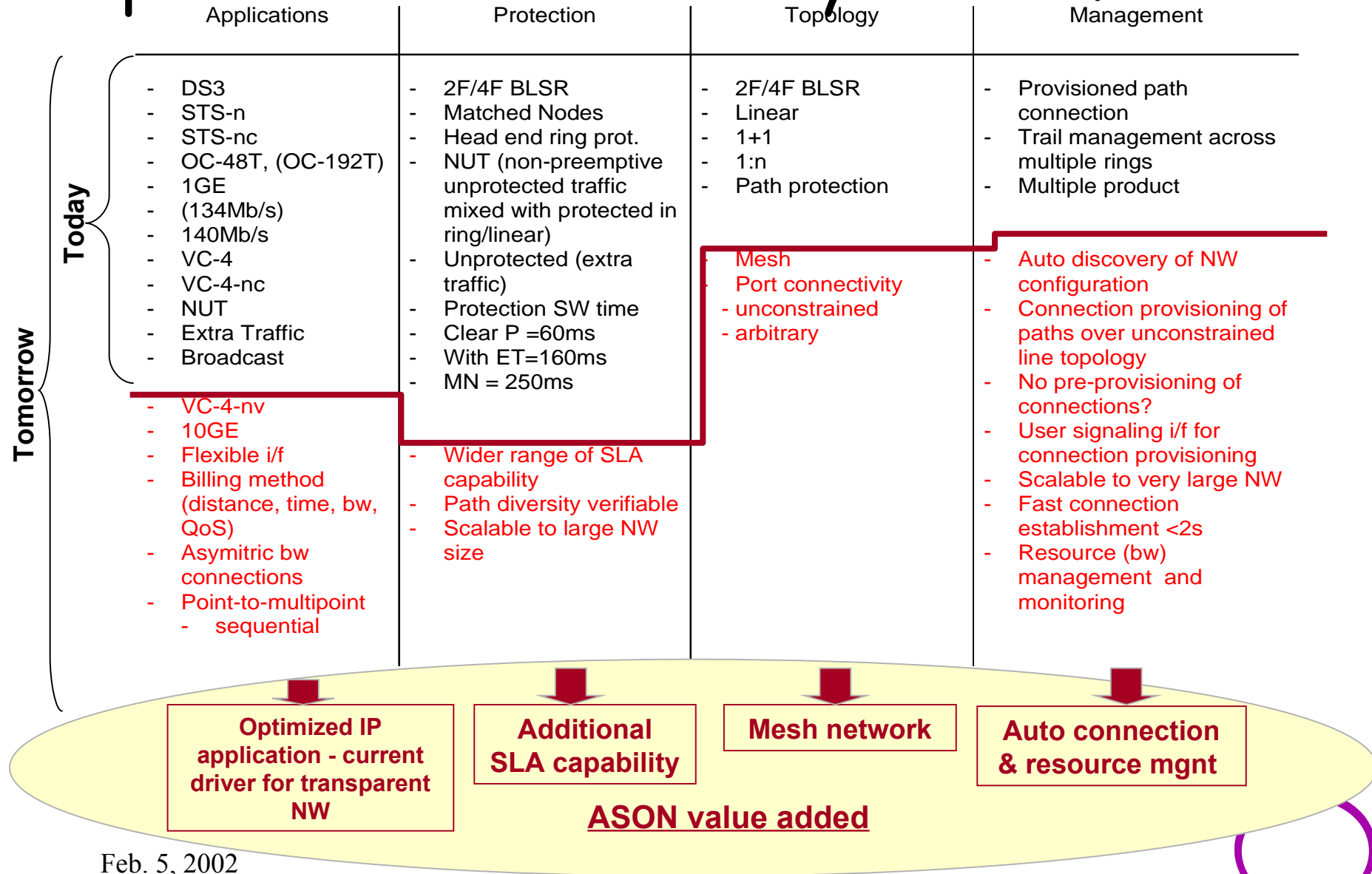
Figure 12.0 Feb. 5, 2002

# What is ASON?

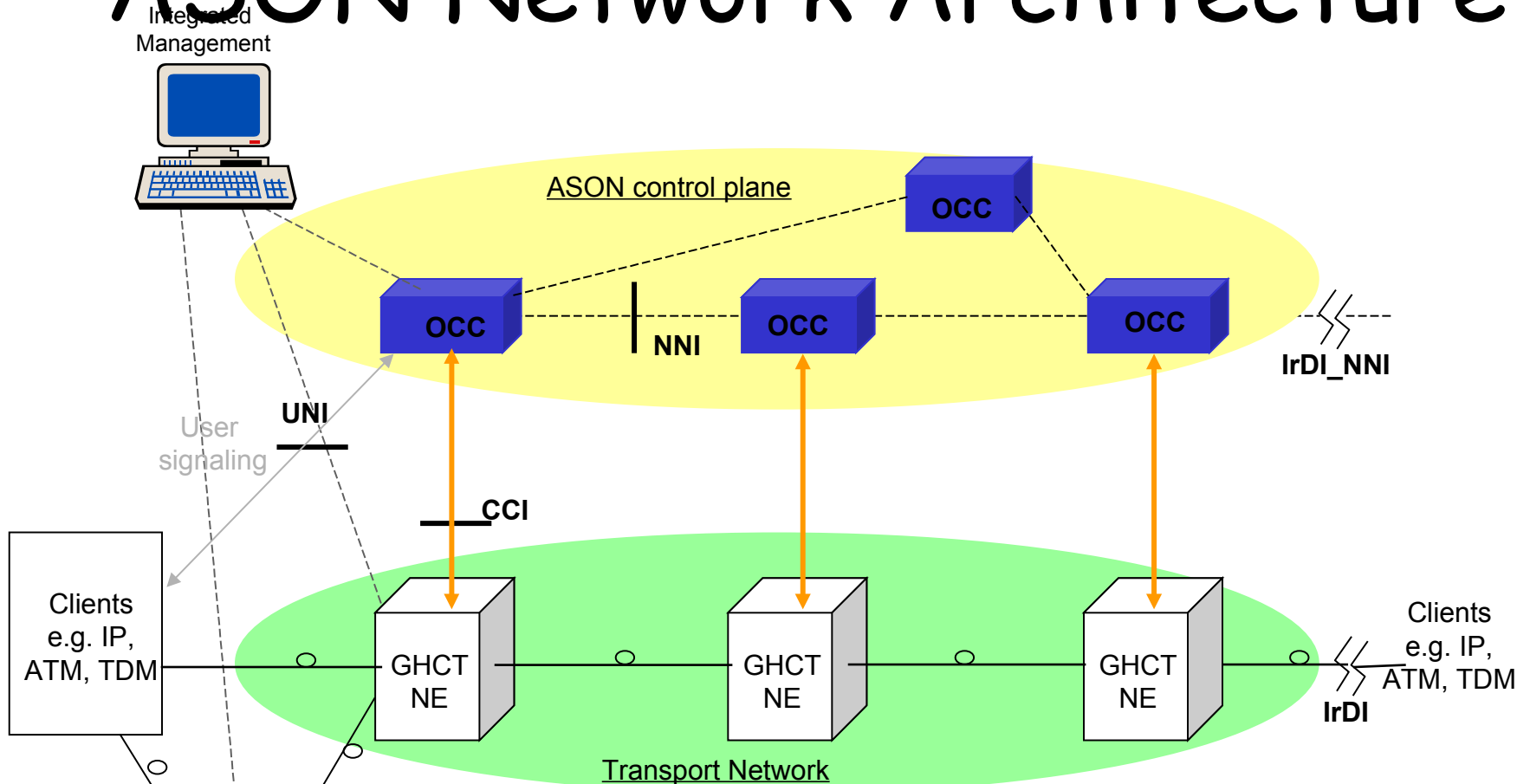
- The Automatic Switched Optical Network (ASON) is both a framework and a technology capability.
- As a framework that describes a control and management architecture for an automatic switched optical transport network.
- As a technology, it refers to routing and signalling protocols applied to an optical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



# Optical Network: Today vs. Tomorrow

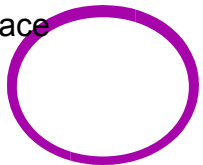


# ASON Network Architecture

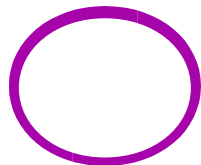
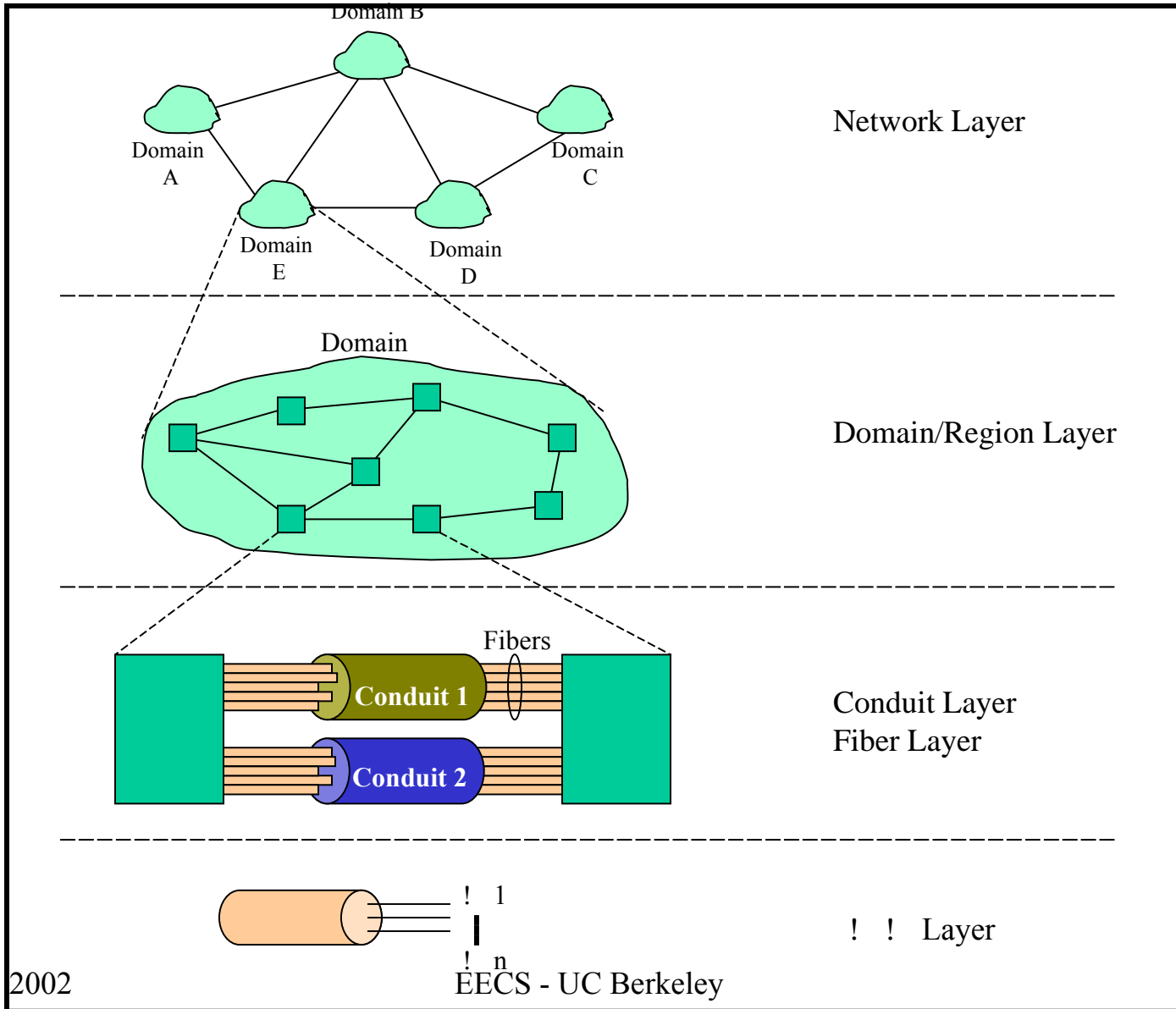


GHCT NE: Global High Capacity transport NE  
 ASON: Automatic Switched Optical Network  
 OCC: Optical Connection Controller  
 IrDI: Inter Domain Interface

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

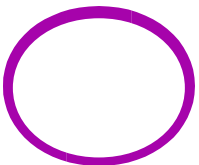


# ASON Layer Hierarchy

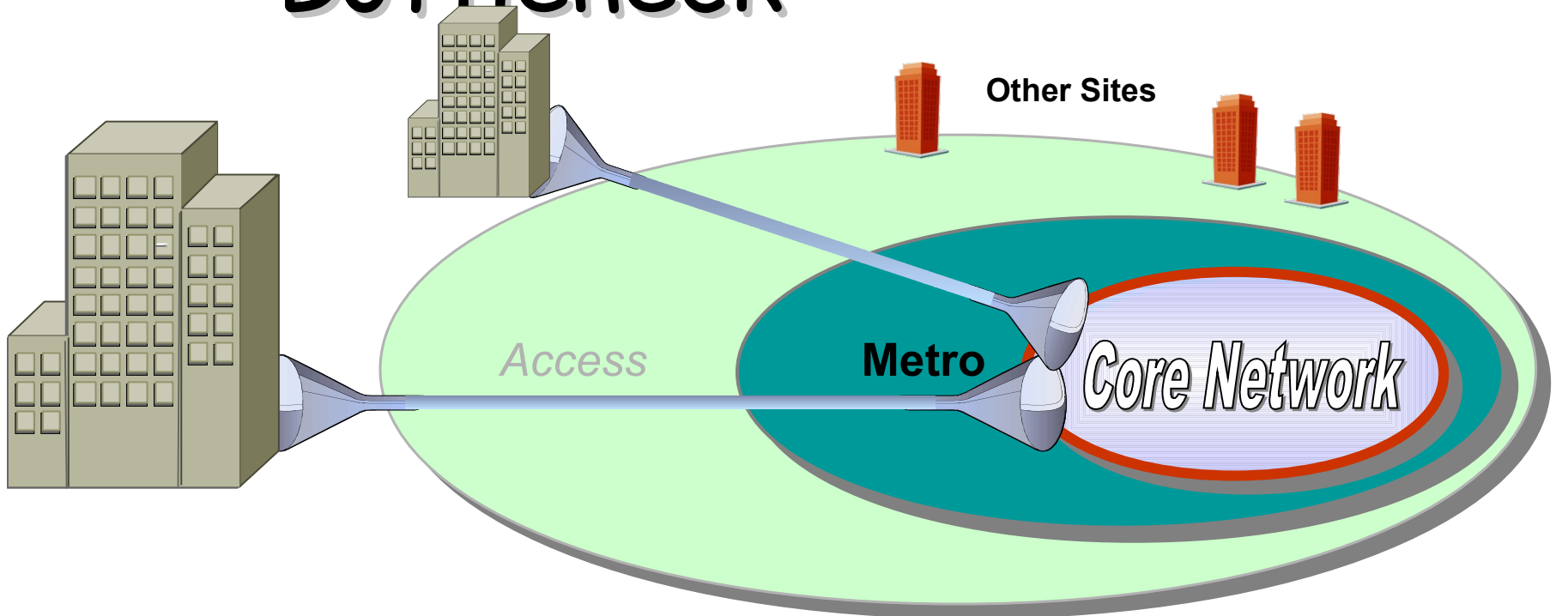


# Resilient packet ring (802.17)

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



# The Metro Bottleneck



**End User**

**Ethernet LAN**

**IP/DATA**  
**1GigE**

**Access**

**T1**  
**DS1**  
**DS3**

**LL/FR/ATM**

**1-40Meg** ETOS UC Berkeley

**Metro**

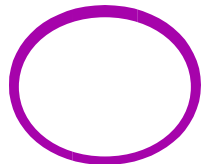
**OC-12**  
**OC-48**

**1Gig+**

**Core**

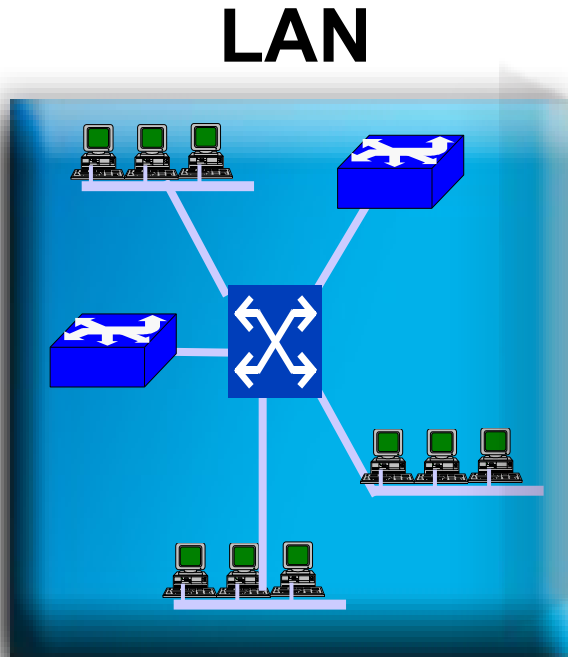
**OC-192**  
**DWDM n x !**

**10GigE+**



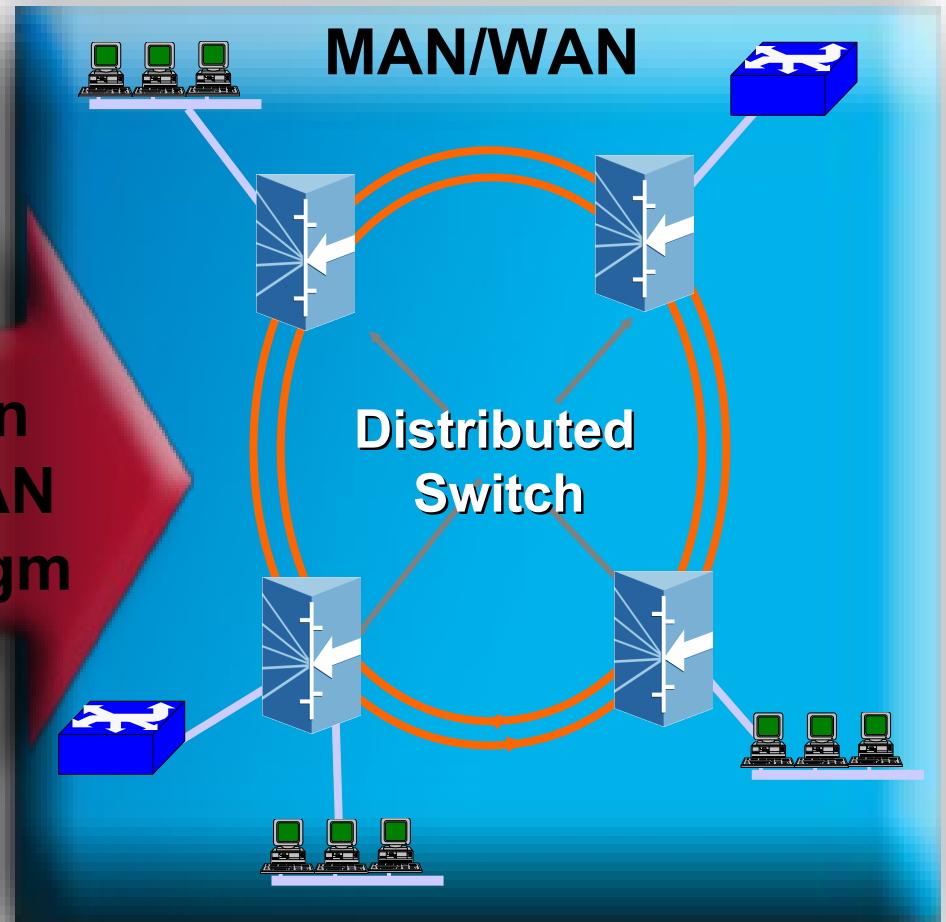


# RPR - Expanding the LAN to the MAN/WAN



- Low Cost
- Simplicity
- Universality

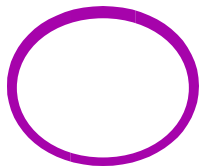
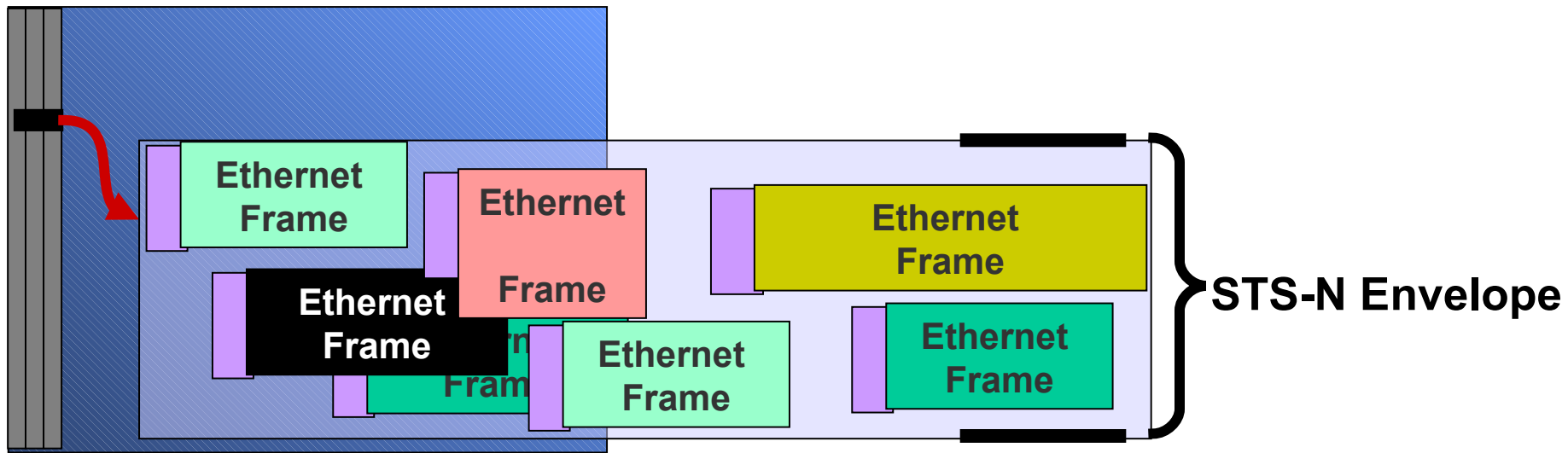
LAN in the MAN Paradigm



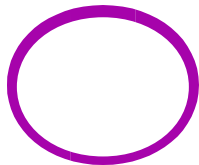
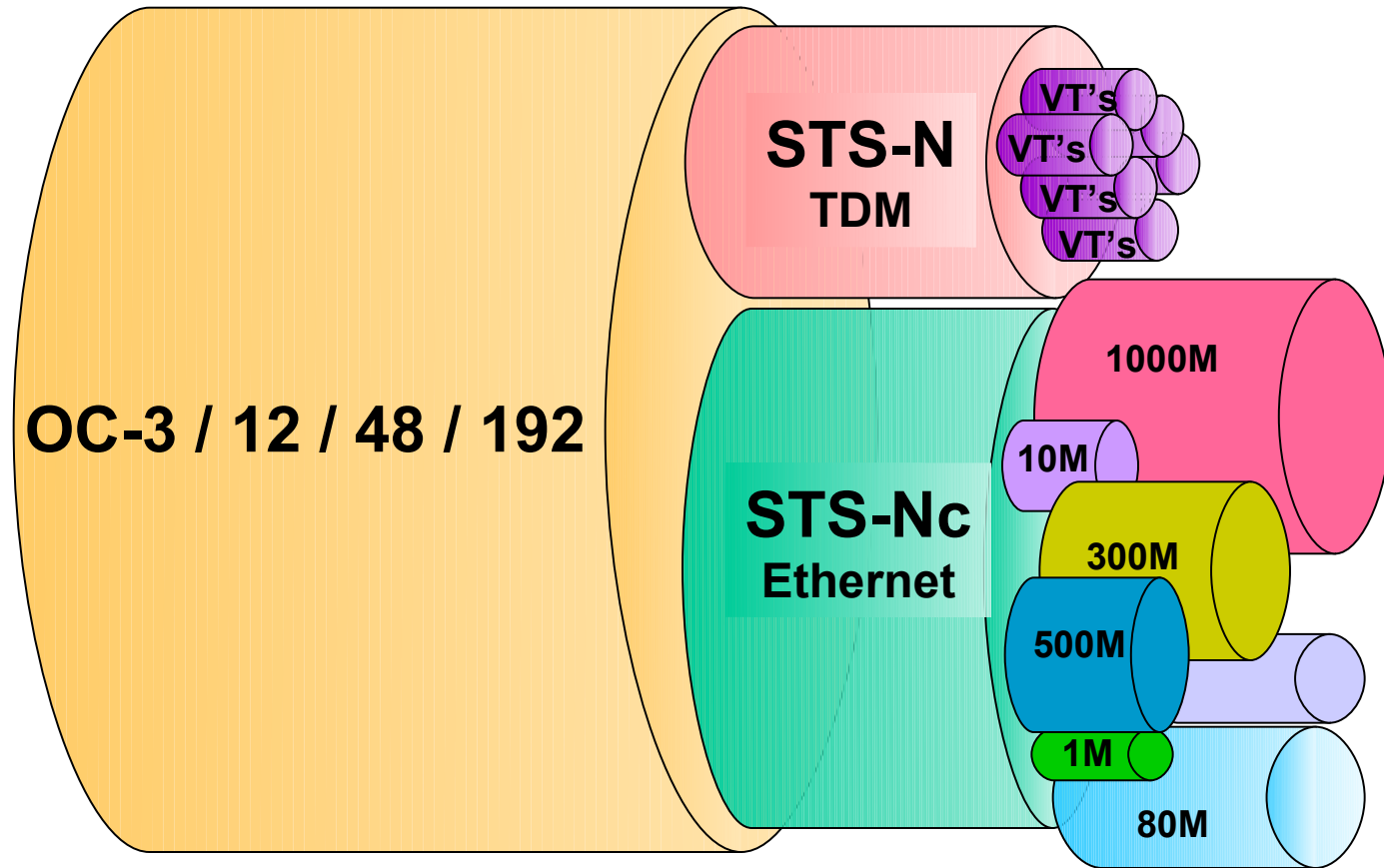
- Low Cost
  - Simplicity
  - Universality
- +
- Scalability
  - Reach
  - Robustness

# What is RPR?

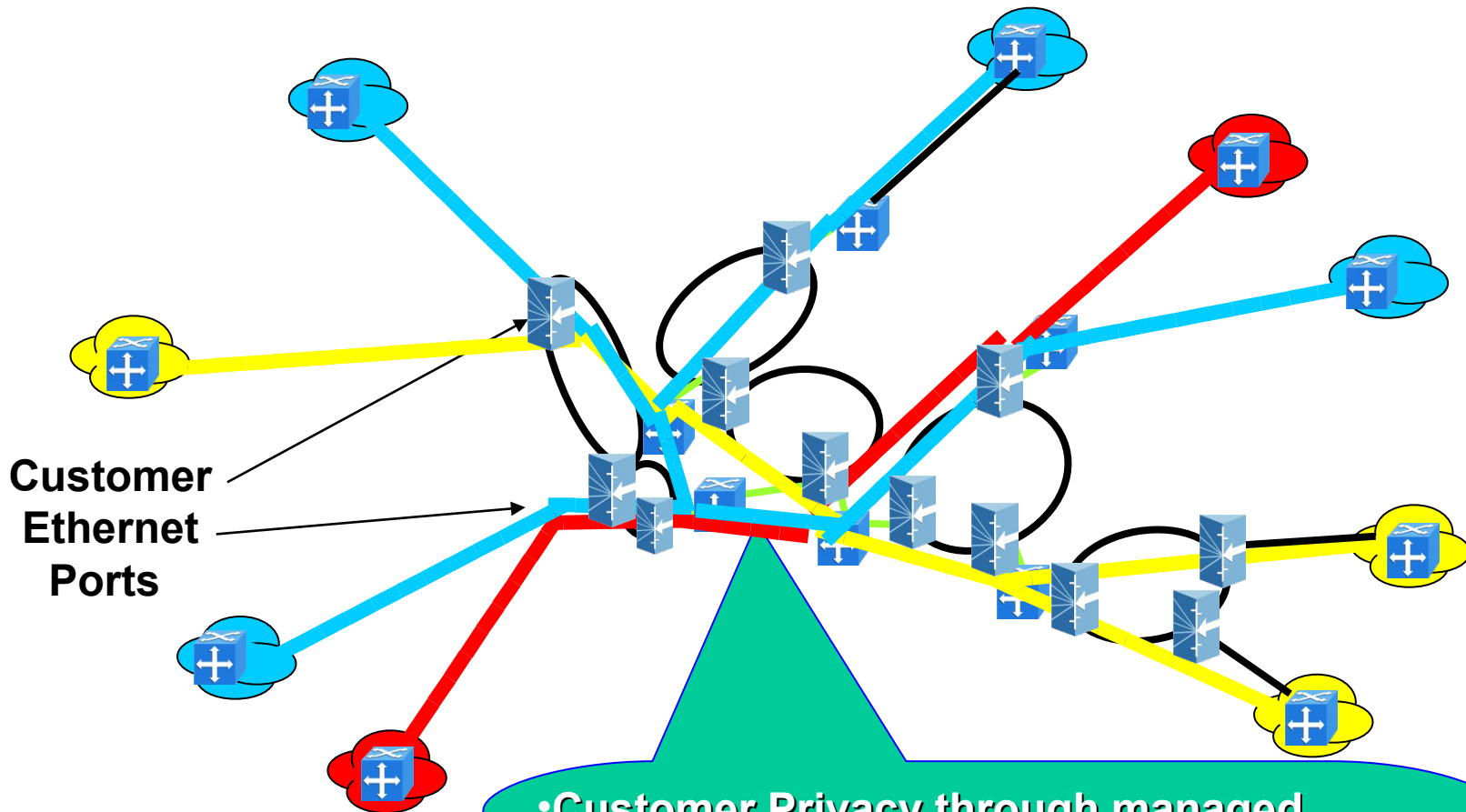
## Ethernet networking on Optics (STS-Nc)



# Scalable Bandwidth and Services



# Network & Customer Management



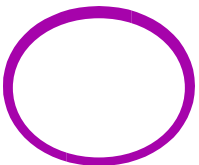
Customer  
Ethernet  
Ports

- Customer Privacy through managed Virtual LANs (802.1Q tags)
- Customer Agreements through flow attributes (802.1p prioritized queues and traffic policing)

Feb. 5, 2002

# 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**

