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Área de Ingeniería Telemática

Introduction to Optical Burst Switching

Area de Ingeniería Telemática
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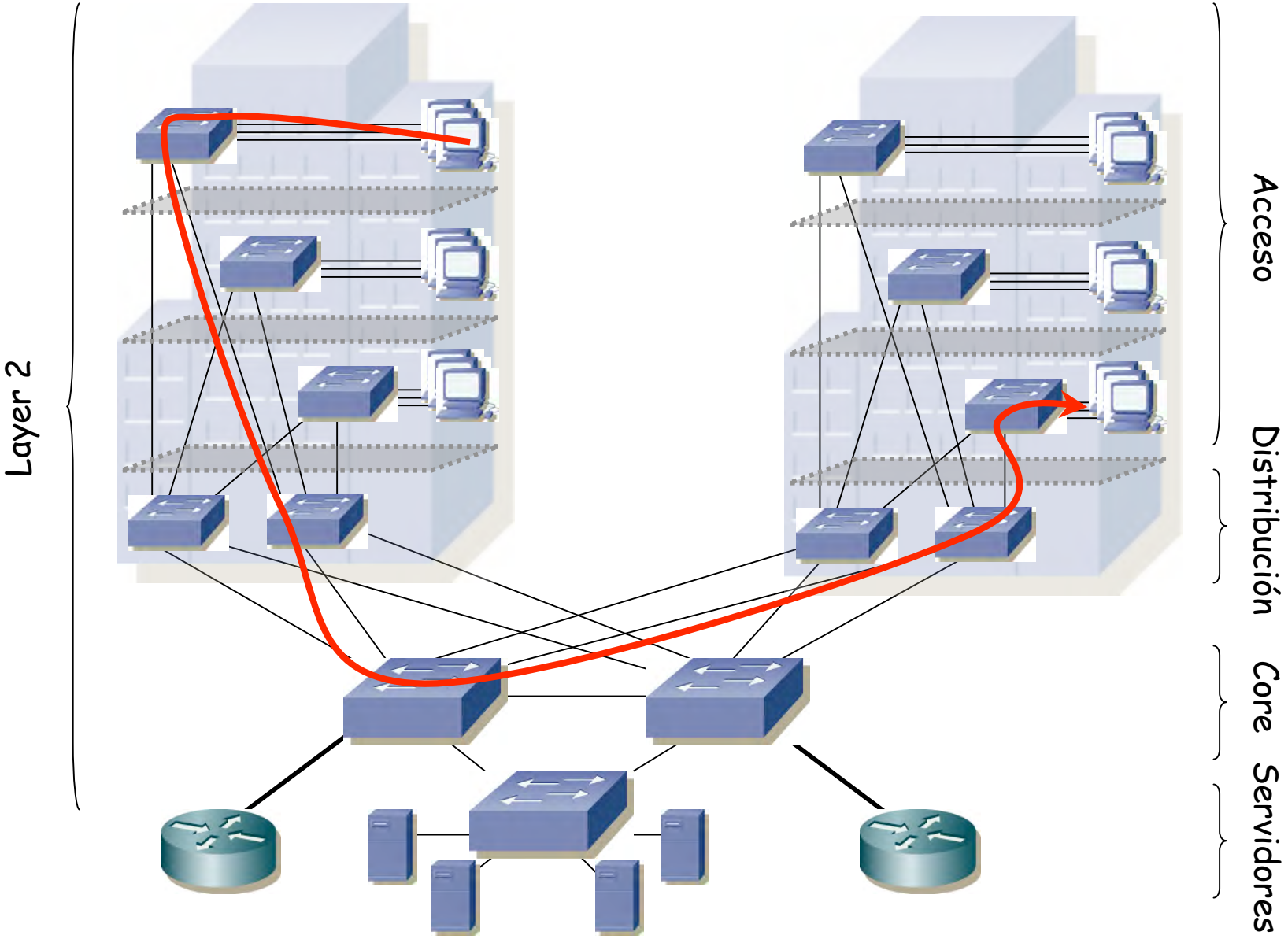
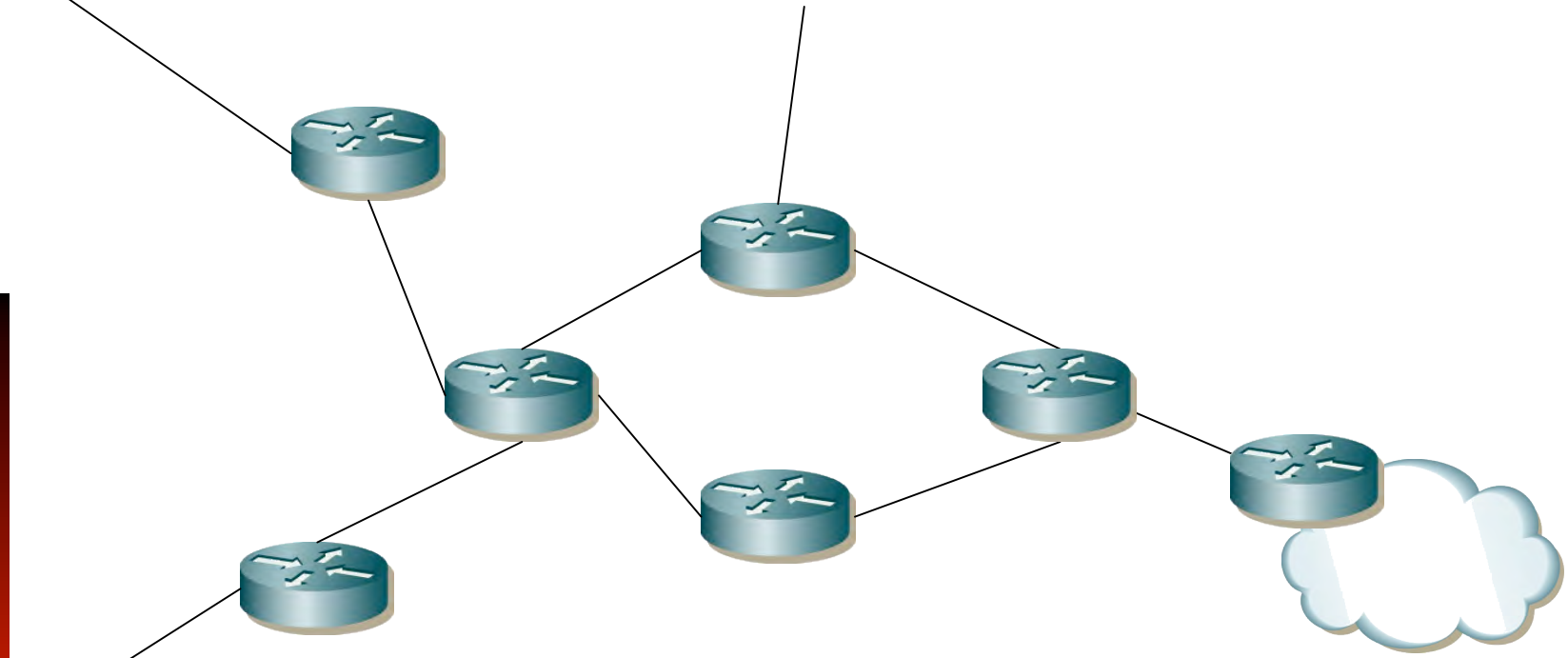
LANs

Campus-wide LAN



WANs

WANs



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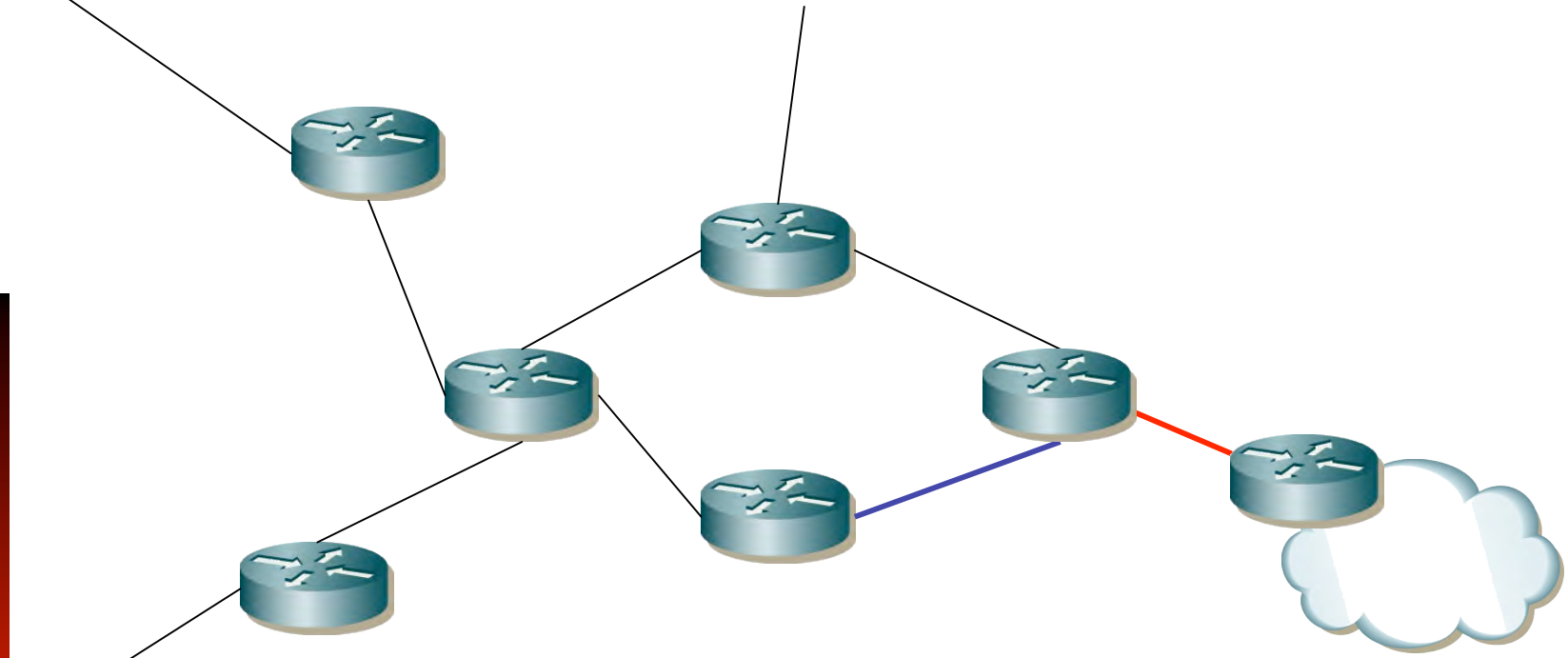

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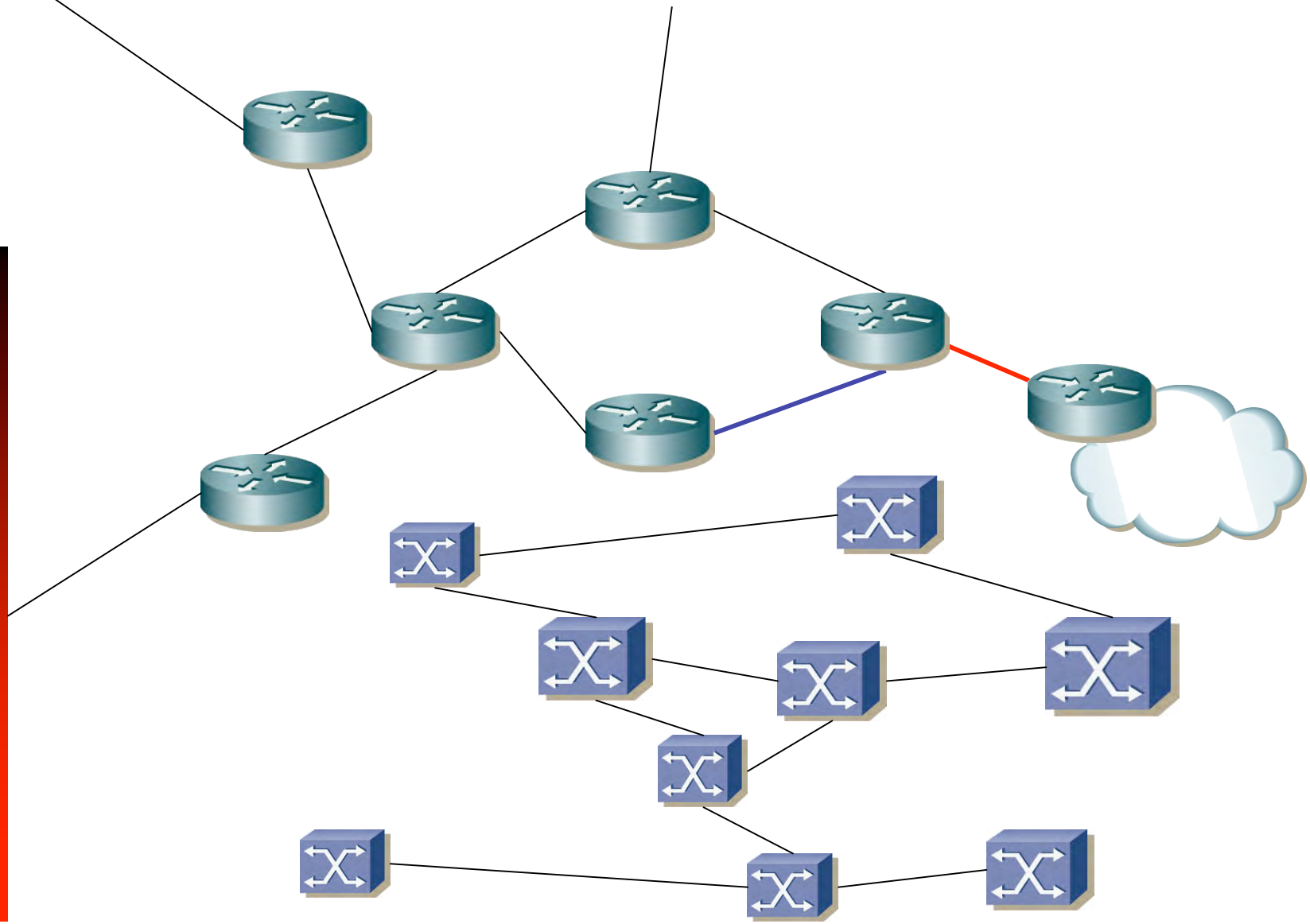

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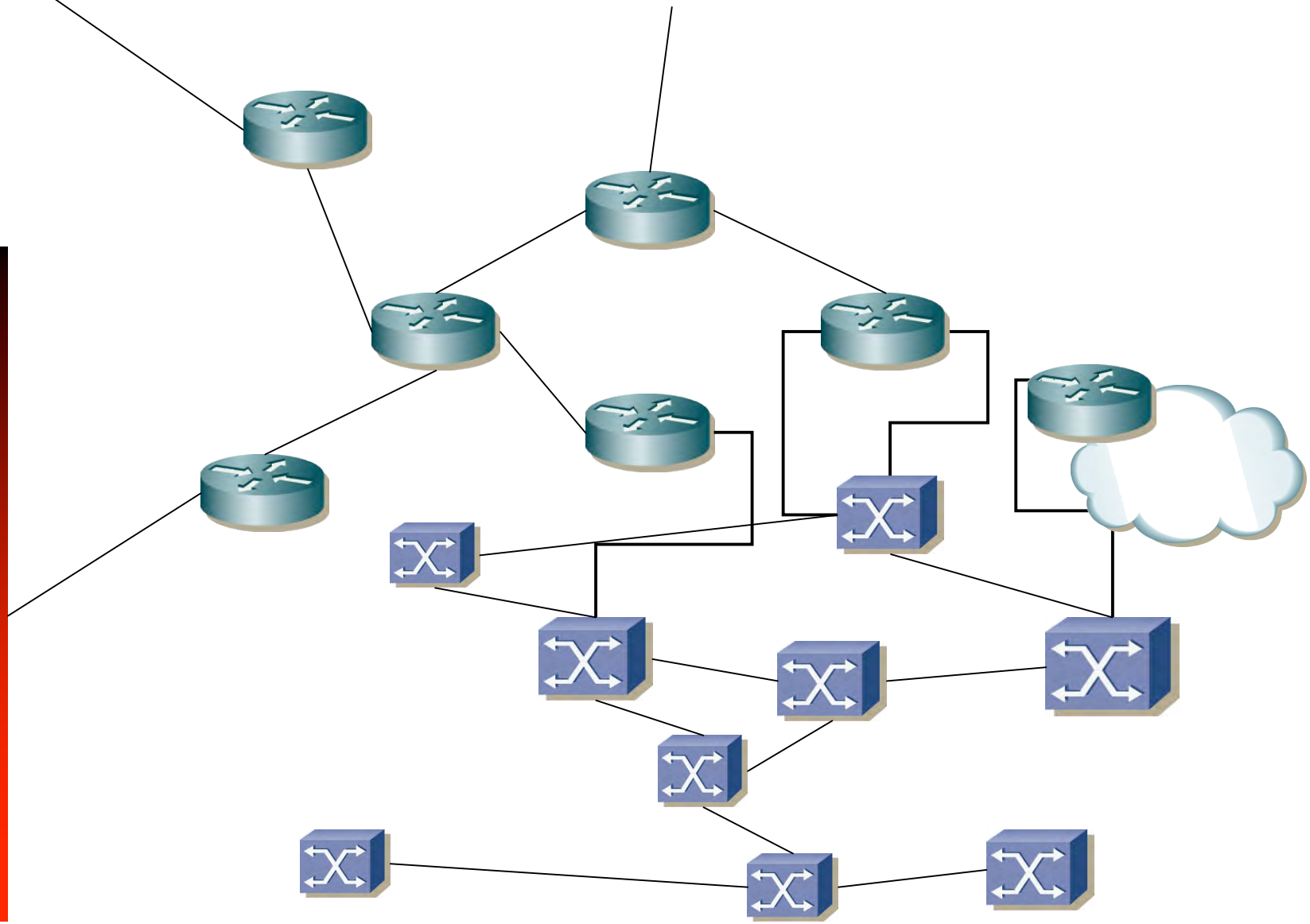

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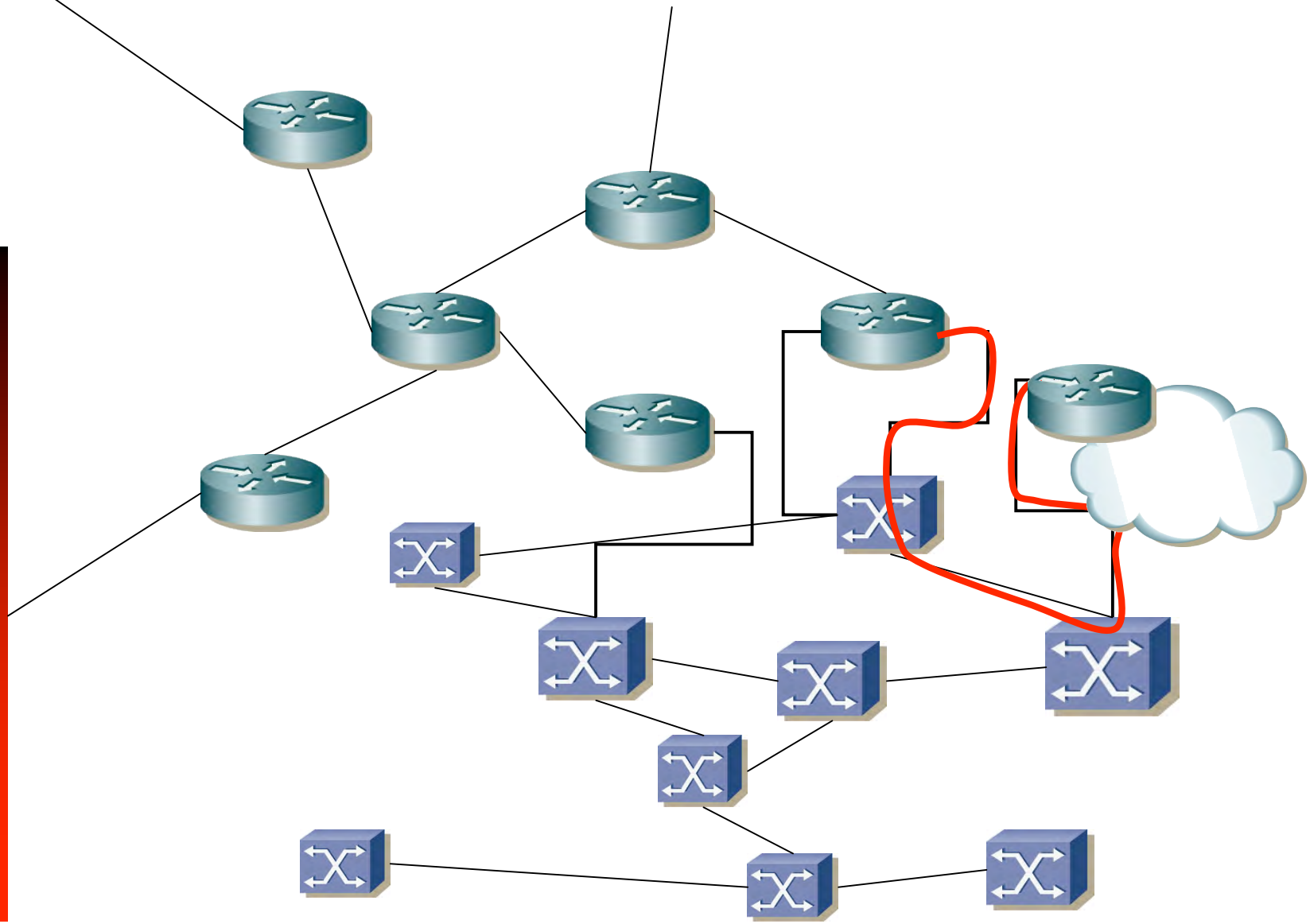

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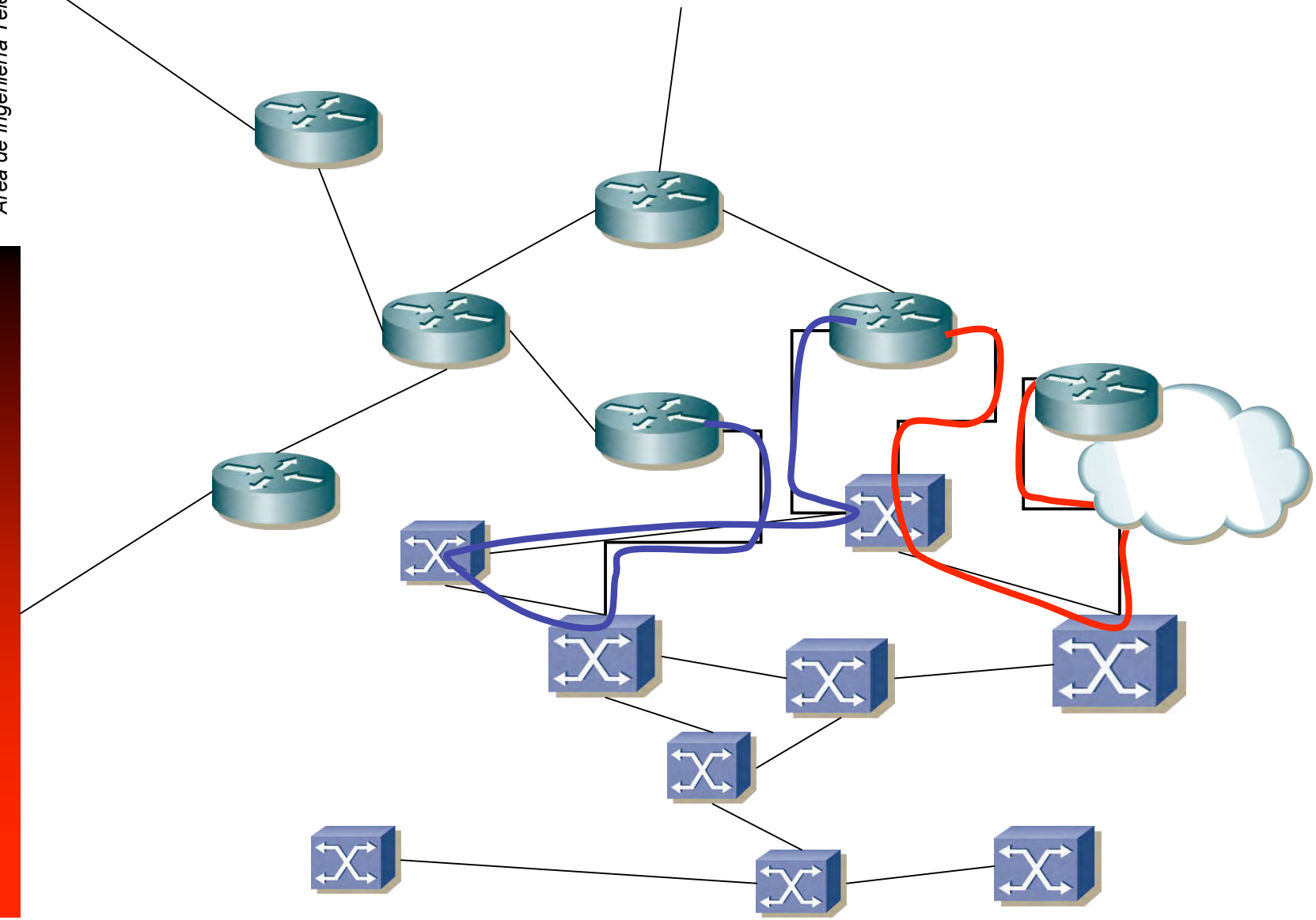

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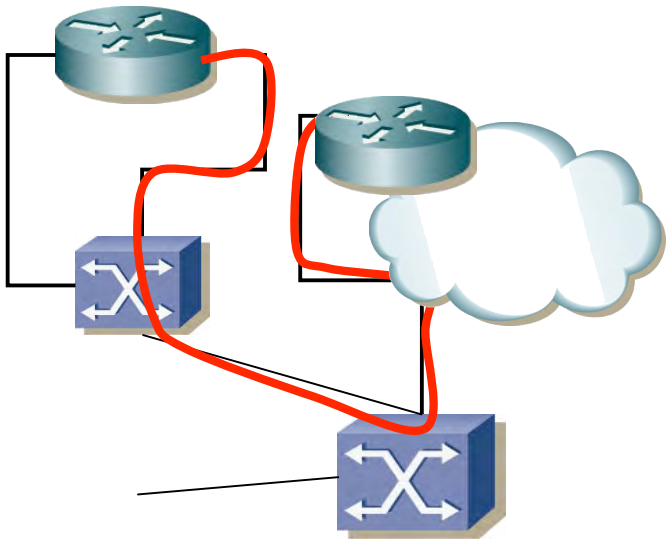

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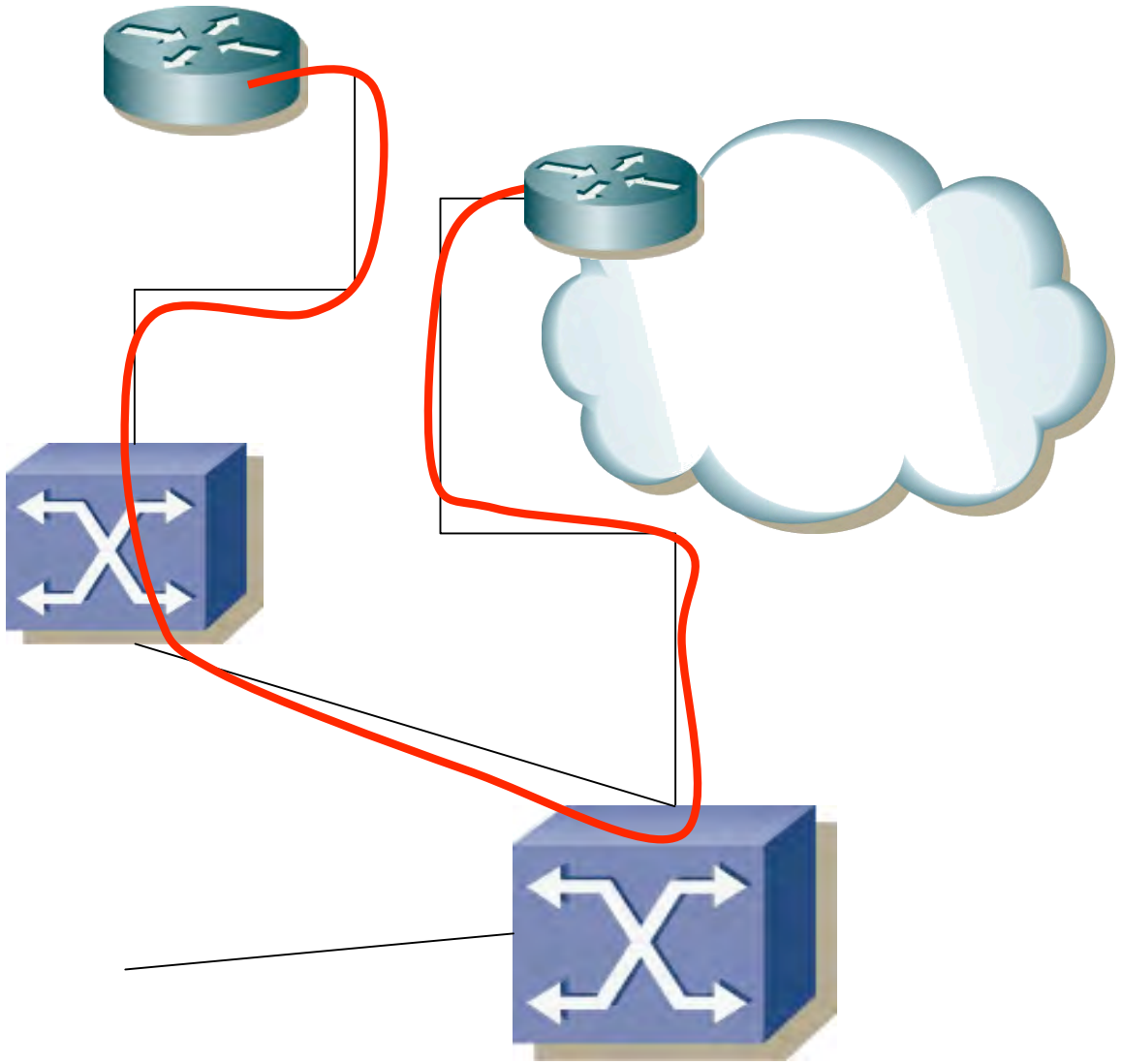

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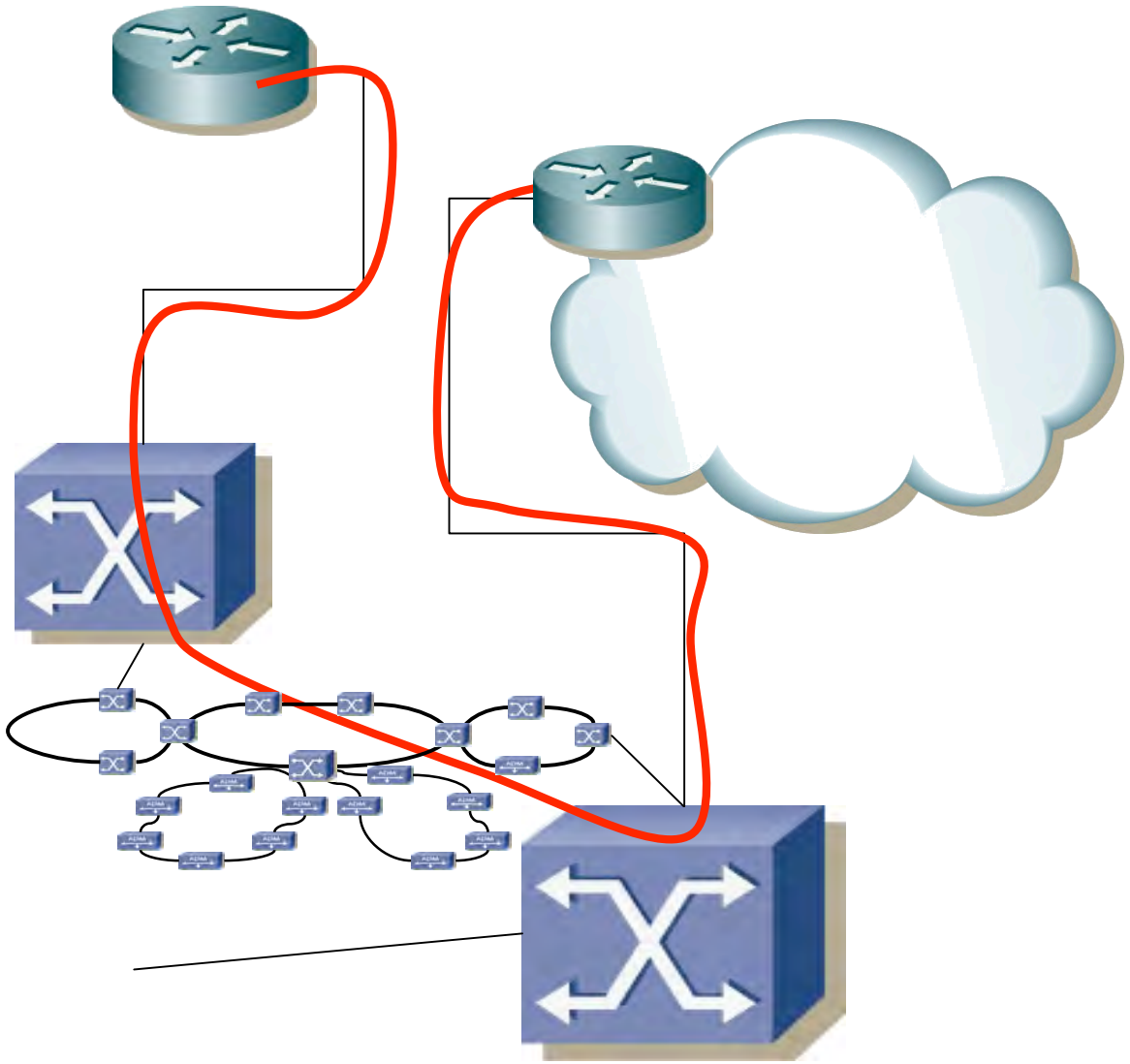

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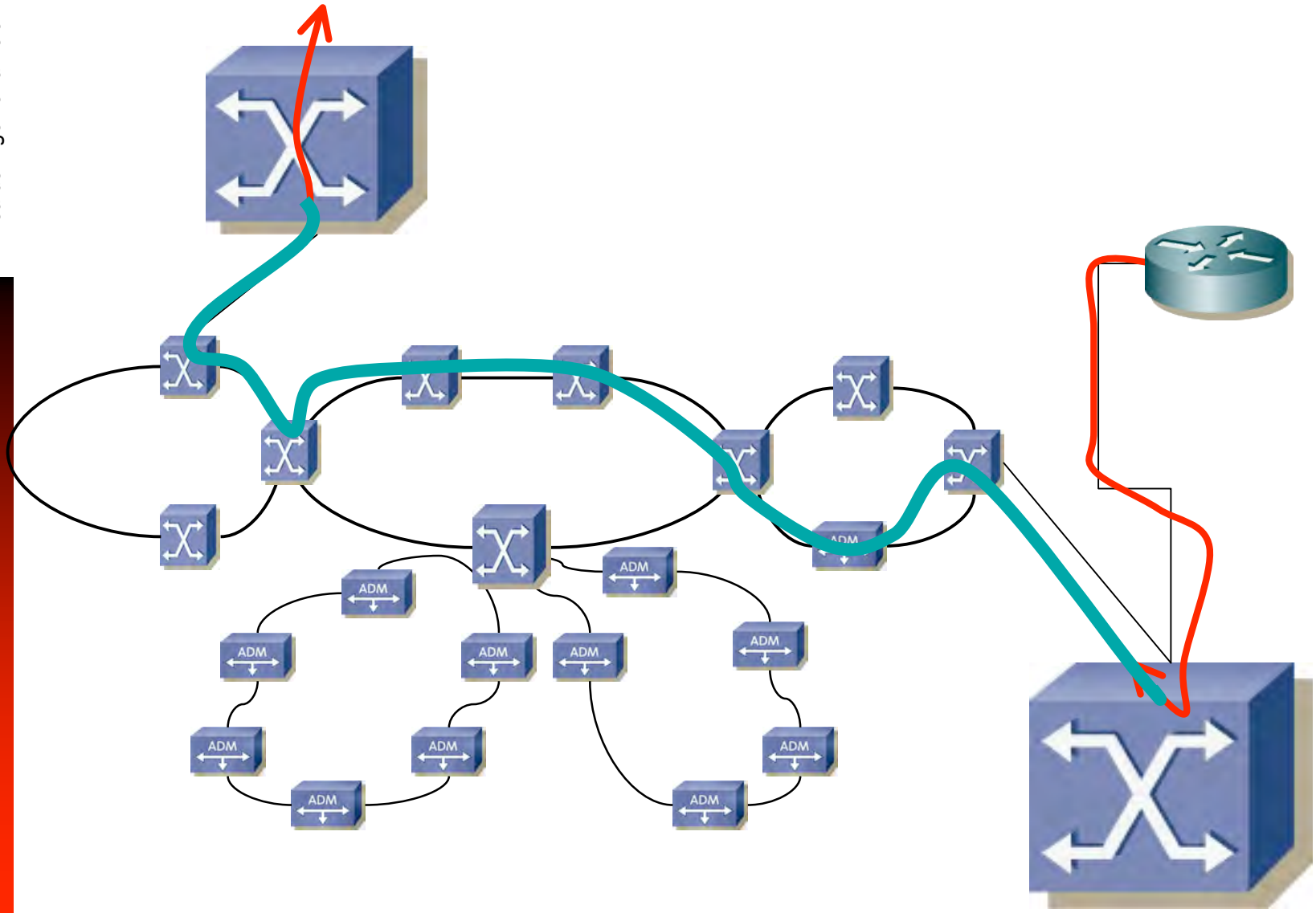

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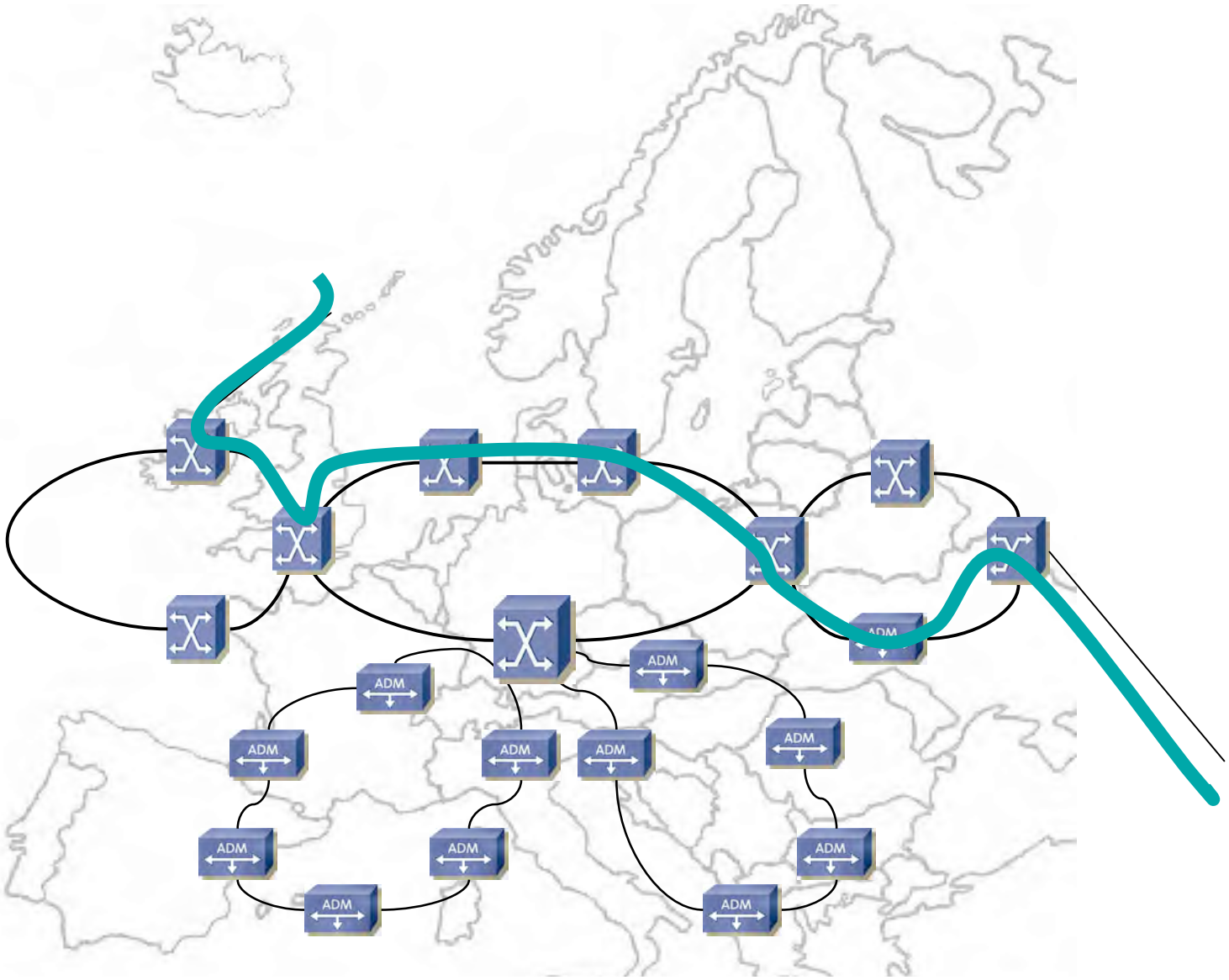

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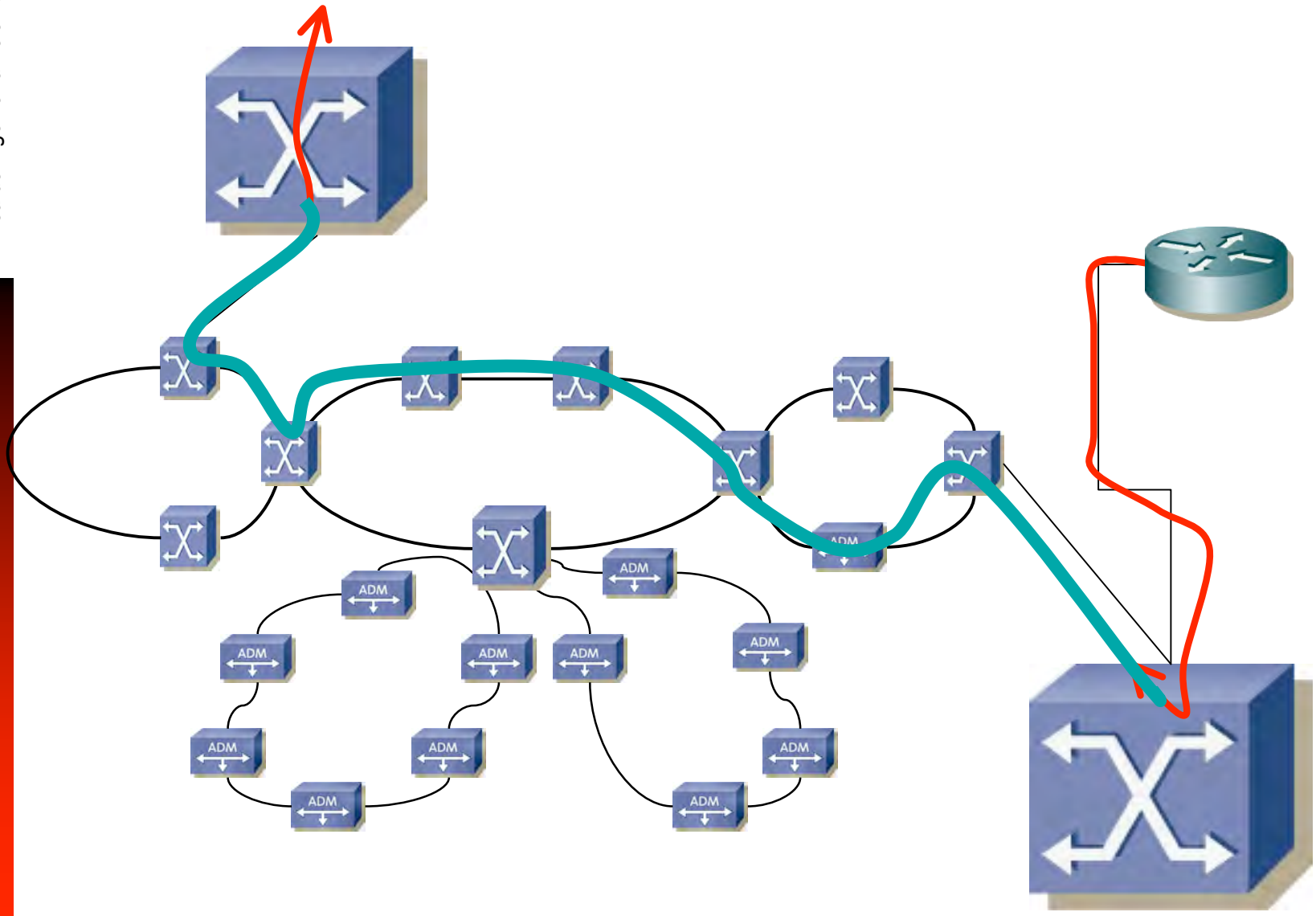

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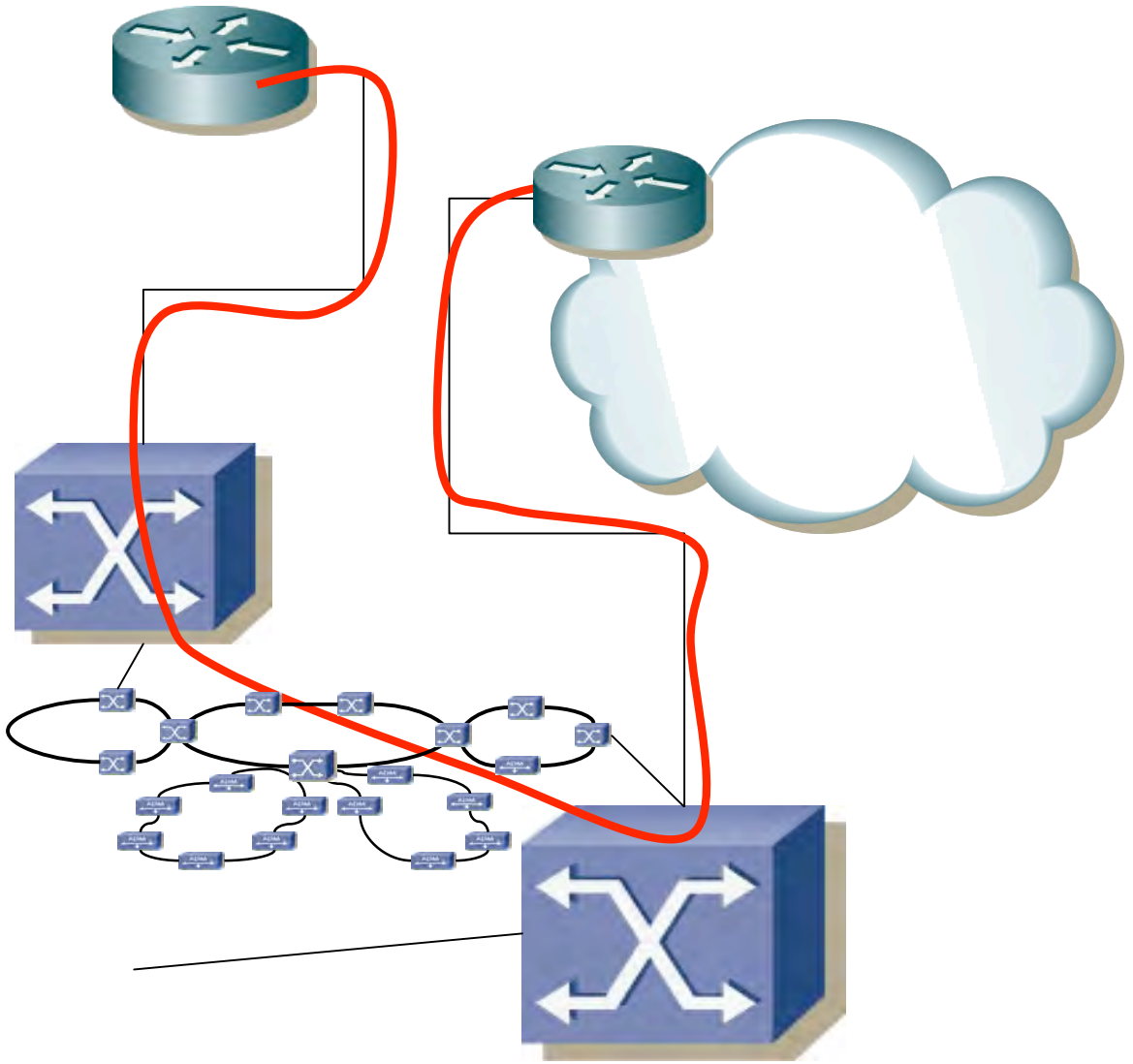

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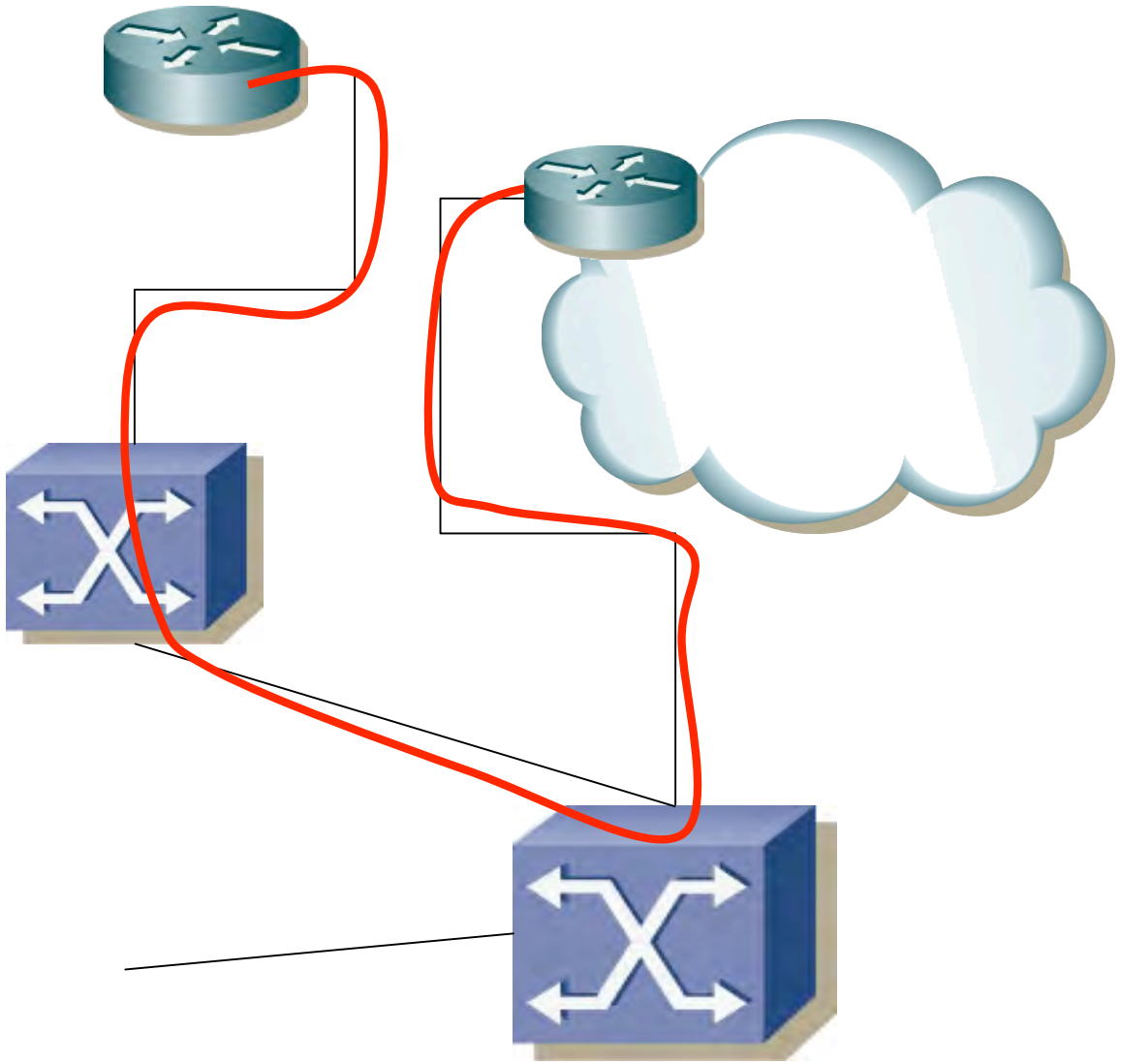

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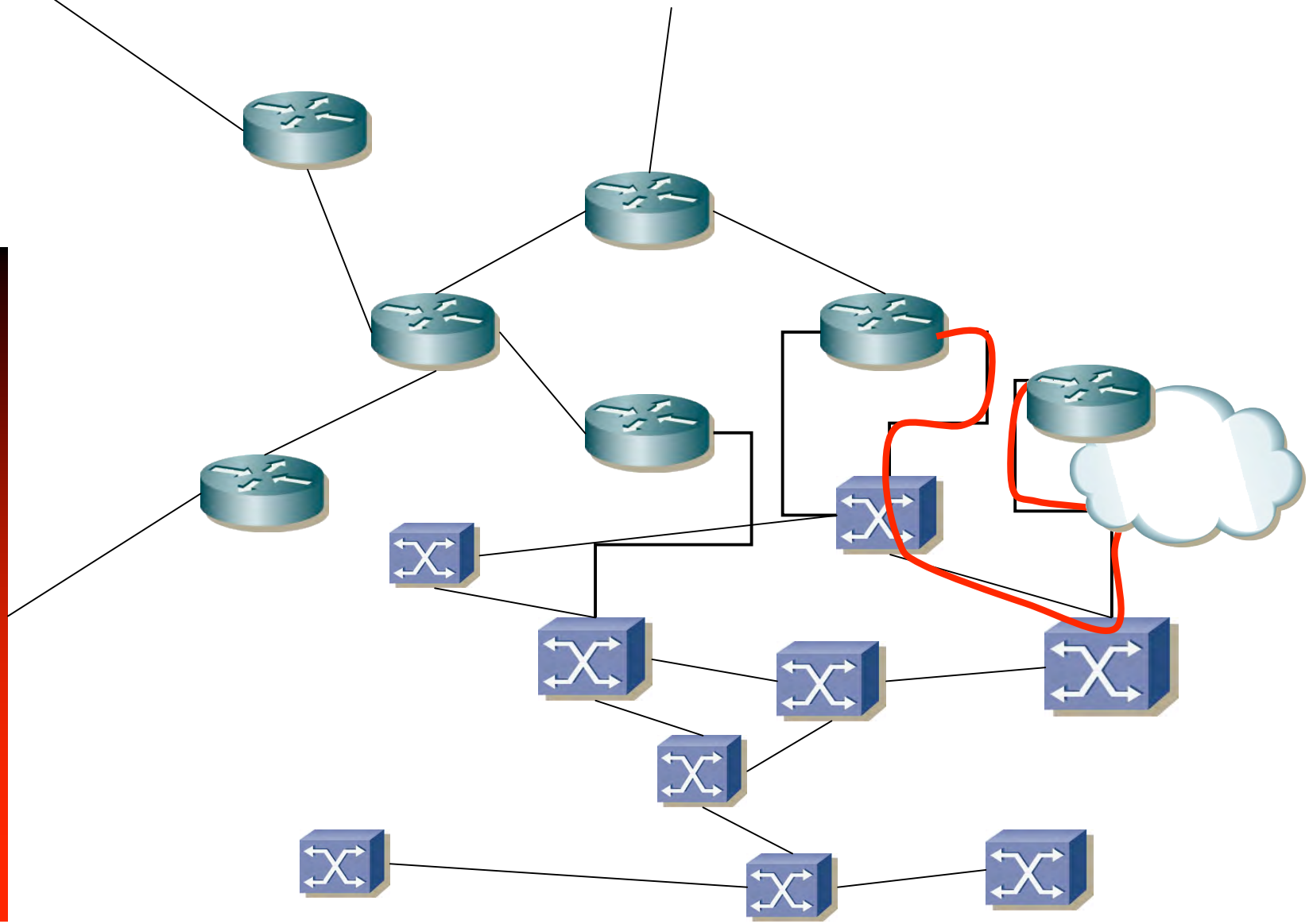

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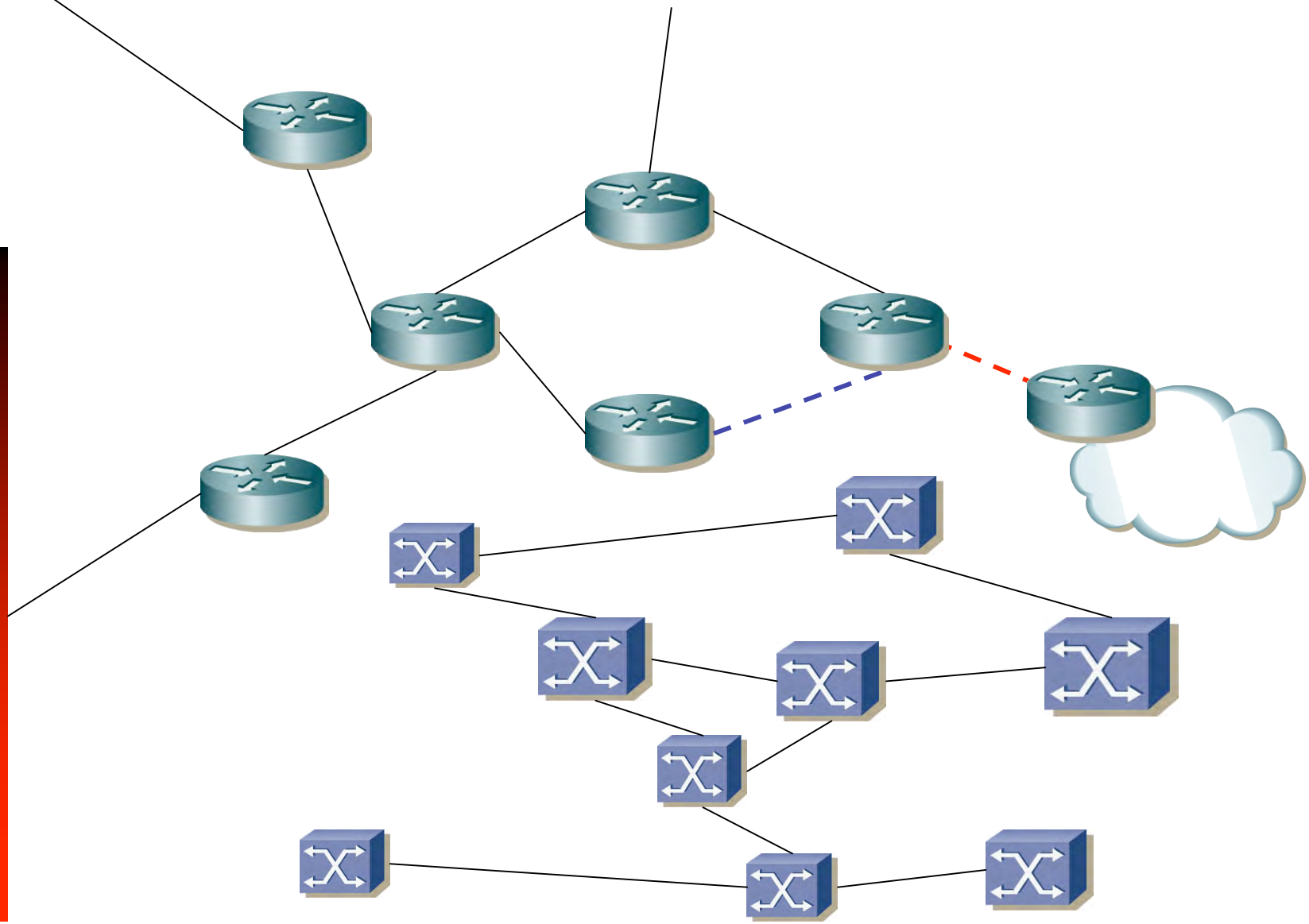
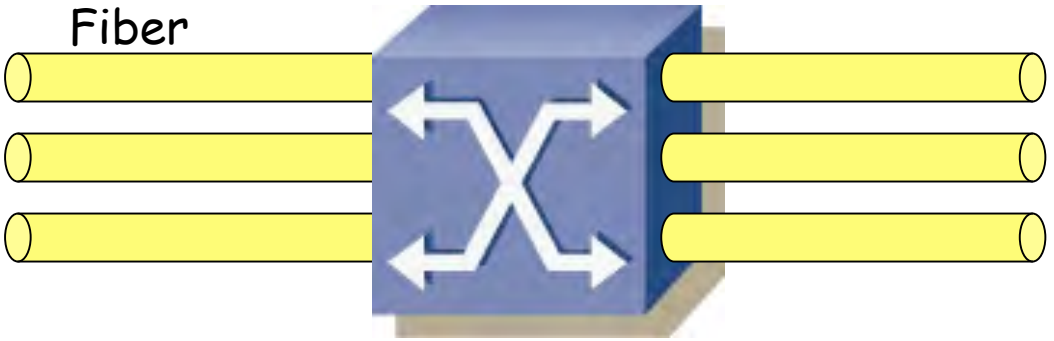


Electronic vs Optical Switching

- Today in MAN/WAN:
  - Optical data transmission (fiber optics)
  - Electronic switching/processing
- Electronic switching uses electronic switching fabrics
  - O/E/O
- Optical switching uses optical switching fabrics
  - Payload stays in the optical domain



Advances in WDM Networking

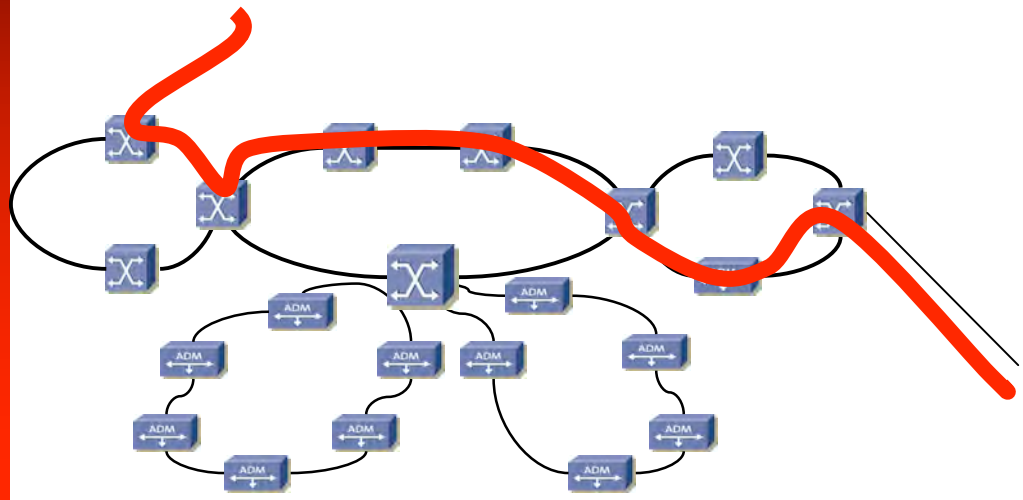
- Transmission (long haul)
  - 80 λs now, and additional 80 λs soon
  - OC-48 (2.5 Gbps) per λ and OC-192 (10 Gbps)
  - 40 Gbps per λ also on the way (>1 Tbps per fiber)
- Cross-connecting and Switching
  - Up to 1000 x 1000 optical cross-connects (MEMS)
  - 64 x 64 packet switches (switching time < 1 ns)

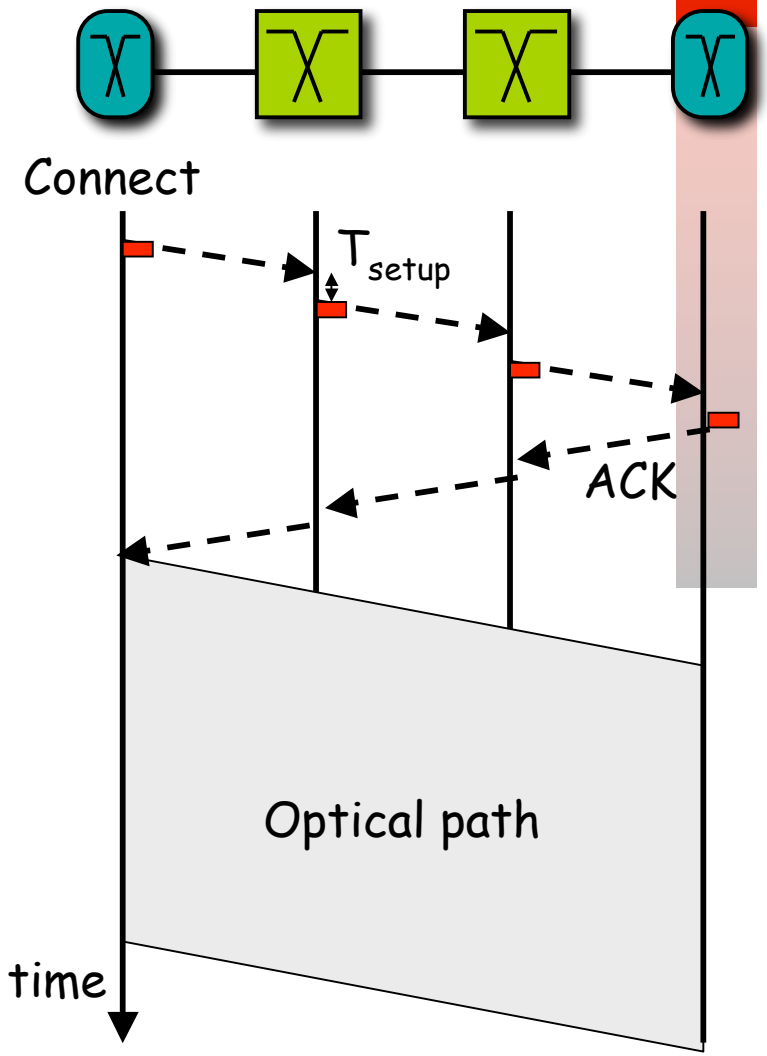
Caveats of OEO Switching

- Internet traffic doubles 6 months (1997-2008)
- Moore's Law: Semiconductor performance doubles every 18 months
- The first time in history that improvements have been required faster than the improvement rate for semiconductors, Moore's Law.
  - Complex operations are needed at a OEO router's line card for example processing the packet header, longest prefix match, packet buffering, etc.
- The cost of OEO at OC-48 (2.5Gbps) and at OC-192 is relatively high

Circuit Switching

- Two-way (request and acknowledge)
- RTT = tens of ms
- Long setup delays
- Suitable for smooth traffic and QoS guarantees due to fixed bandwidth allocation
- Inefficient for bursty (data) traffic
  - Wasted bandwidth during off/low-traffic periods
  - Overhead due to frequent set-up/release





Wavelength Routing

- Lightpath (or λ path) is like a circuit
- λ-path specific pros and cons:
  - Very coarse granularity (OC-48 and above)
  - Limited # of wavelengths (thus # of lightpaths)
  - No aggregation (merge of λs) inside the core
    - traffic grooming at the edge can be complex/inflexible
  - Mature OXC technology (msec switching time)
- Current state of the art

Packet Switching

- A packet contains a header (e.g., addresses) and the payload (variable or fixed length)
  - Can be sent without circuit set-up delay
  - Statistic sharing of link bandwidth among packets with different source/destination
- Store-and-forward at each node
  - Buffers a packet, processes its header, and sends it to the next hop
- One-way process

Optical Packet Switching

- Optical packet consists of a header and a payload
- Packet header is processed all-optically at each node and switched to the next hop

\+ Statistical multiplexing of data

\+ Suitable for bursty traffic

\- Requires fast switching speeds (nanoseconds)

\- Stringent synchronization requirements

\- Lack of optical memory

\- More viewed as a longer term solution

OBS Approach

- Main design objectives
  - Decreasing complexity of OPS
  - Statistical multiplexing in optical domain
  - Buffer-less network
  - User data travels transparently as an optical signal and cuts through the switches at very high rates
- Solution
  - Sending a header to temporarily reserve a wavelength path
  - After that, sending an optical burst (a block of IP packets) through the network
- Thanks to the great variability in the duration of bursts, the OBS can be viewed as lying between OPS (one-way reservation) and WS networks (two-way reservation)

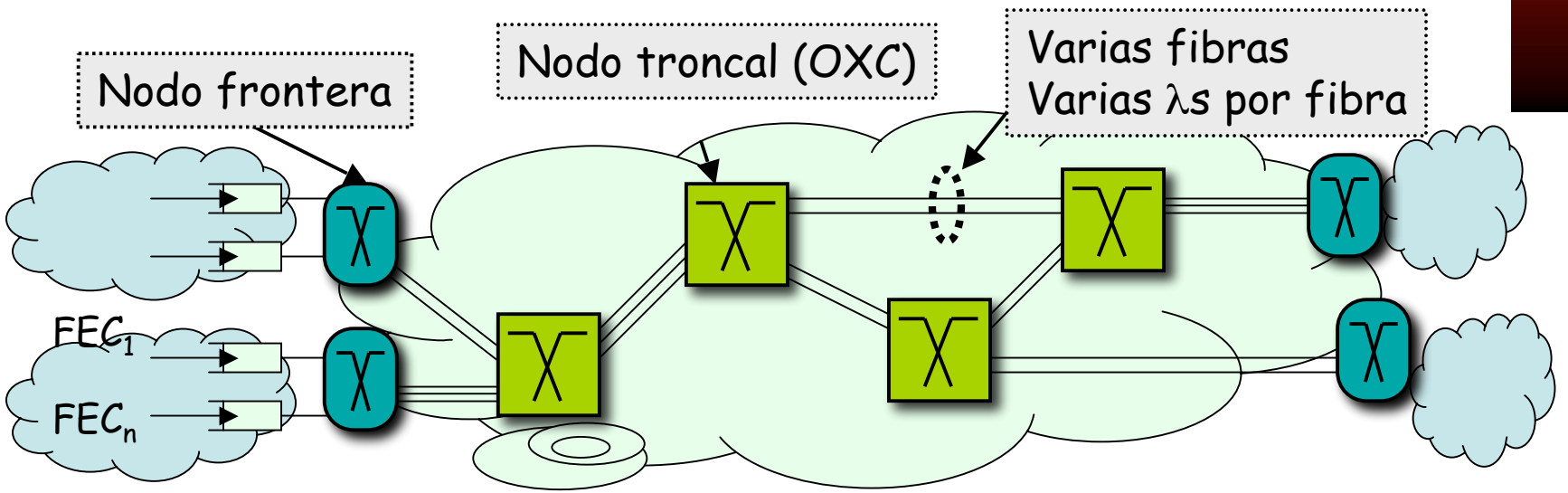
OBS: Tipos de nodos

Frontera (edge)

- Agrupan paquetes en ráfagas
- Envían las ráfagas a la red
- Desensamblan ráfagas

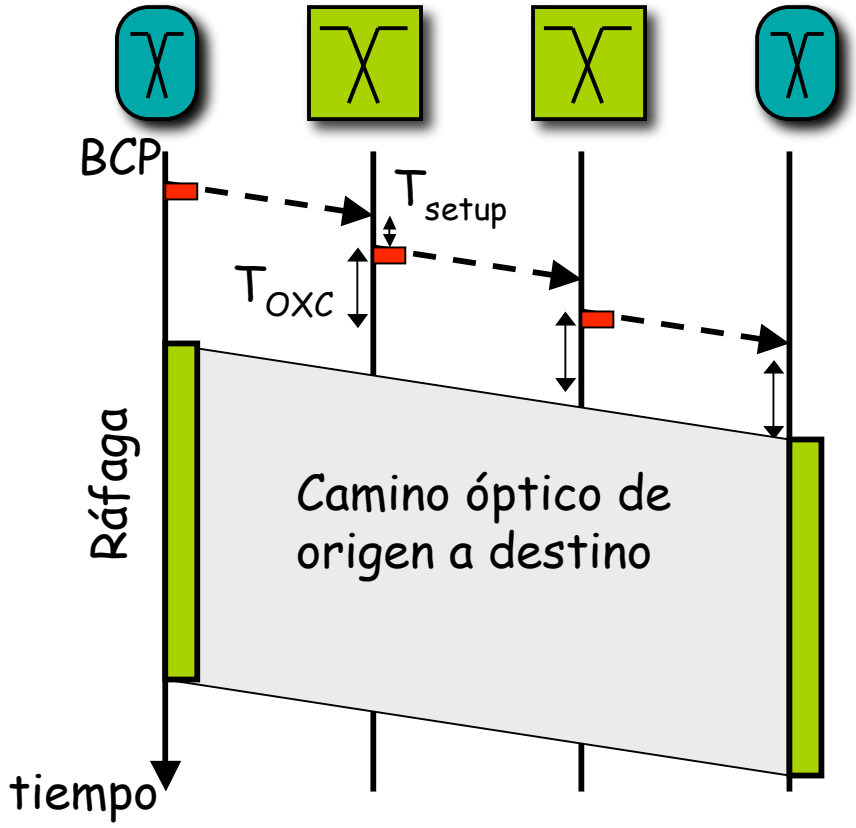
Troncal (core)

- Procesan la señalización
- Conmutan las ráfagas en el dominio óptico
- Resuelven la contienda



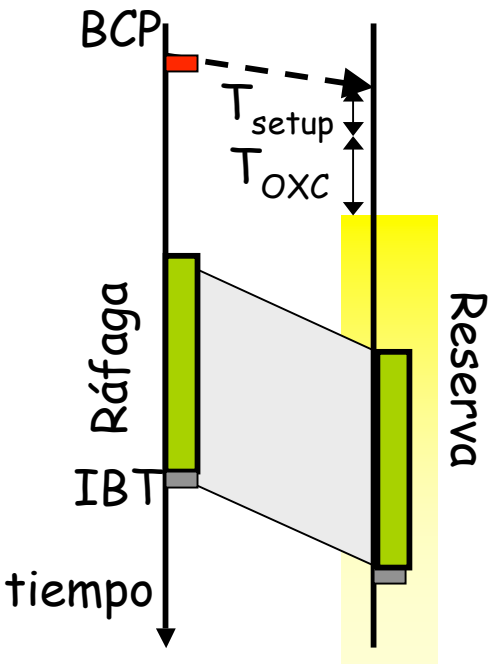
OBS: Señalización

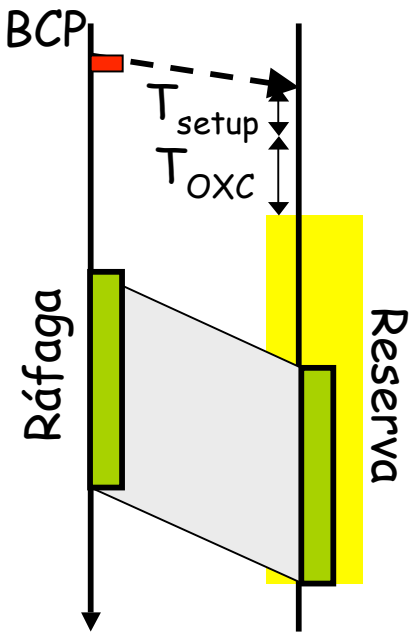
- Se envía con anterioridad a la ráfaga
- Por un canal diferente
- Se procesa electrónicamente
- Separación temporal suficiente para crear un camino conmutado
- Sin confirmación (TAG):
  - Ráfaga de 100KB a 10Gbps: 80 μs de transmisión
  - 200Km: 1ms de propagación
- Tell-and-Wait (TAW)

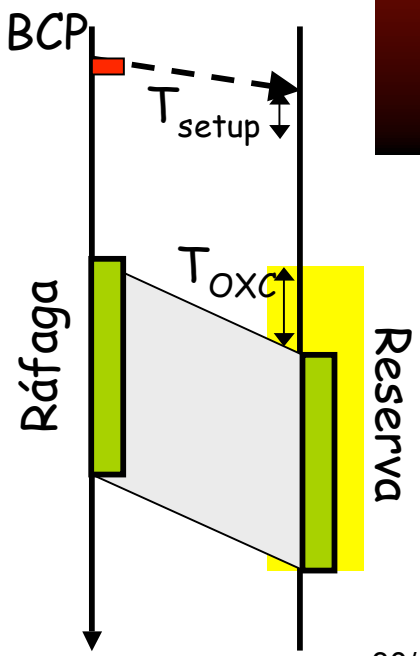


OBS: Señalización y reserva

- Immediate Reservation: Reserva desde la llegada del BCP hasta final de ráfaga (IBT = In Band Terminator)
  - JIT (Just In Time)
- RLD (Reserve a Limited Duration): BCP incluye instante final de la reserva
- RFD (Reserve a Fixed Duration): BCP incluye inicio y final de la ráfaga
  - JET (Just Enough Time)

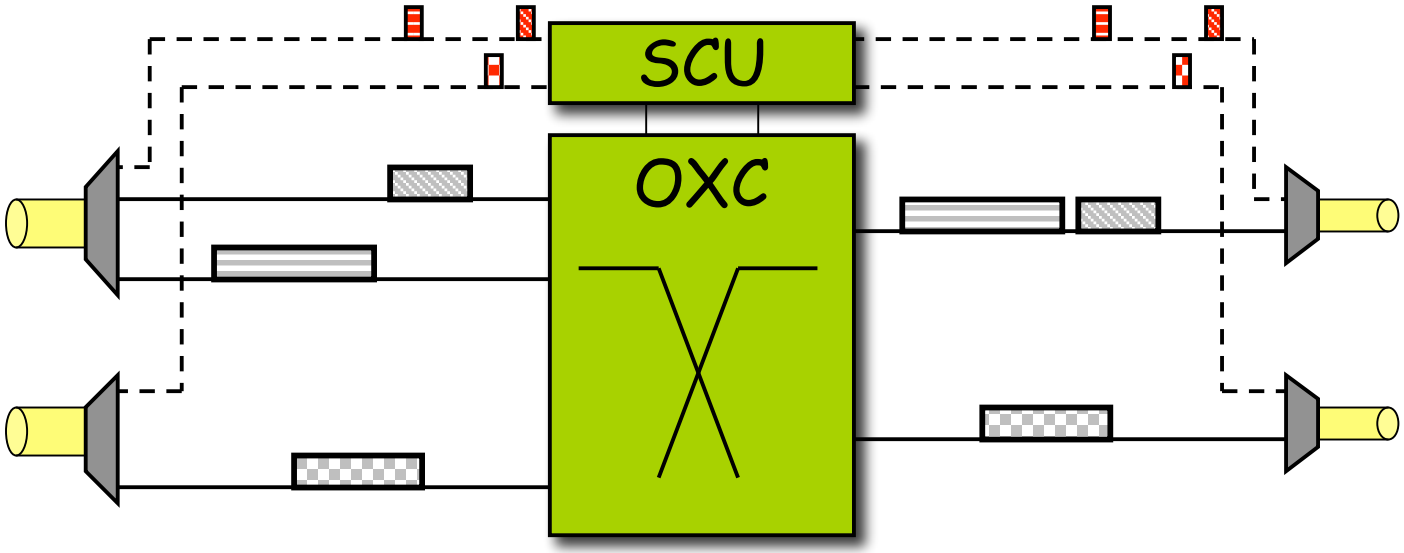




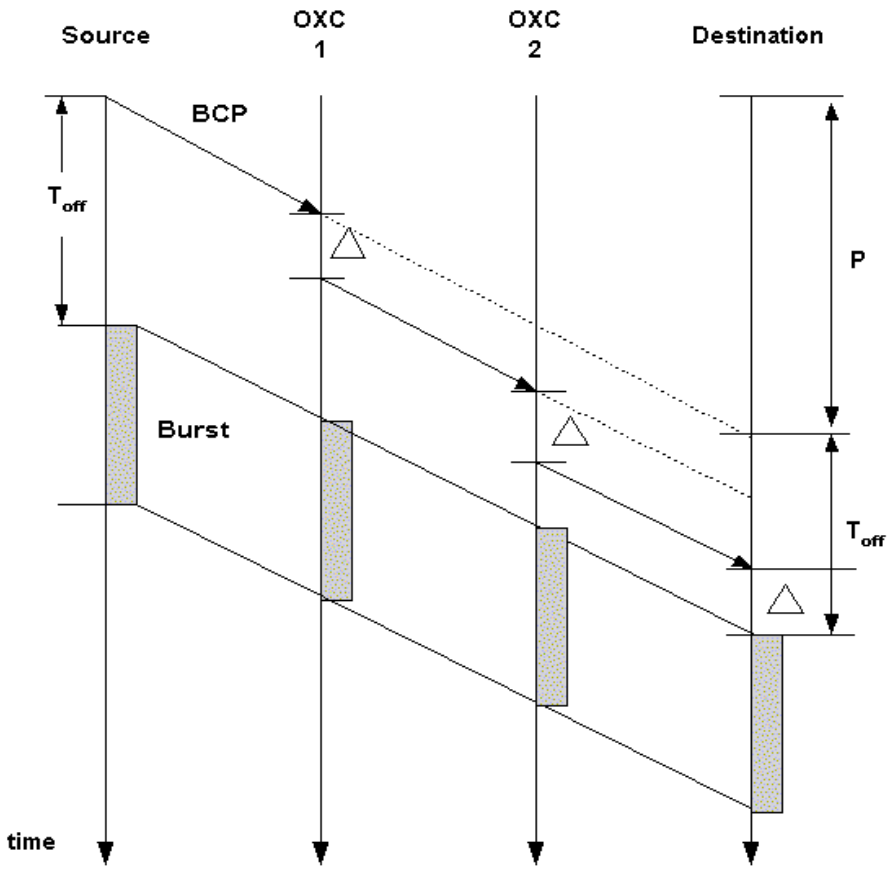


OBS: Conmutador

- Switch Control Unit
- Optical Cross Connect
- Canales de control
- Canales de datos



JET (Cont'd) – The case of 3 hops



△ : Processing time at each node

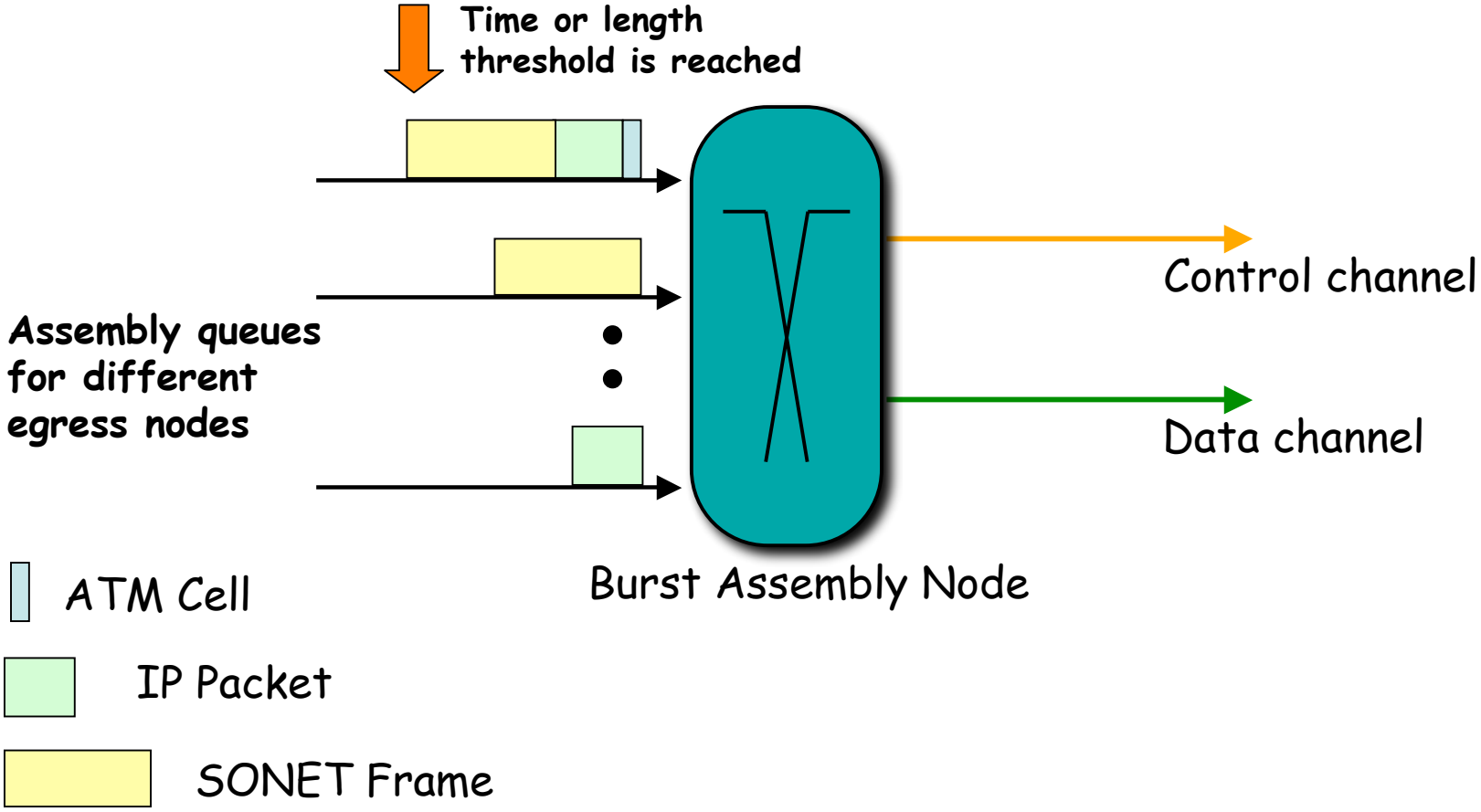
T_{off} : Offset time

P : Propagation time

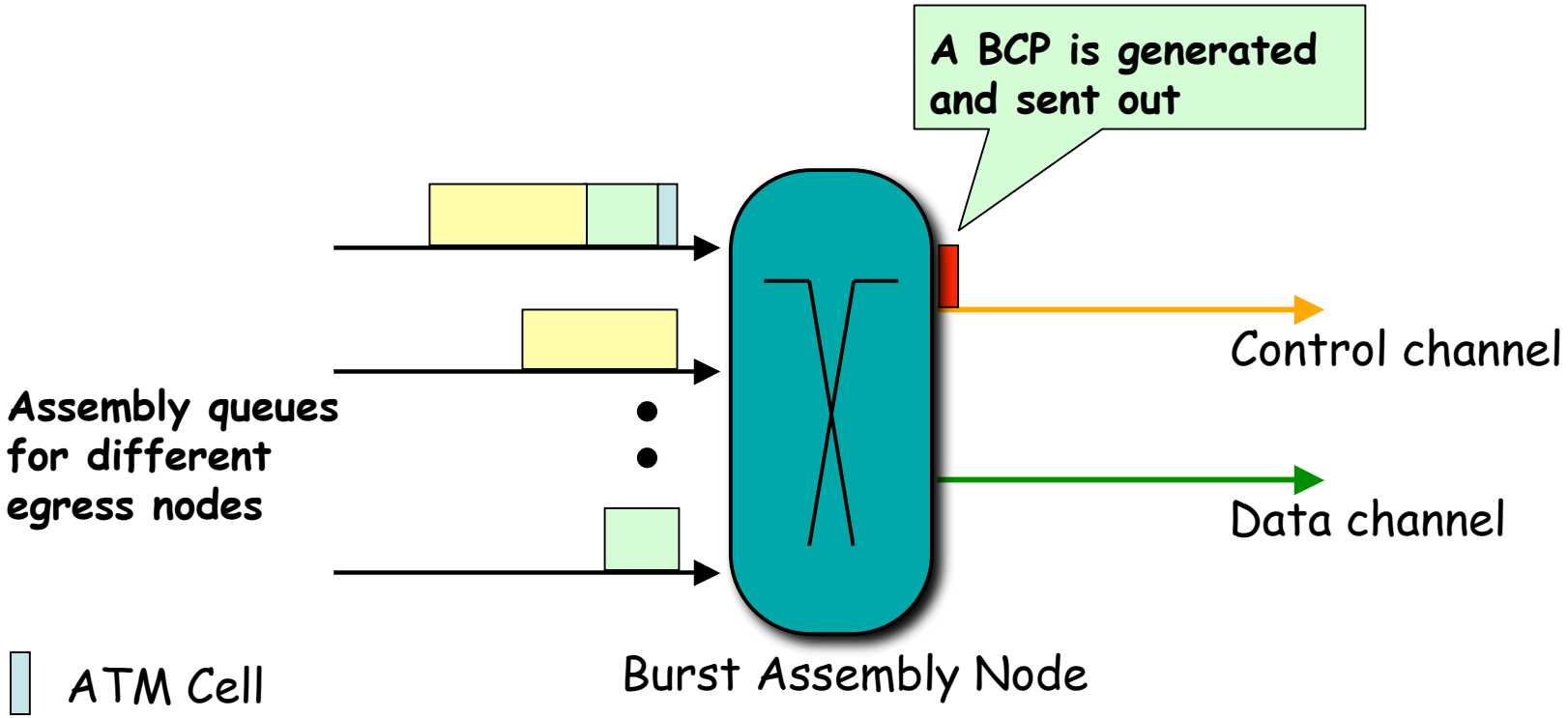
$T_{off} \geq H^* \Delta, H = 3$

- $T_{off} \geq H \Delta, H = 3$
- T_{off} should be updated at each OXC i.e., $T'_{off} = T_{off} - \Delta$

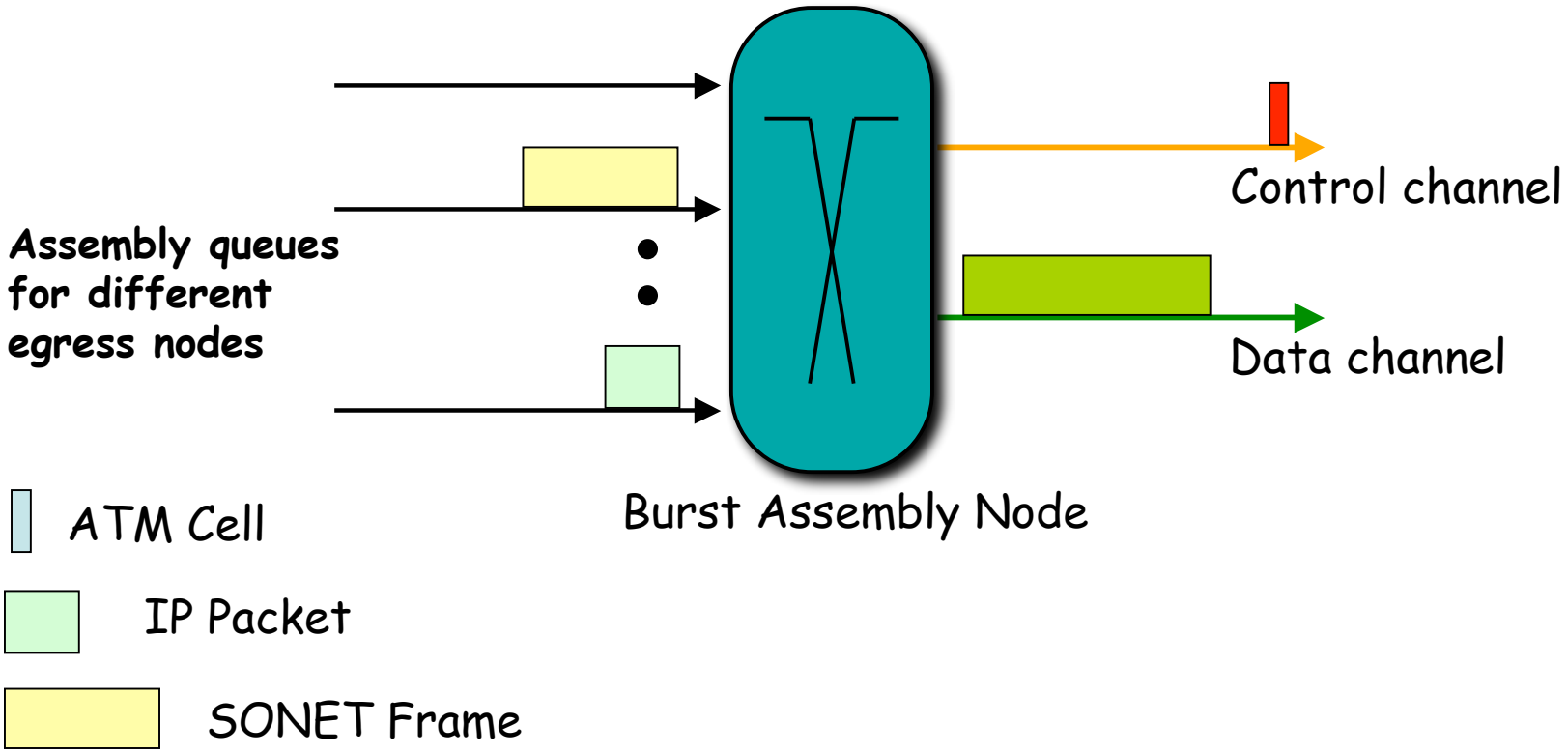
Burst Assembly



Burst Assembly



Burst Assembly



Edge Node

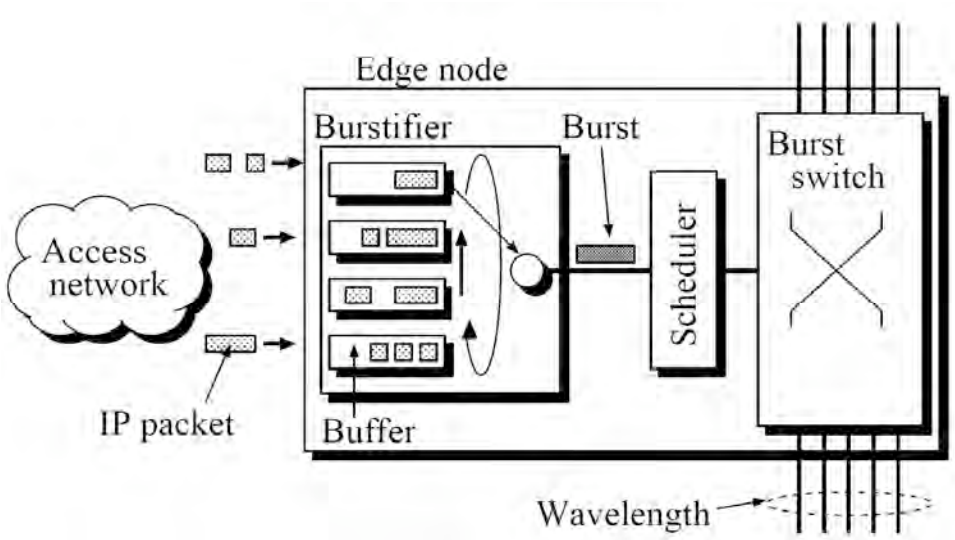
- Consists of electronic router and OBS interface
- Functions
  - Electronic data buffering and processing
  - Burst Aggregation (BA) responsible for collecting data from legacy networks and building the burst unit
    - impact on the overall network operation by the control of the burst characteristics
    - in order to reduce the burst loss probabilities in the network the aggregation function can segment data bursts for the purpose of their partially dropping in core nodes when contention occurs

Edge Node

- Setting up the pre-transmission offset time
  - in simple fixed offset scheme, the offset time is calculated as a sum of the total processing times at all the intermediate hops
  - offset time is one of the crucial OBS network parameters since its incorrect estimation has impact on data lost
- Sending the control packet
- Sending the burst

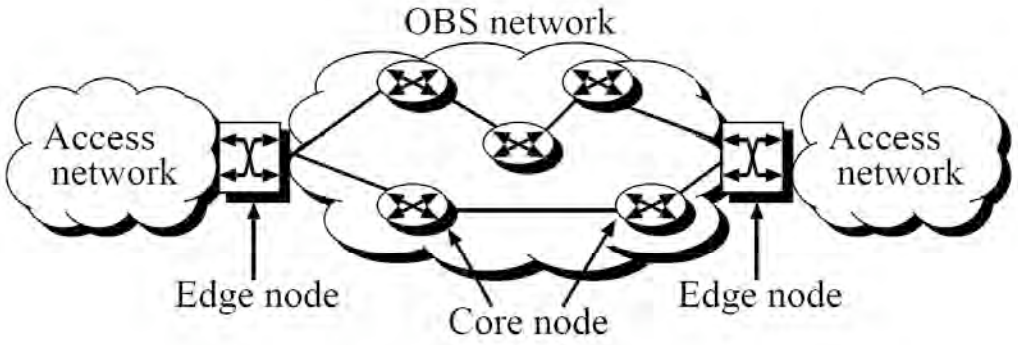
Edge Burst Switch Architectures

Architecture of a typical OBS ingress node

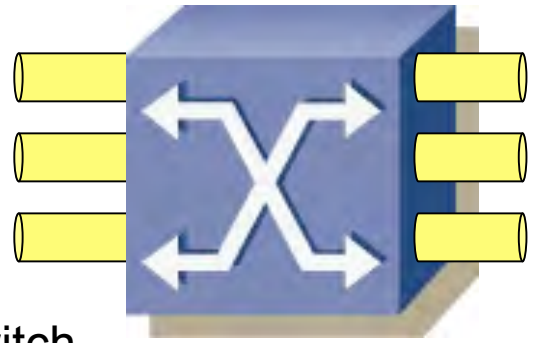


Assembly Methods:

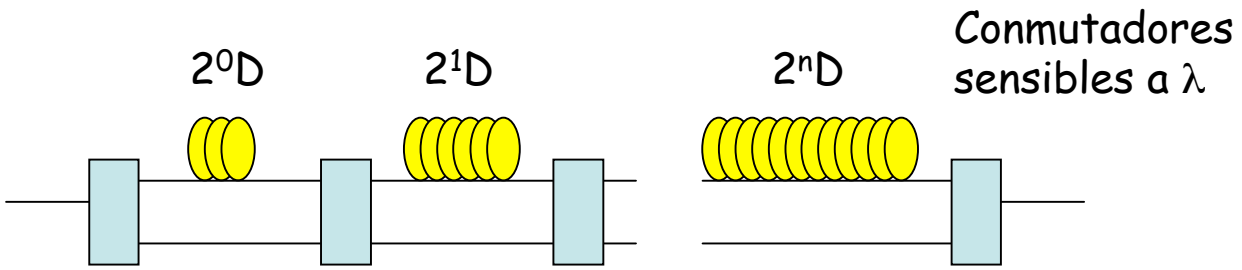
- Timer-based
- Burst-length-based
- Mixed timer / burst-length-based
- Adaptive
- Predictive
- Bursts may also need to be larger than a minimum threshold so padding required



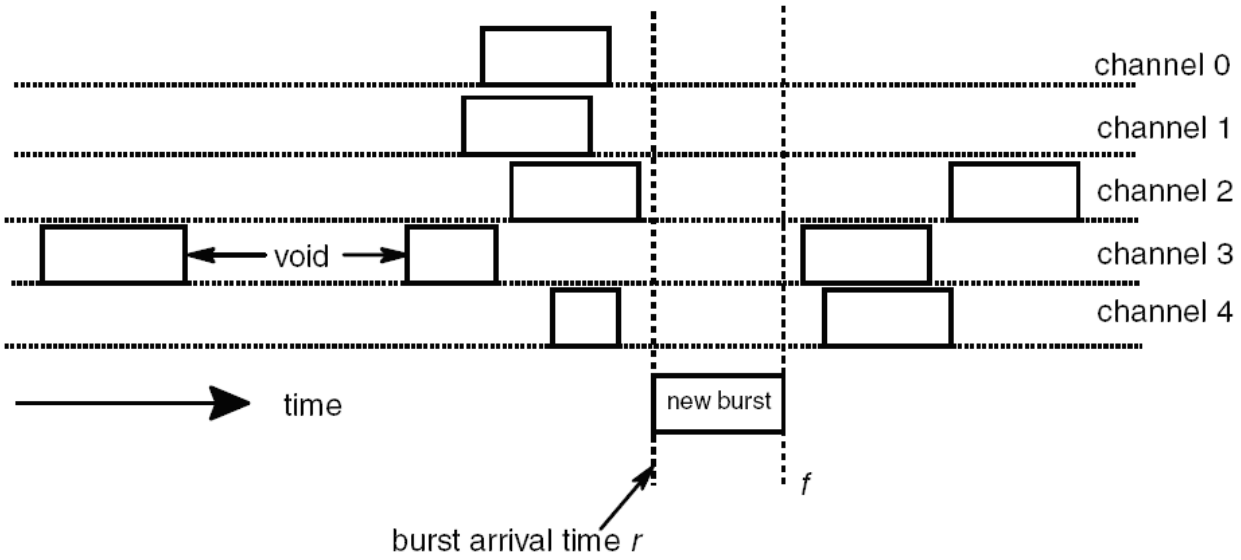
Core Node



- Hardware requirements
  - O/E/O conversion for header processing
  - λ-conversion
  - Switching speeds fast enough
  - *M* ports, *c* wavelengths per port; *Mc x Mc* switch
  - Eventually optical “buffering” (FDLs)
    - Por construcción las FDLs normalmente presentan un retardo múltiplo de un valor básico “D”
- Operation
  - Processing of incoming control packets (electronically) and sending it to the next node that lays on the routing path
  - Contention resolution (by a proper scheduling algorithm)



Scheduling


channel 0
channel 1
channel 2
channel 3
channel 4
void
time
new burst
f
burst arrival time r

Lecturas

- T. Battestilli and H. Perros. An introduction to optical burst switching. IEEE Communications Magazine, 41(8):S10–S15, August 2003.
- C. Qiao and M. Yoo. Optical burst switching (obs) - a new paradigm for an optical internet. Journal of High-Speed Networks, 8(1), 1999.
- Y. Chen, C. Qiao, and X. Yu. Optical burst switching: A new area in optical networking research. IEEE Network, 18(3):16–23, May/June 2004.
- S. Verma, H. Chaska, and R. Ravikanth. Optical burst switching: a viable solution for terabit ip backbone. IEEE Network, 14(6):48–53, Nov./Dec. 2000.