Hierarchical Dynamic Optical Circuit Switching for Future Internet Architecture

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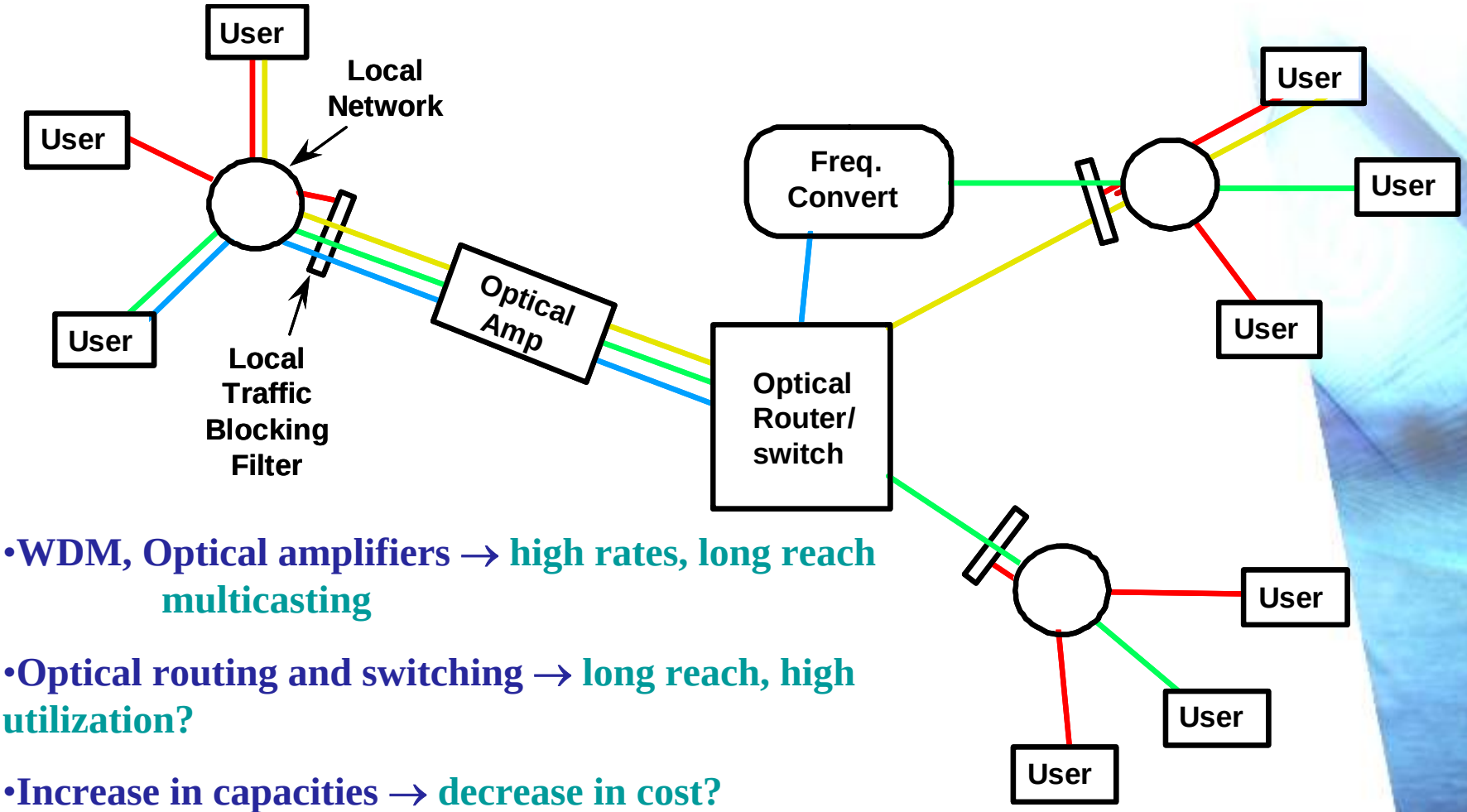
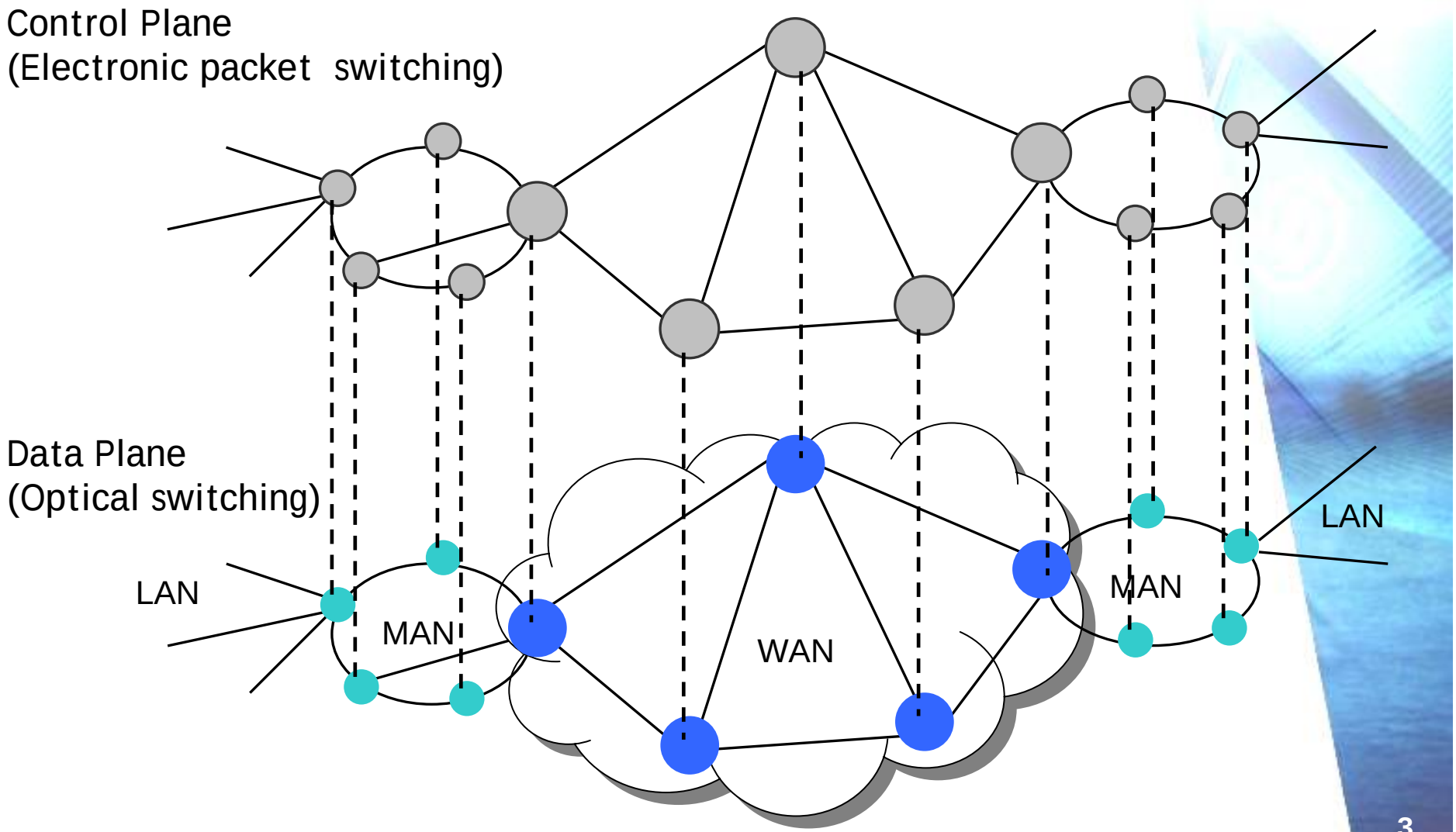
Optical network



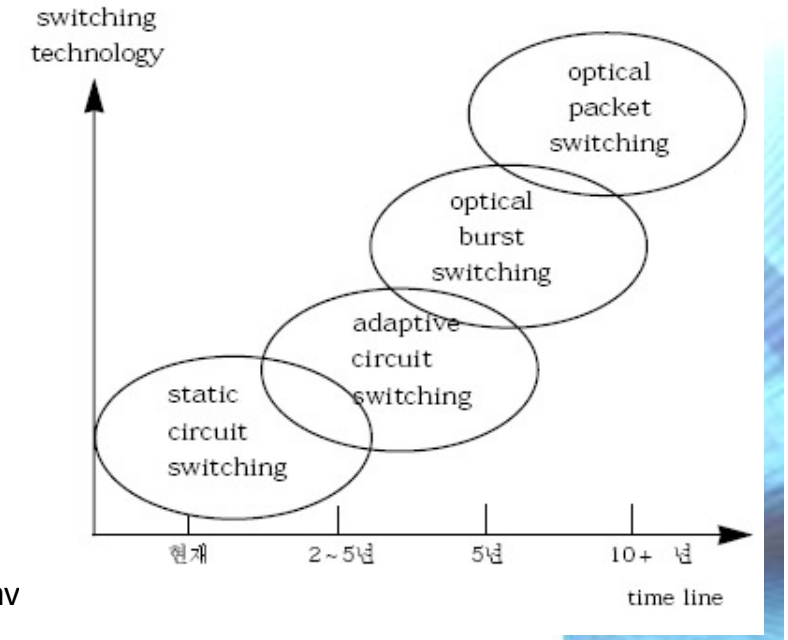
- WDM, Optical amplifiers → high rates, long reach multicasting
- Optical routing and switching → long reach, high utilization?
- Increase in capacities → decrease in cost?

Control Plane of Optical Transport Arch.



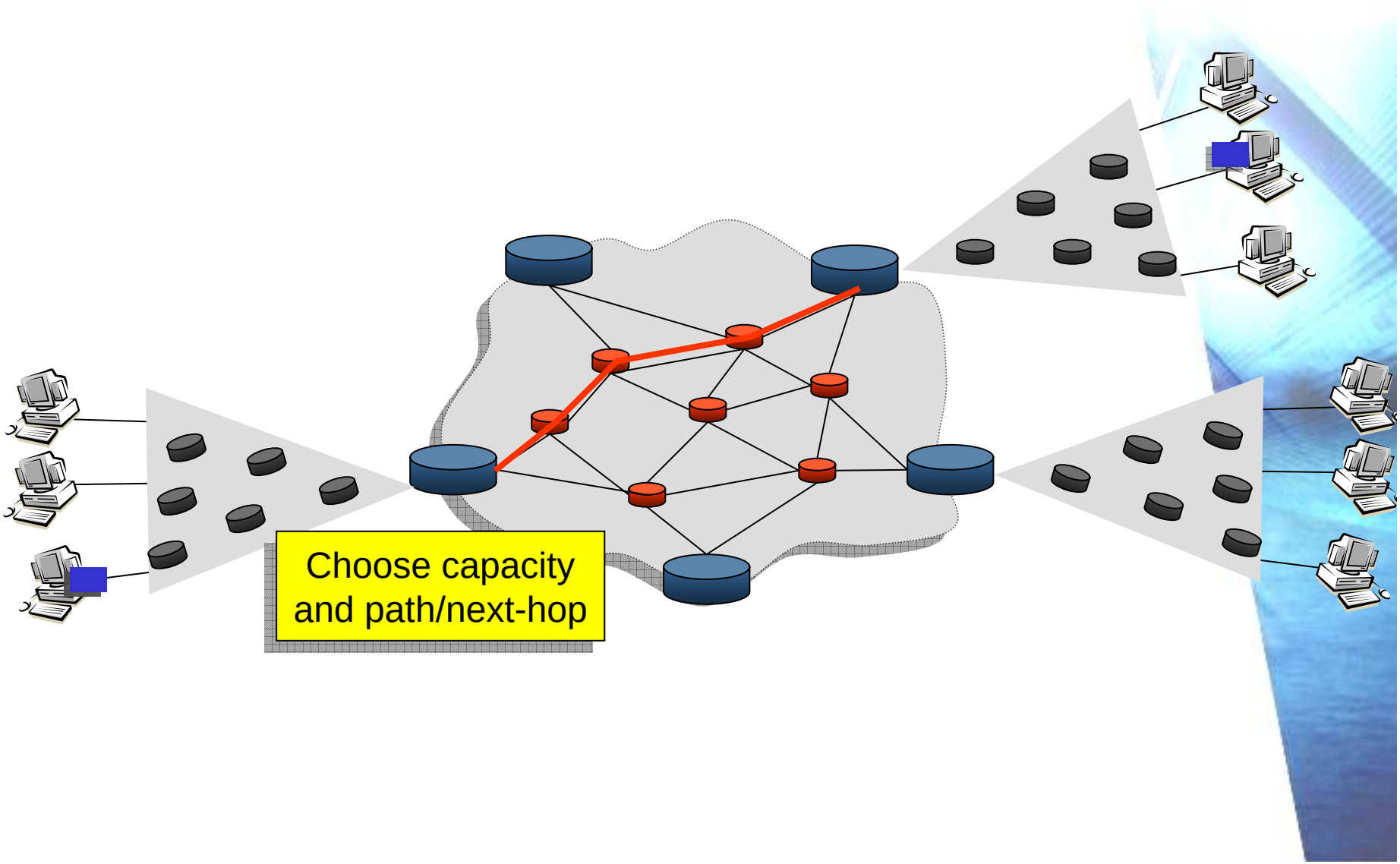
OCS, DOCS, OBS, OFS, OPS

- OCS (Optical Circuit Switching)
  - Limited circuit
  - Low efficiency (due to fixed bandwidth)
  - Unfashionable
- DOCS (Dynamic Optical Circuit Switching)
  - Well-suited to optics
  - Circuit switches are simple
  - Higher capacity per unit volume/watt
  - Lower cost per Gb/s
- OBS (Optical Burst Switching)
  - Assemble the packets (have same destination)
    - make bursts at the edge
  - Distributed Switch through transparently without any conv
  - No need for Optical buffer

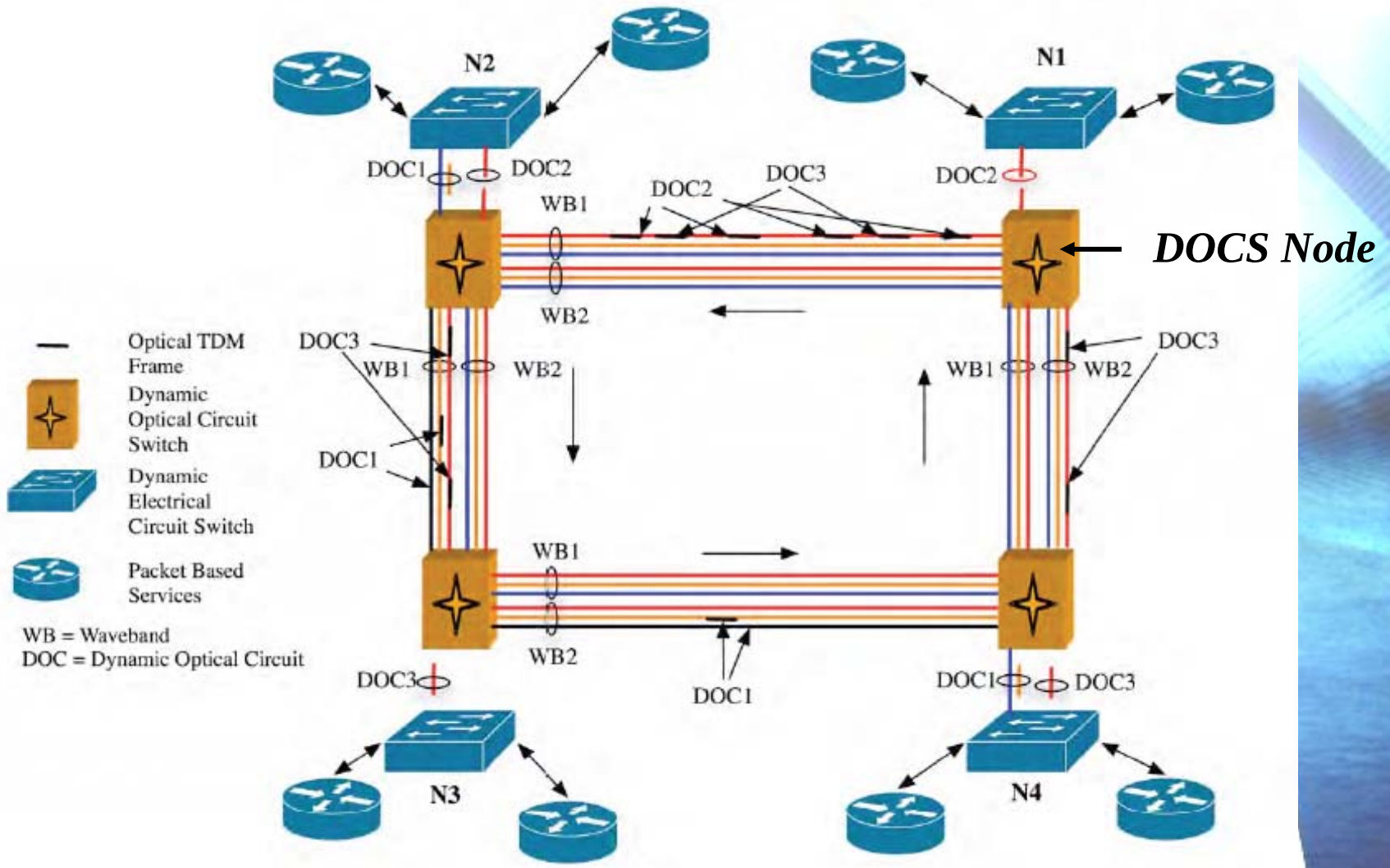


- OFS (Optical Flow Switching)
  - **scheduled flow-based transport architecture**
  - a hierarchical access network
  - statistical multiplexing of large flows from many users in a scheduled fashion
- OPS (Optical Packet Switching)
  - Using Packet (= Header (for routing) + Data)
    - Need buffers, Long Switching time, difficulty of bit-level processing

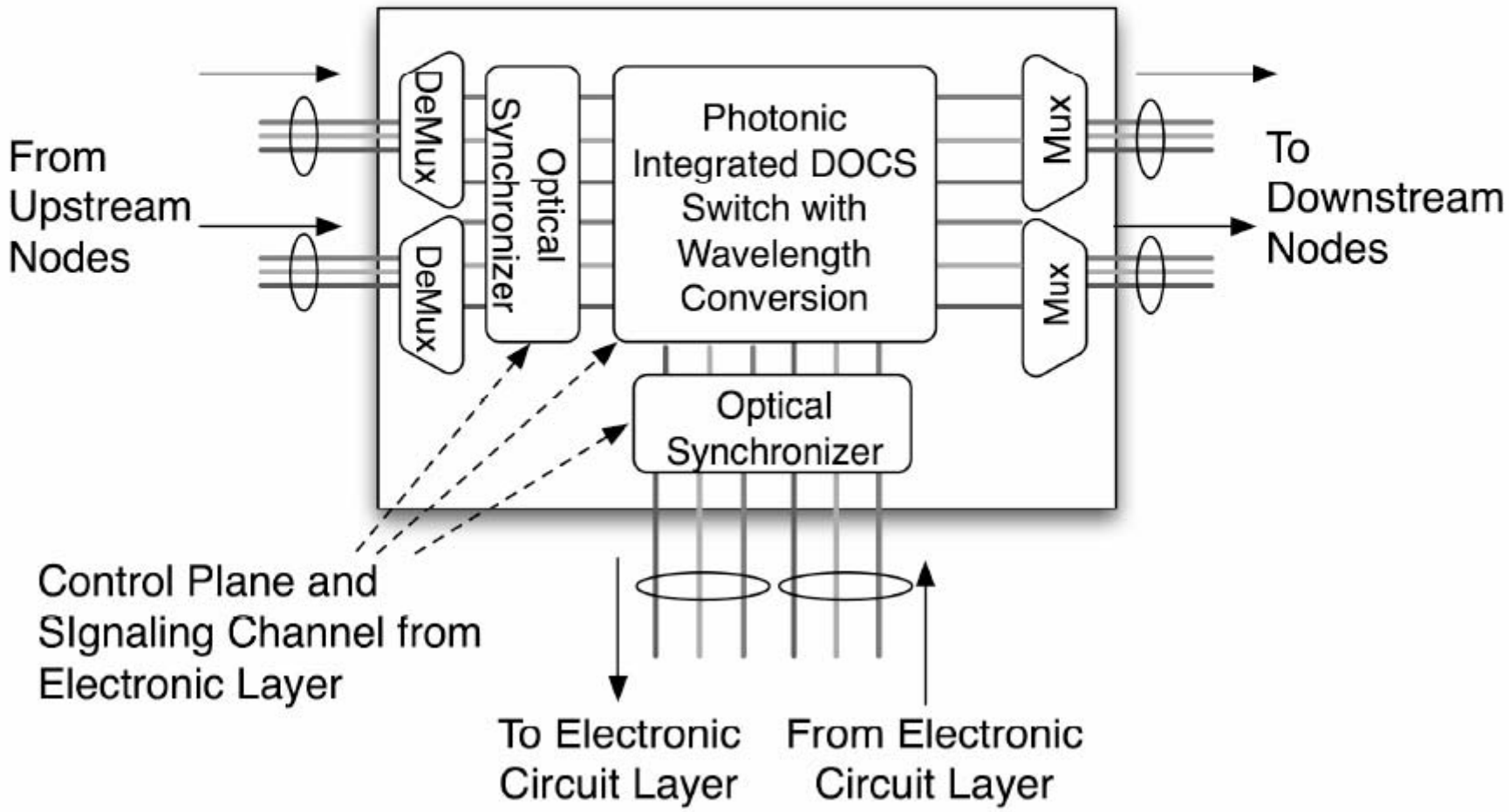
Dynamic Optical Circuit Switching (DOCS-Stanford)



DOCS Network Example

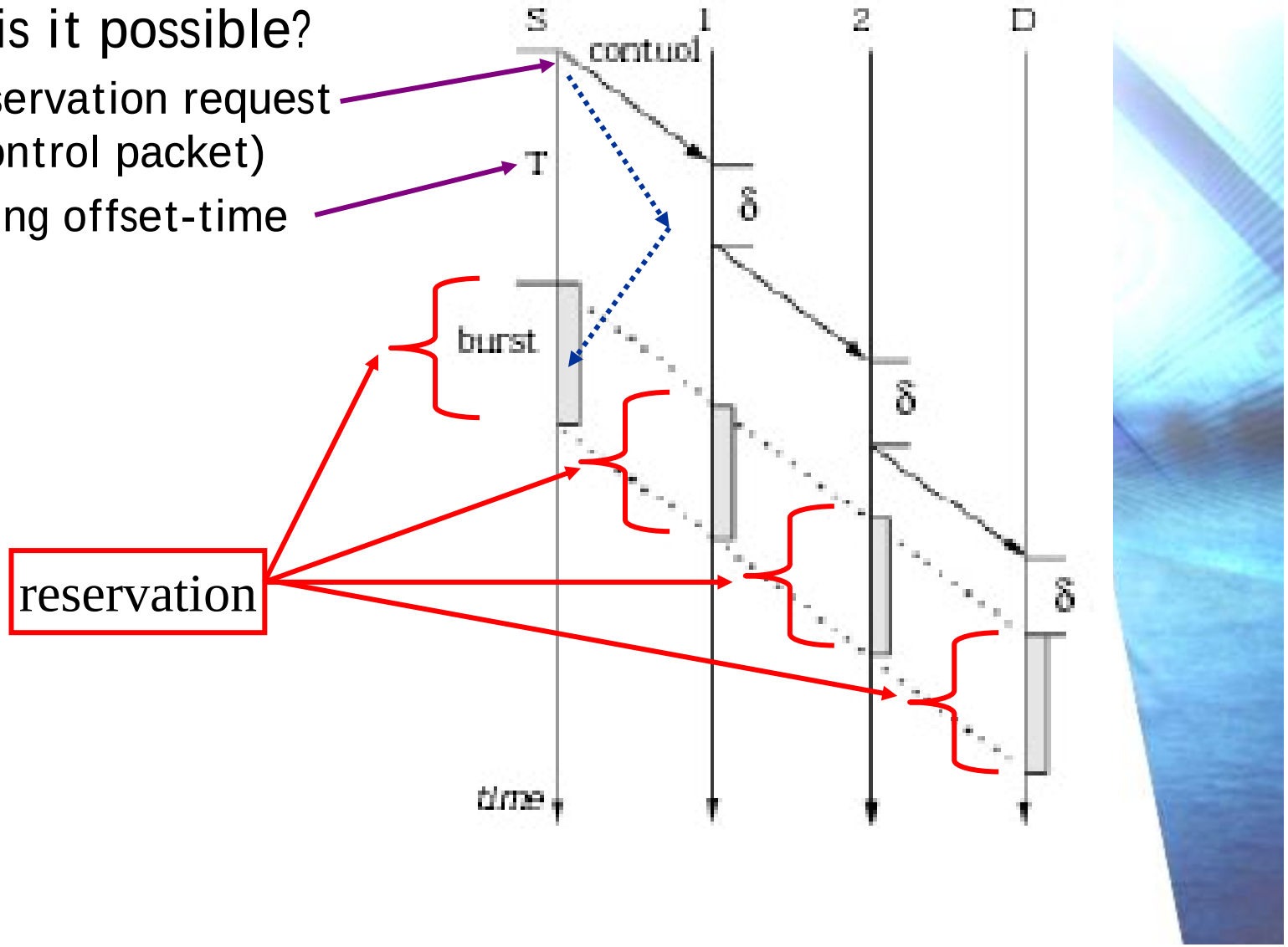


Dynamic optical circuit switched node

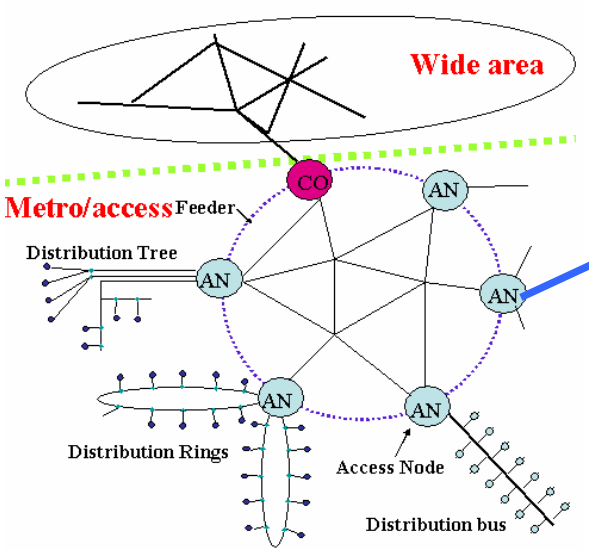


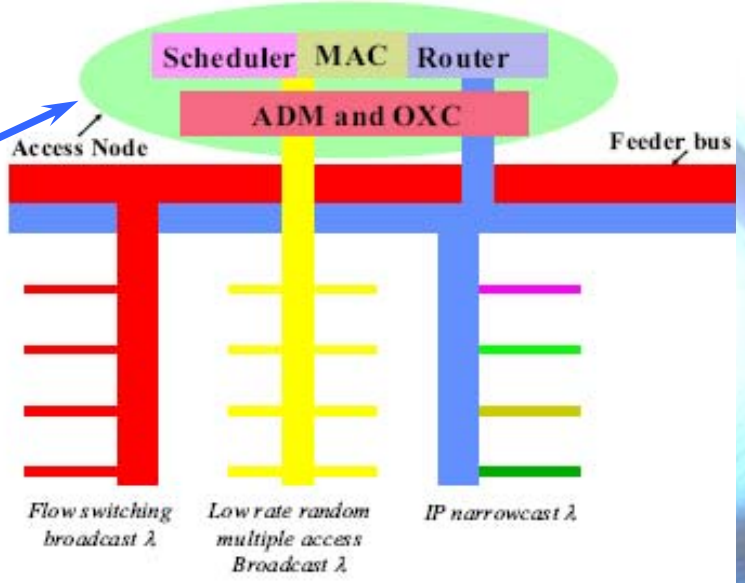
Optical Burst Switching (OBS)

- How is it possible?
  - reservation request (control packet)
  - Using offset-time

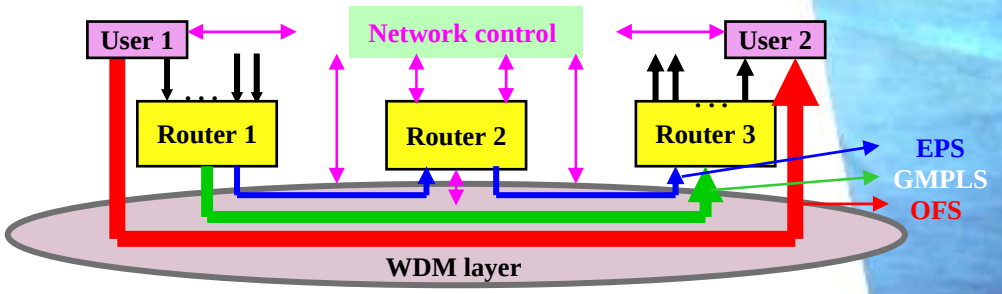


Optical Flow Switching (OFS-MIT)





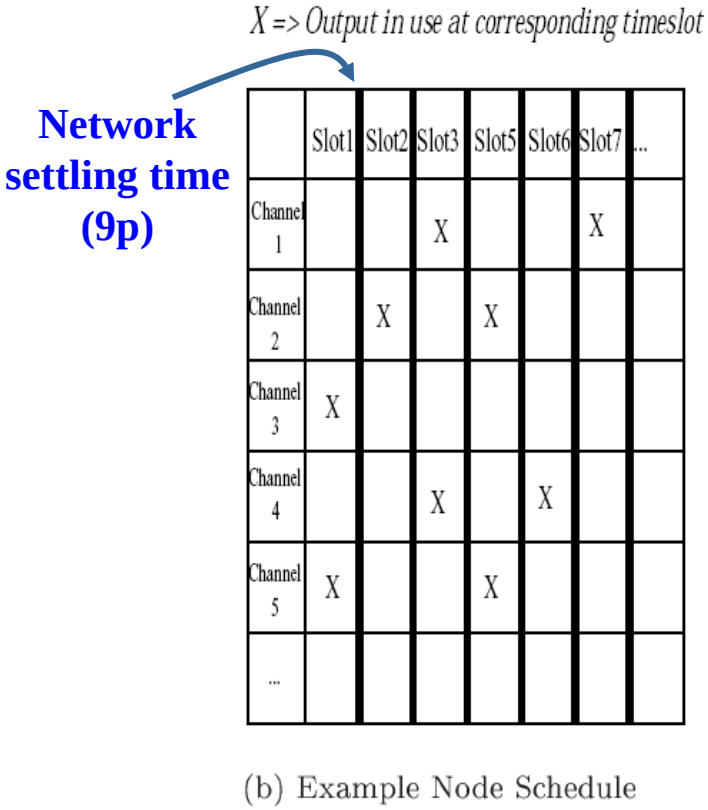
- Physical and logical architecture
- Transport mechanisms –flow switching
- Routing: separate IP and optical control planes
- Scalable, Low cost
- Dynamic broadcast group formation
- End-to-End lightpaths for long duration (>100 msec) transactions



SNU INC lab.

OFS

- Given network timing information, many on-demand scheduled connection setup approaches are possible



(b) Example Node Schedule

1. FSS (Xmit) makes a flow request to local ONRAMP Node (Node 1)
   - Transmission target is Recv
   - Duration of transmission is known
2. Node 1 computes the earliest timeslot with a free route, wavelength pair for Xmits transmission (t0)
   - This scheduling is on-demand
3. Node 1 communicates t0 to Nodes 2 and 3, which updates OXC scheduler
4. At time t0, Nodes 1, 2 and 3 configures OXCs (as per their local scheduler) and inform Recv and Xmit to tune to the chosen channel.
   - Xmit is then informed of the newly created connection
5. Upon expiration of flow time, resources are released for next transmission

Motivation (1/2)

Cost per unit of optical fiber capacity is well below that of Moore's Law

Low electric power consumption

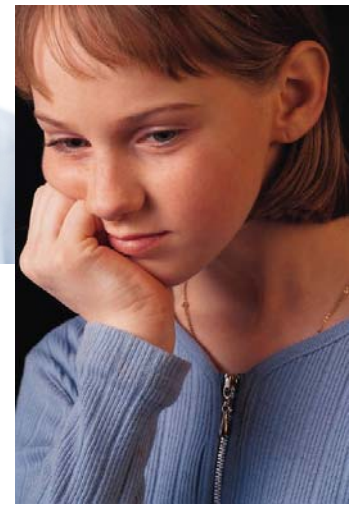
Efficient accommodation of emerging traffic
(Remote conference, IPTV, VoIP…)

QoS, Multicasting, Broadcasting, Large traffic volume

Design of Optical Transport Architecture

Motivation (2/2)

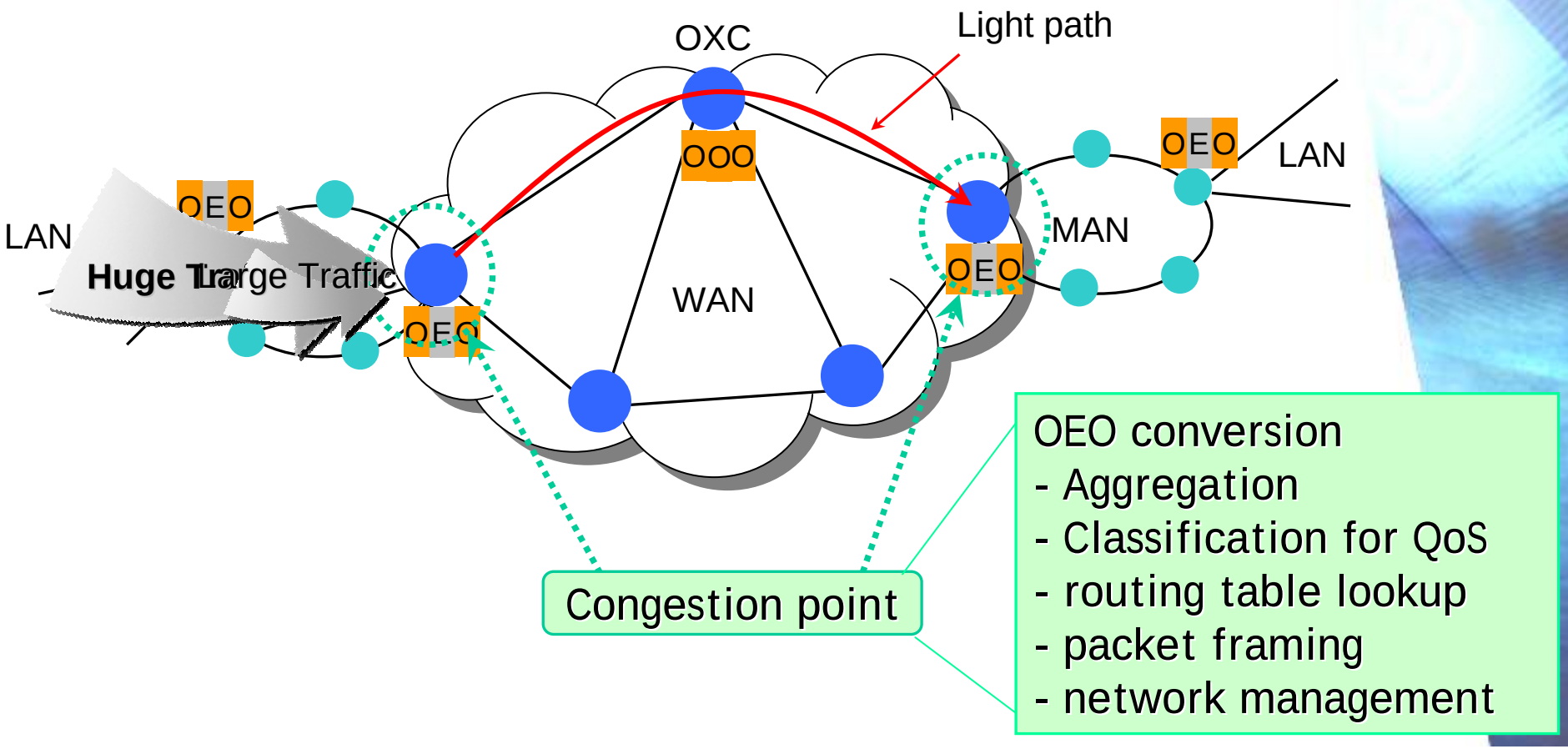
- Estimate of the next-generation network
  - Individual bandwidth requirements per household are expected to reach approximate **1.1Tb per month by 2010** in the U.S alone
  - The bandwidth required for each broadcast streams can vary b/w 1 to 19.39Mbps: **19.39Mbps** is the maximum data rate as defined by the ATSC for **HDTV broadcasts using MPEG-2 transport**
  - The capacity of fiber network will be **40-100Gbps per wavelength**



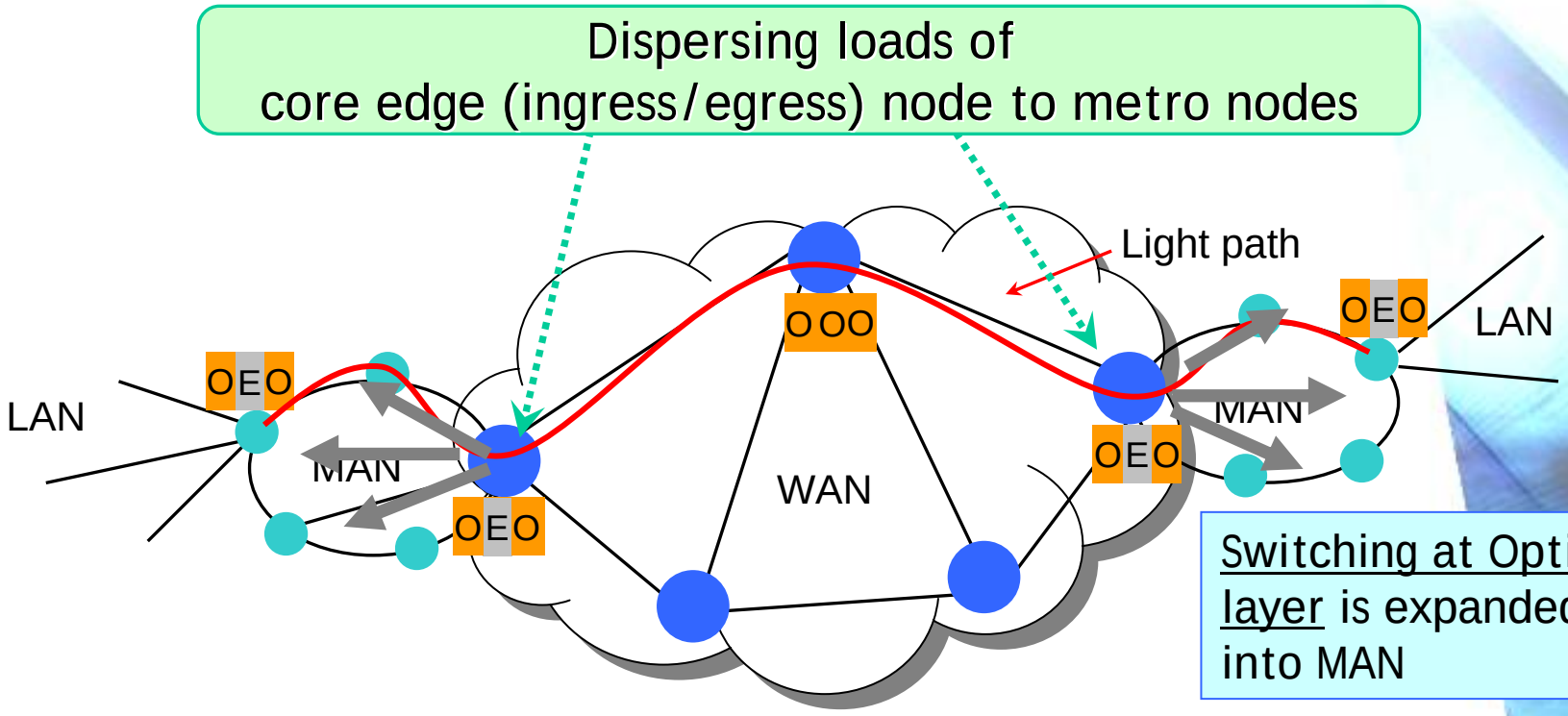
- We have been led to believe less layers are better(i.e., cheaper)
- Is fine grain switching necessary at all in the core?
- Why don't we just do wavelength switching only in the core and let the MAN do the finer grain grooming?
- why shouldn't the core only change circuits in a quasi-static fashion, leaving major highways(of wavelengths) connecting major MANs and only add or subtract wavelengths based on slow changes in average loads?

Problem Statement

- Next cycle of build-up in the core
  - Long duration (quasi-static) optical circuit switching (GMPLS)



Our Approach



Core node ⟷ Core node : light path establishment, scheduling info exchange

Core node ⟷ Metro nodes : time slot scheduling in given wavelengths

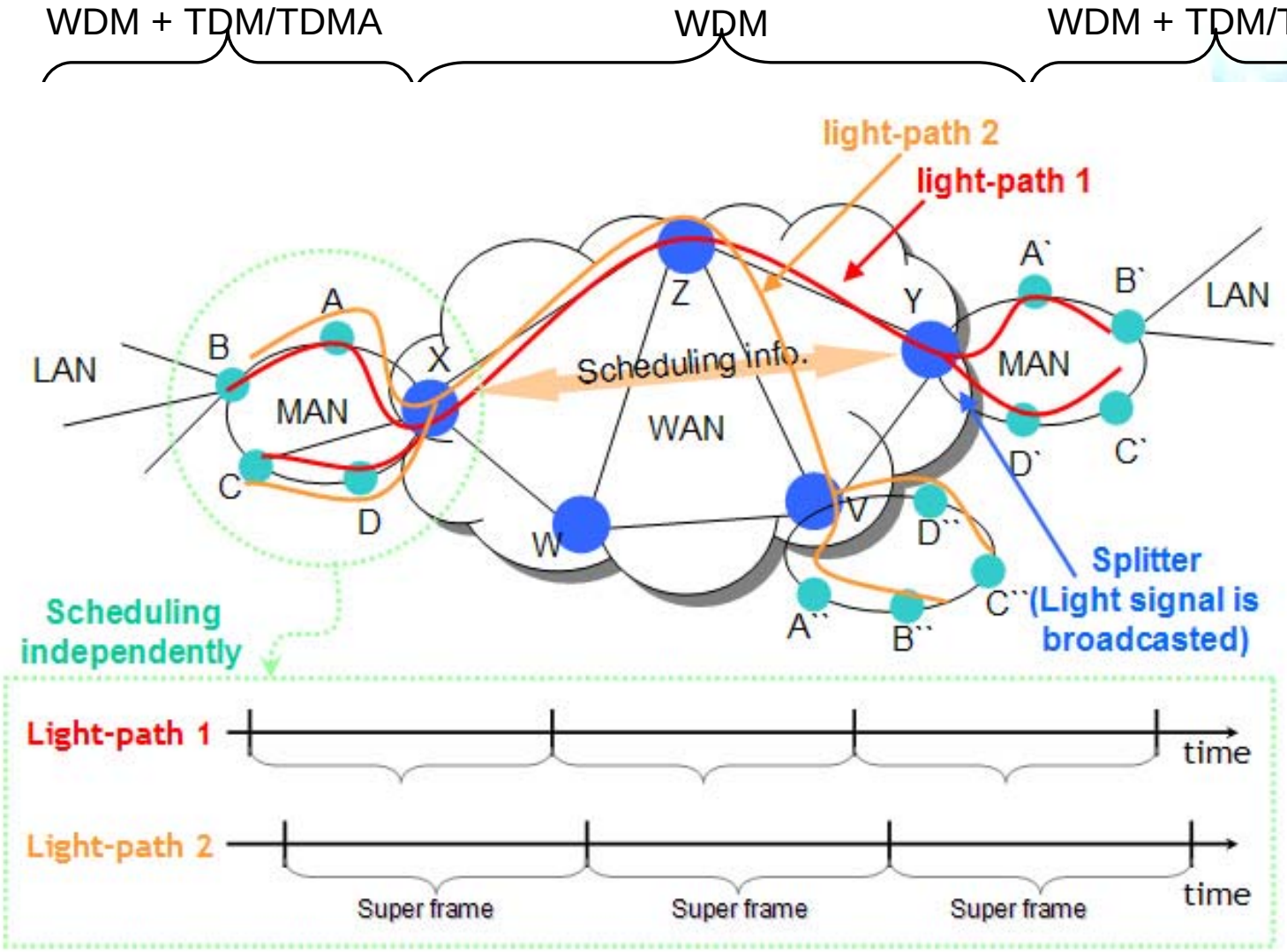
Metro nodes : time slot request, aggregation/de-aggregation

Role of WAN/MAN

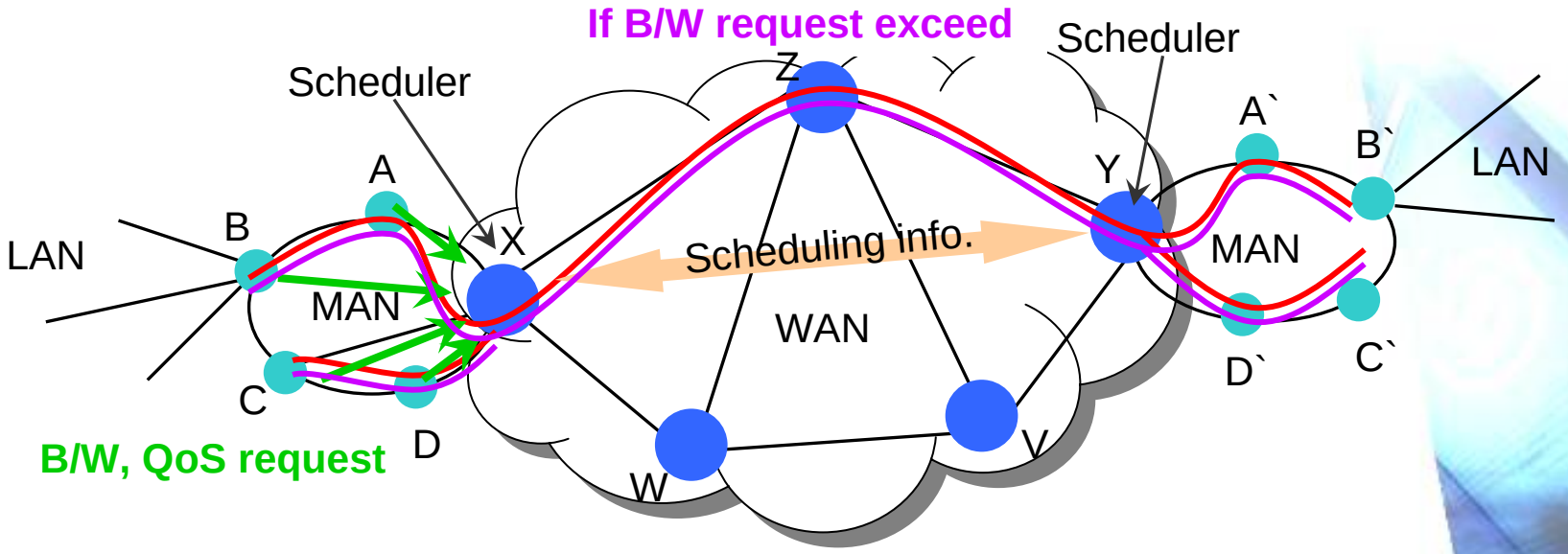
- Wide Area Network (WAN)
  - Granularity: Wavelength (WDM)
  - Light-path establishment
  - MAN management/control (scheduling)
  - Traffic bypass (OOO)

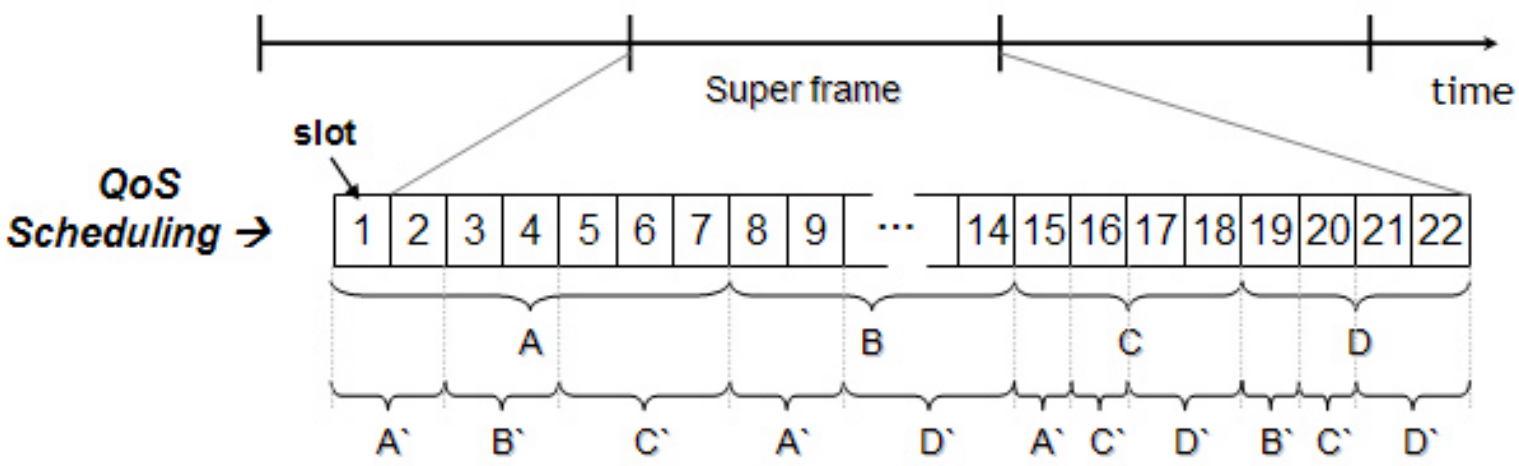
- Metro Area Network (MAN)
  - Granularity: Wavelength, time slot (WDM, TDM/TDMA)
  - Traffic aggregation/de-aggregation

Hierarchical Optical Transport Architecture

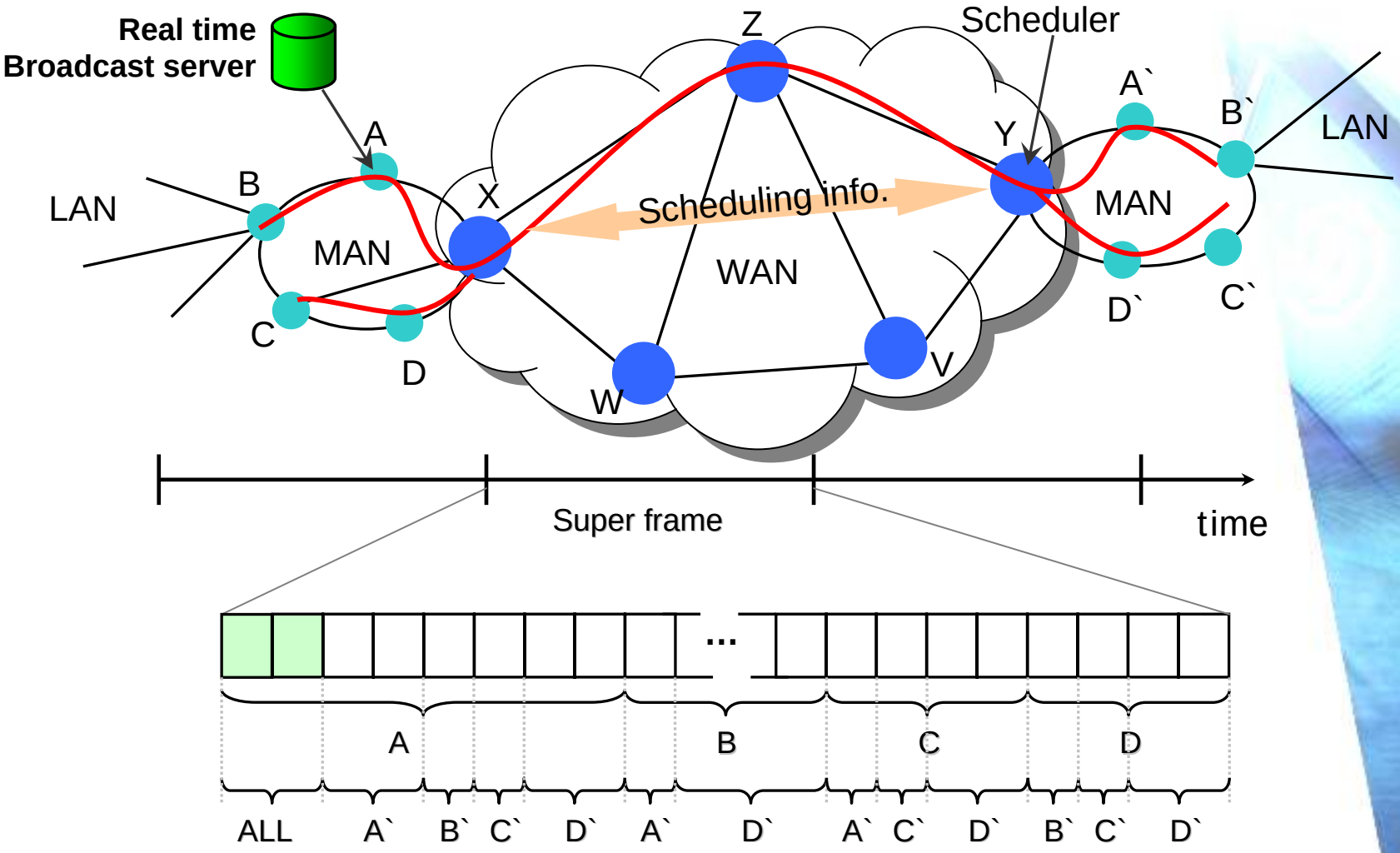


QoS support

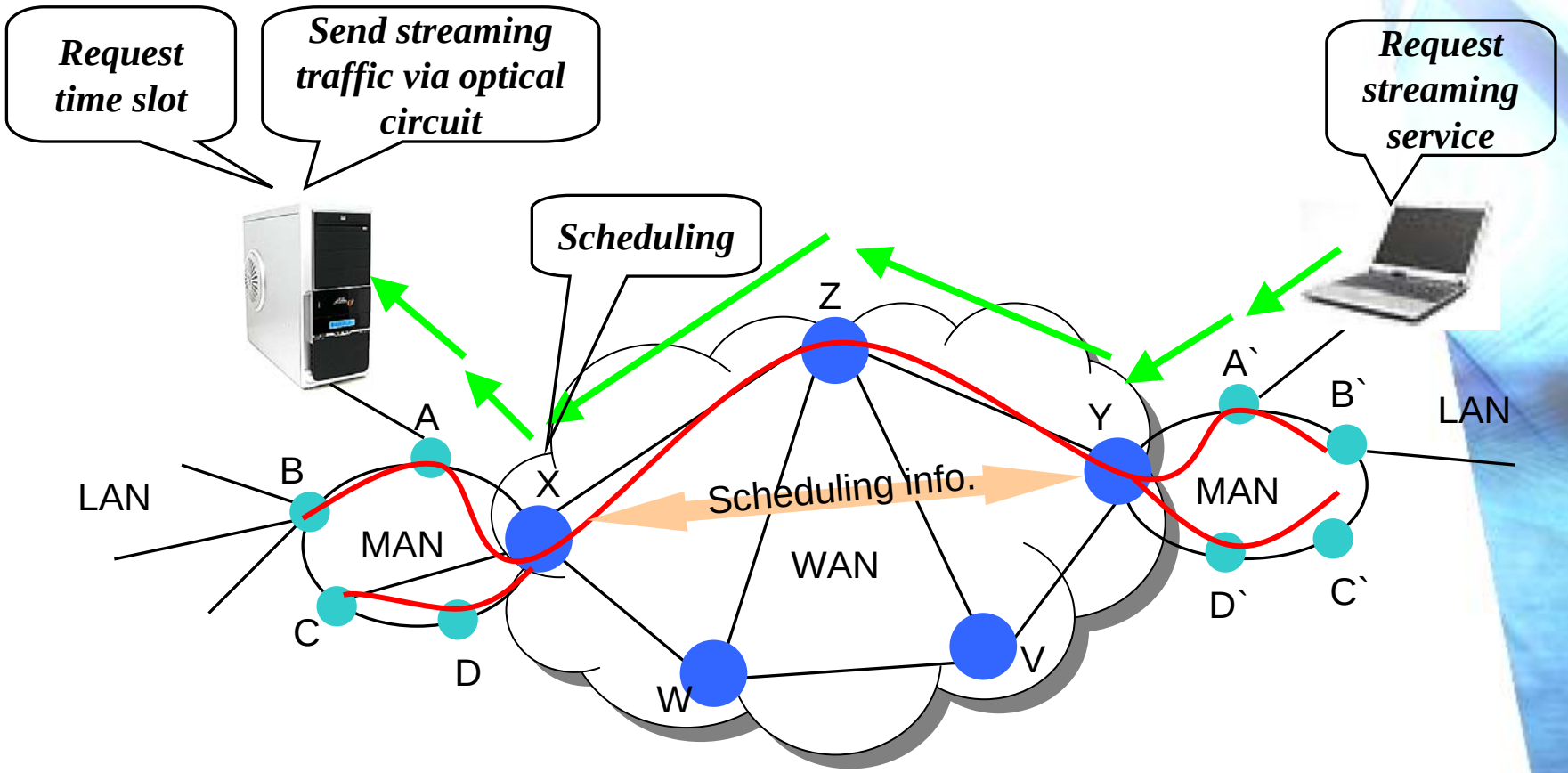

If B/W request exceed
Scheduler
Scheduler
Z
A
B
LAN
X
Y
A`
B`
LAN
Scheduling info.
MAN
MAN
WAN
C
D
B/W, QoS request
W
V
D`
C`


Super frame
time
slot
QoS
Scheduling →
1 2 3 4 5 6 7 8 9 ··· 14 15 16 17 18 19 20 21 22
A
B
C
D
A` B` C` A` D` A` C` D` B` C` D`

Multicast/Broadcast support



Optical Circuit Establishment Process



Characteristics of the proposed scheme

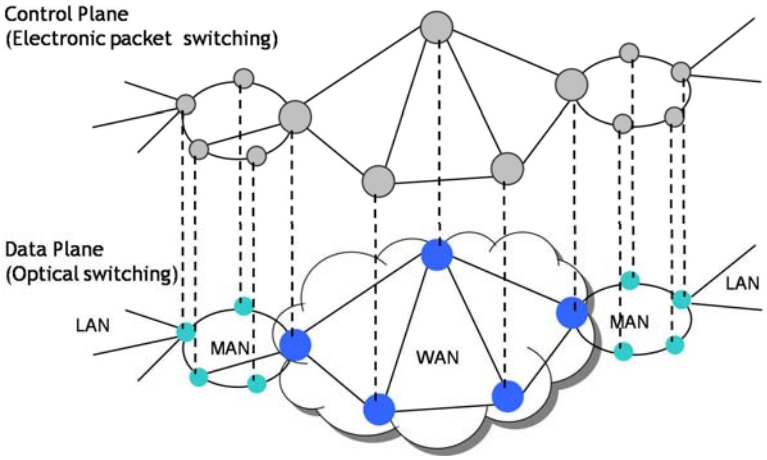
- No need for global synchronization
  - **Not** local synchronization btw the switches within **different MAN**
  - **But** local synchronization btw the switches within **same MAN**
    - TDM synchronization technologies in metro/access network

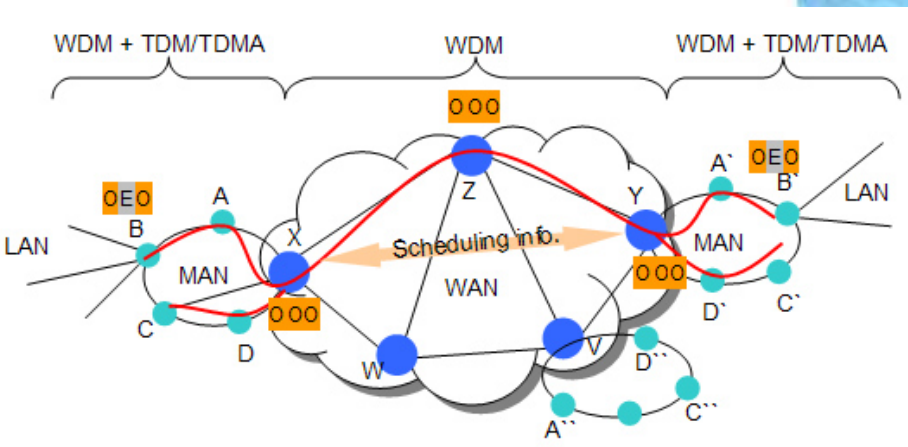
- Multicasting/broadcasting supporting
  - Based on splitter and amplifier in MAN
  - Scheduling all switches in corresponding MAN to be reception mode if they need multicasting/broadcasting traffic (ex: IPTV, remote conference)
    - Using TDM (ALL time slot)

Conclusion

- Hierarchical TDM & WDM Optical Transport Architecture
  - Dispersing a load of core edge (ingress/egress) node to metro nodes
  - Switching at Optical layer is expanded into MAN
- Roles of component

Core Area	Metro Area
❖ Efficient transport and switching ❖ Llight path establishment, scheduling info exchange	❖ Data grooming ❖ Time slot scheduling in given wavelengths





Future work

- Introduce a enhanced optical transport architecture based on future internet requirement

- Need to complement in many ways
  - Design of superframe structure
  - Efficient multicast transport arch.
    - Compare the cost existing multicast tree based method with many time transport by different wavelengths