Resource Management in Optical Burst Switched Networks: Performance Evaluation of a European Network

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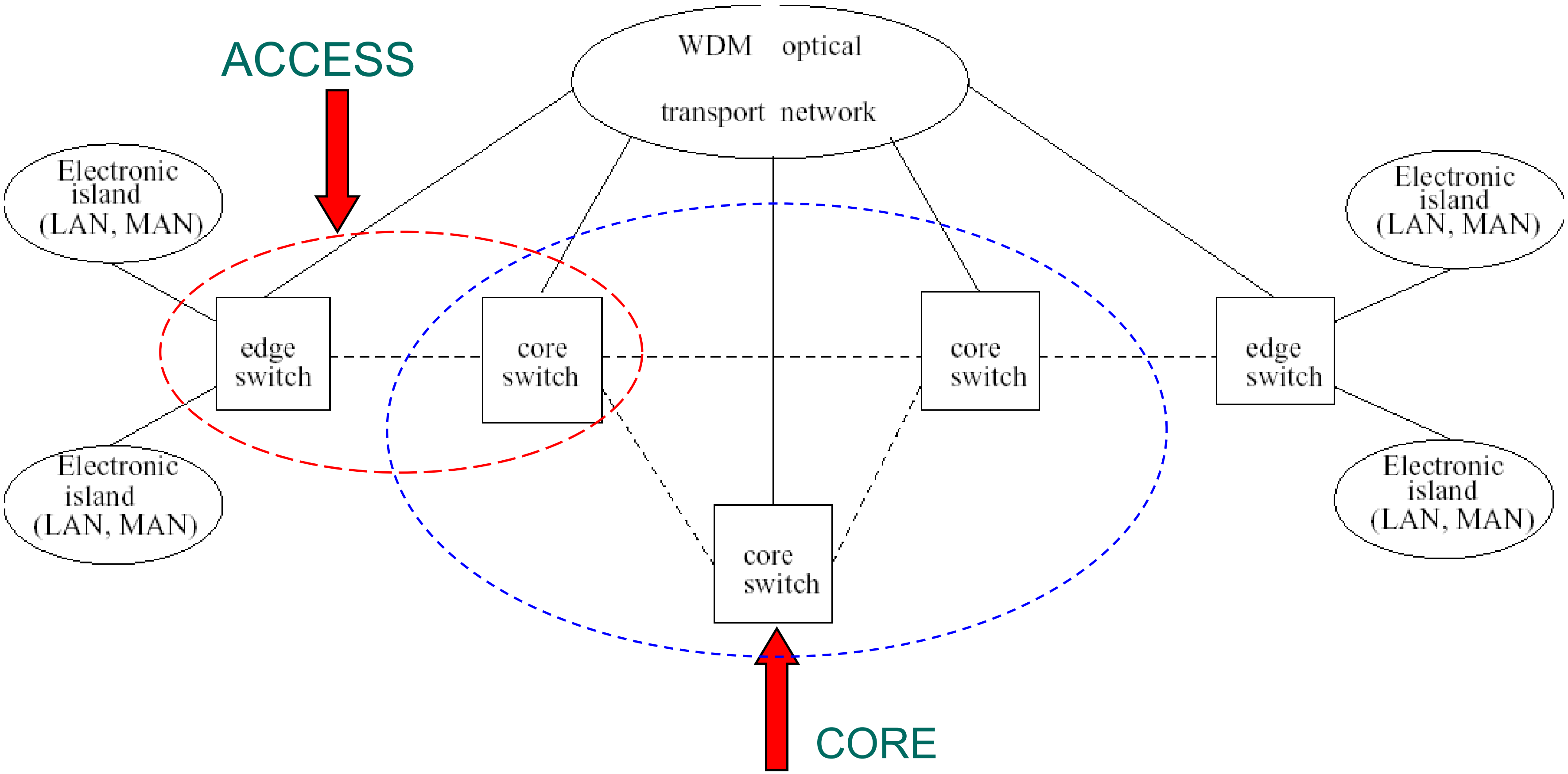
OUTLINE

- **Introduction: Target and Scenario**
- **Focus: the OBS-JET Solution**
- **QoS Management**
  - ✓ **Burst Assembly Algorithm**
  - ✓ **Wavelength converters**
  - ✓ **Deflection Routing**
- **Case Study: a Pan-European Network**
- **Conclusions**

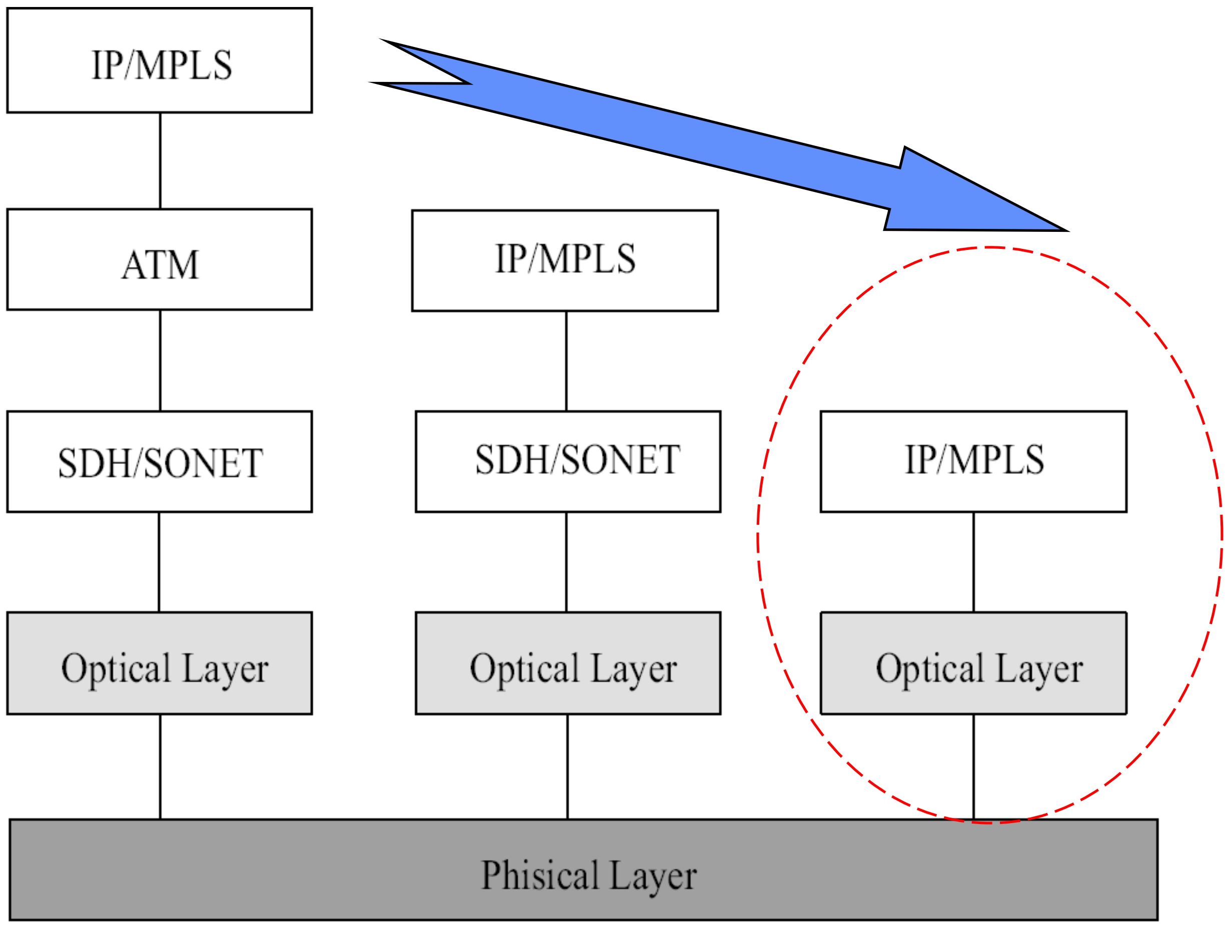
TARGET

- Investigate a feasible short/mid term solution for Optical Transparent Network
- Exploit efficiently DWDM transmission systems
- Suitable for IP-based internetworking
- Support for QoS differentiation (delay vs. loss)
- Investigate suitable signaling and routing protocols (i.e. GMPLS, Constraint Based Routing)
- Develop analysis and simulation tools

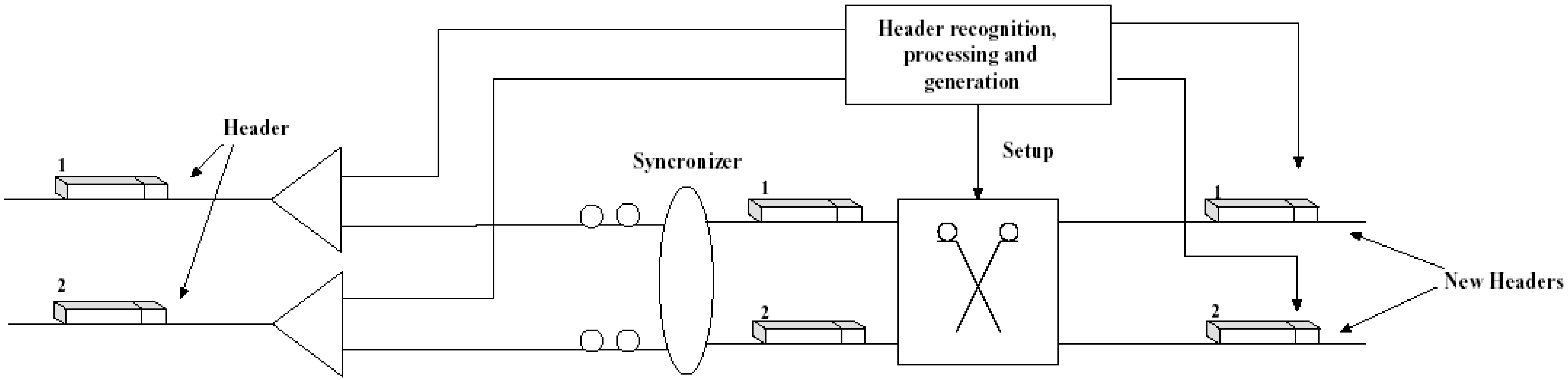
INVESTIGATED SCENARIO



PROTOCOL STACK: EVOLUTION



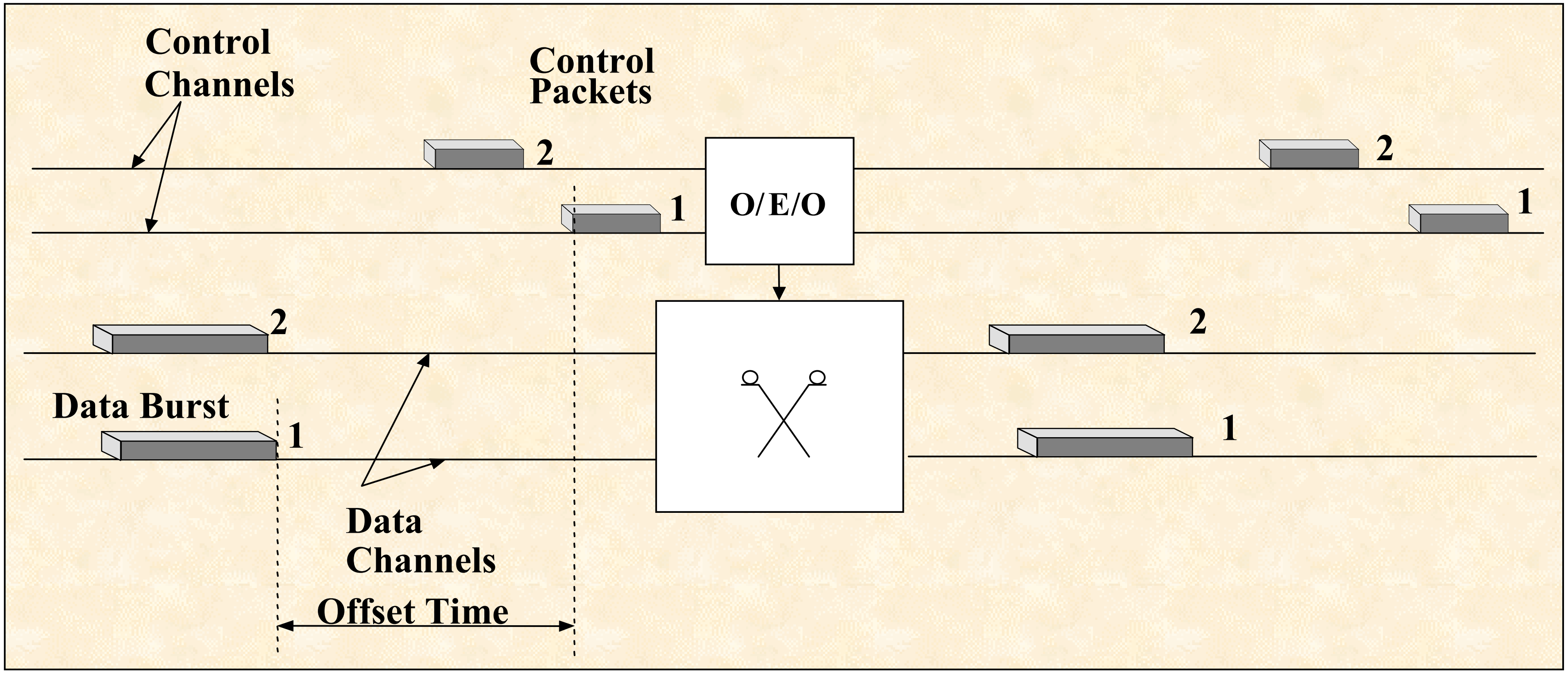
OPTICAL PACKET SWITCHING



- flexible
- efficient
- dynamic resource allocation

- still many technological challanges → Long term solution

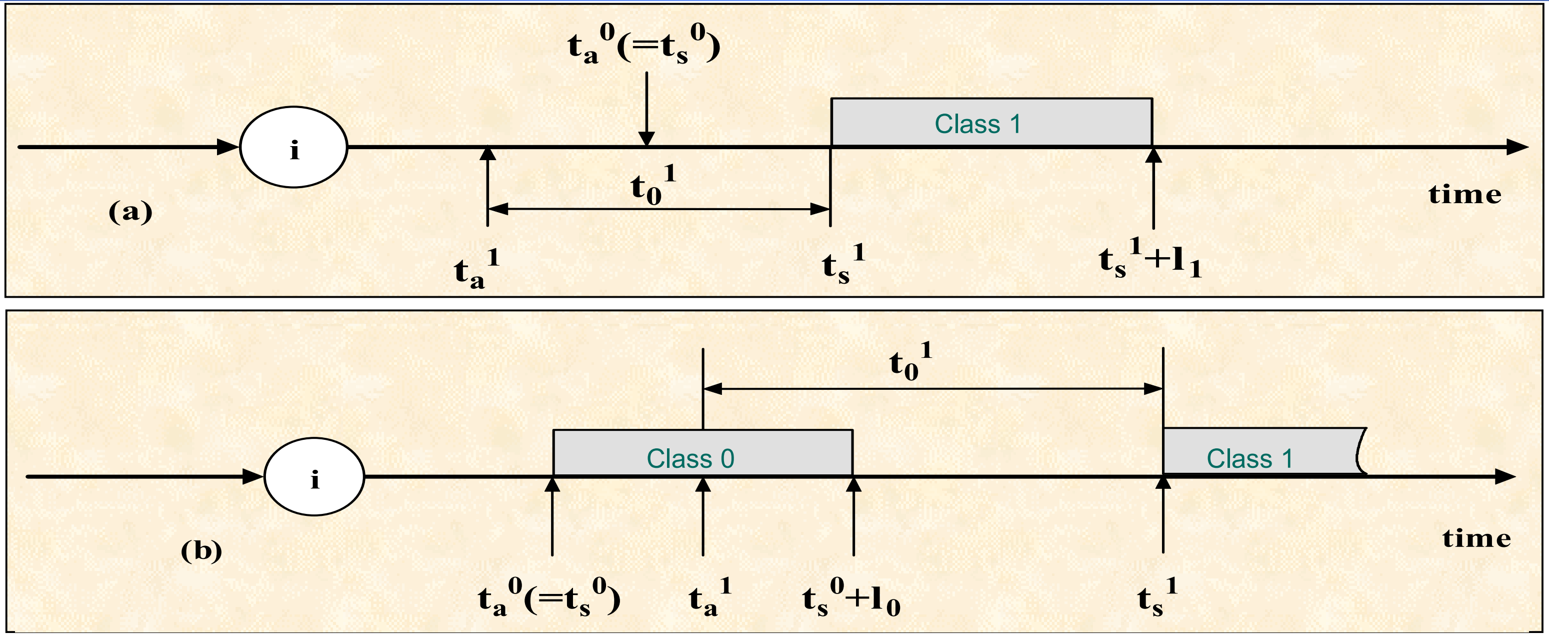
OPTICAL BURST SWITCHING (OBS)



- Dynamic setup of a wavelength path in presence of large data flows
- Data never leave the optical domain; control on separate channels
- Control precedes data by a basic offset time

Good trade-off efficiency-feasibility → Mid-term solution

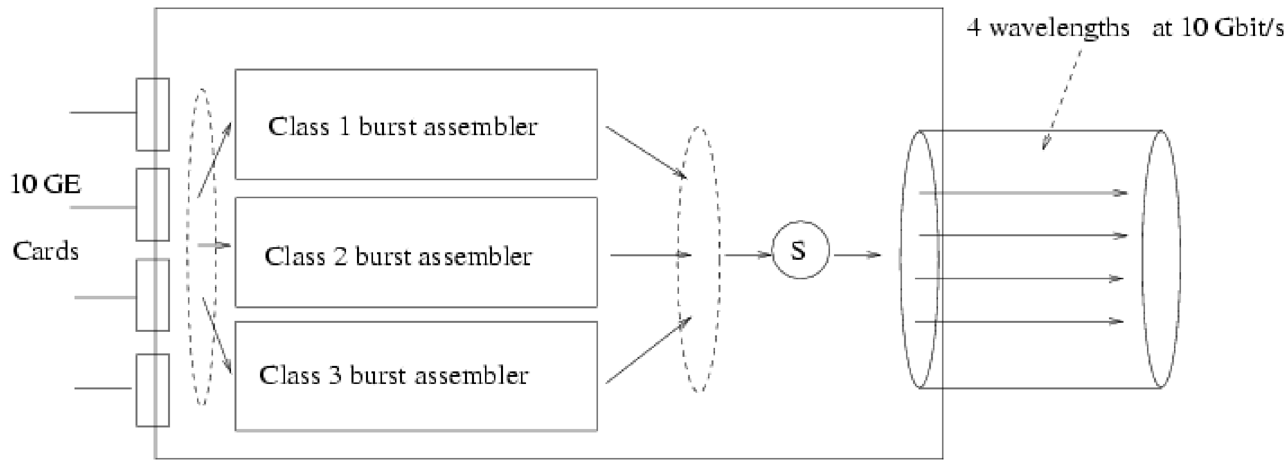
OBS with JUST ENOUGH TIME (JET)



- OBS node reserves resources for the burst duration only
- Offset may include an optional extra-offset for QoS purposes
- Algorithms/protocols are required to properly manage optical resources
- IP&Optical control plane integration: MPLS paradigm
- MPλS maps LSPs into wavelengths
- LOBS: label carried by control packets releasing the wavelength resource

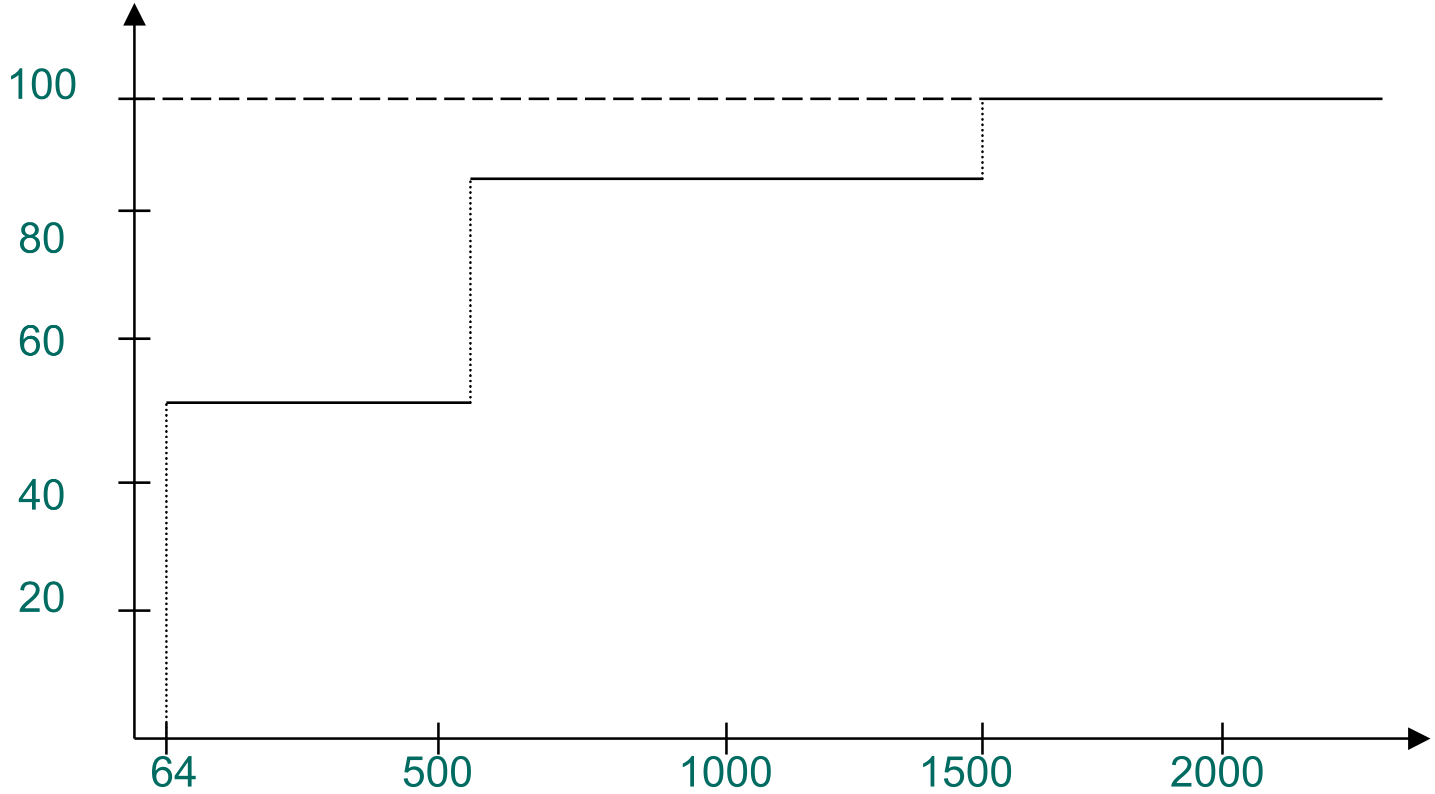
BURST ASSEMBLER (main building block)

- Datagrams grouped according to:
  - ✓ destination
  - ✓ 3 classes of service
- Algorithm T_{max} - L_{min}
- Time sensitive data (class 1): maximum delay T_{max} tolerated
- Loss sensitive data (class 2-3)
  - ✓ efficiency
  - ✓ performance



INTERNET TRAFFIC PATTERN

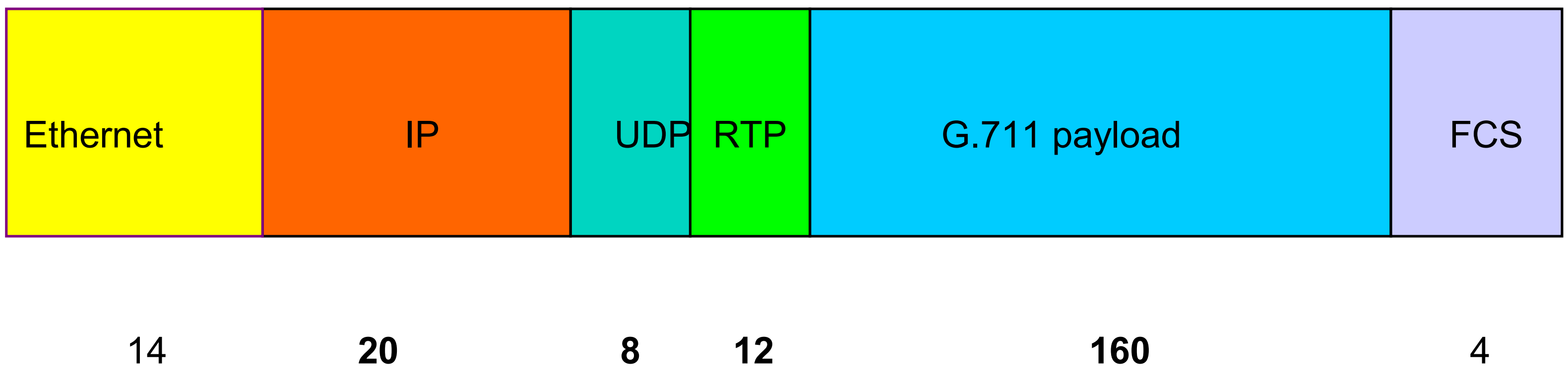
Cumulative Packet Size Distribution



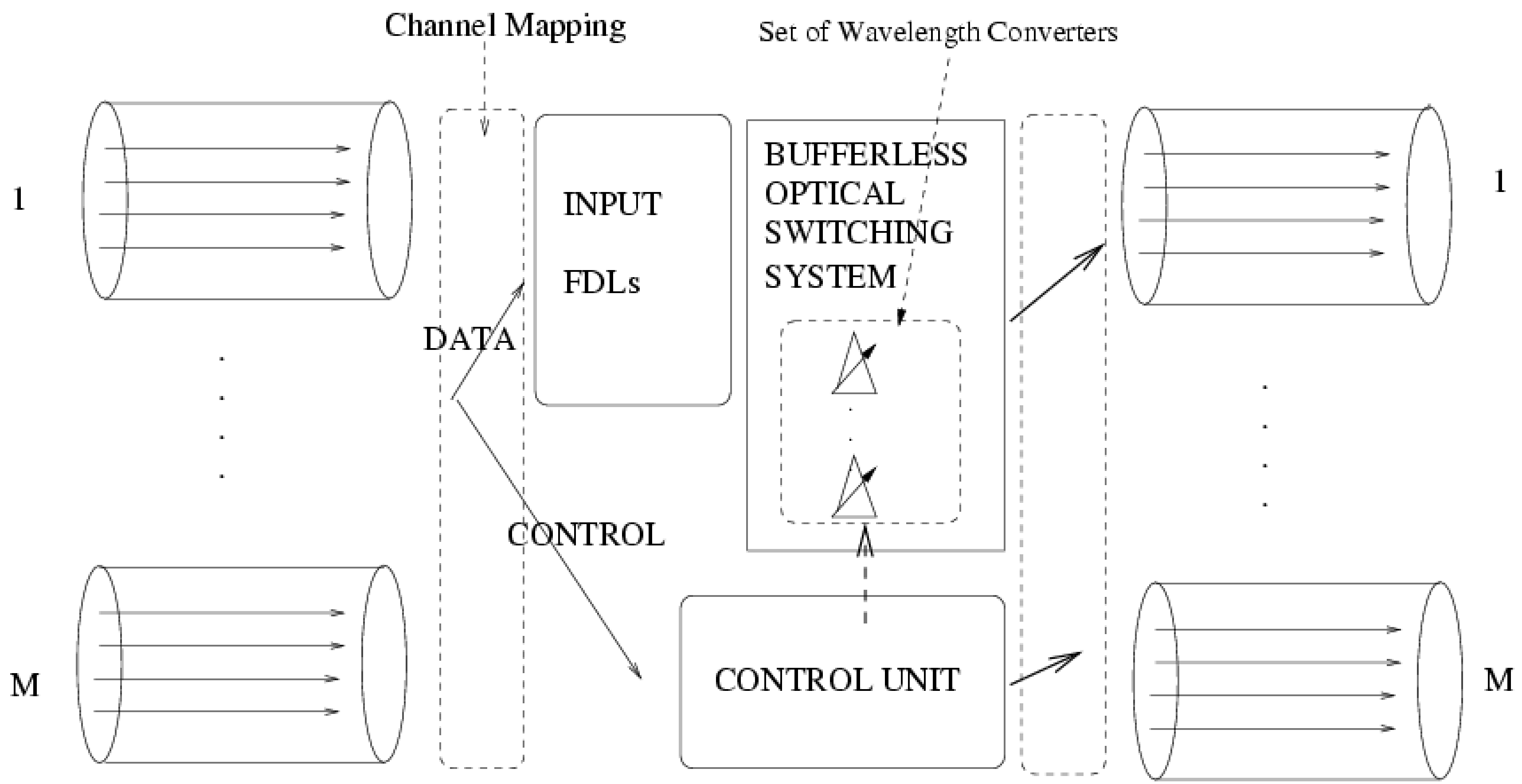
Voice over IP (G.711)

Total frame length:

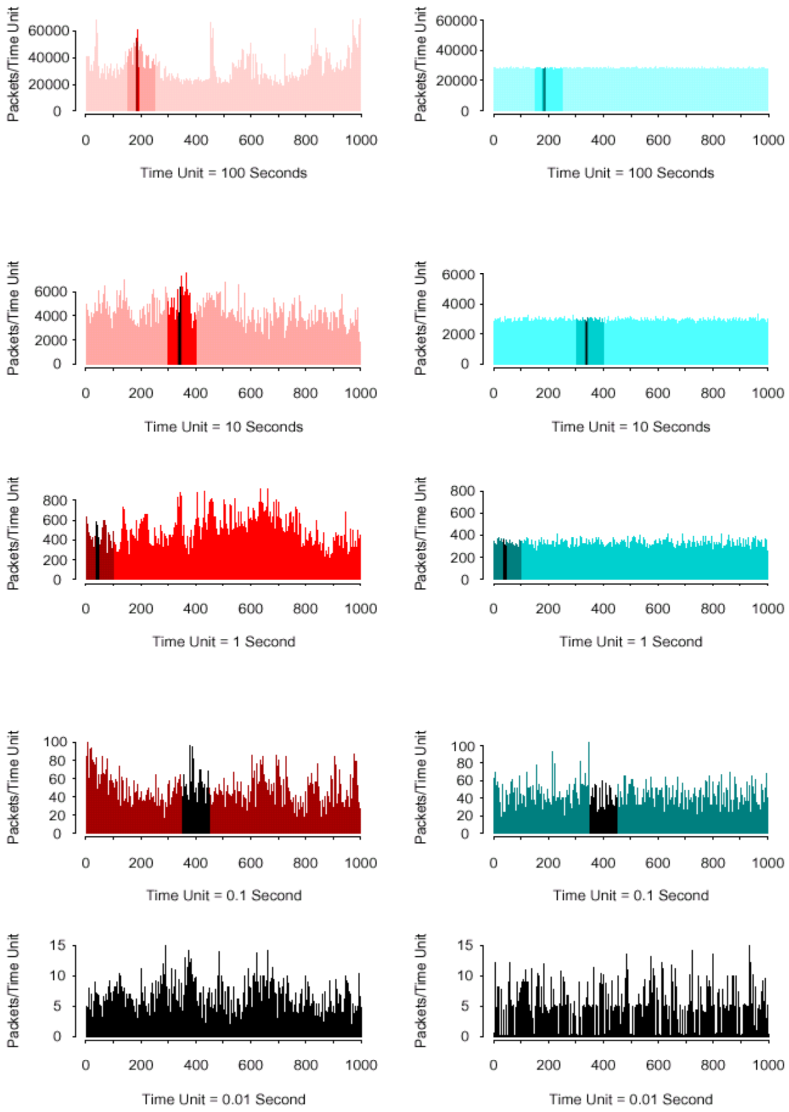
- **218 bytes using Ethernet encapsulation**
- **200 bytes at upper layer**



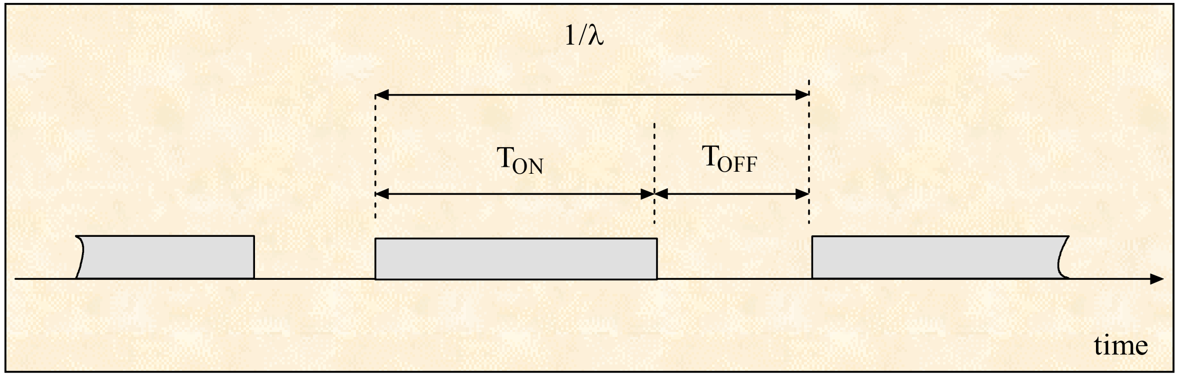
GENERAL CORE ROUTER ARCHITECTURE



SELF-SIMILAR NATURE OF INTERNET TRAFFIC



TRAFFIC SOURCES



ON-OFF sources:

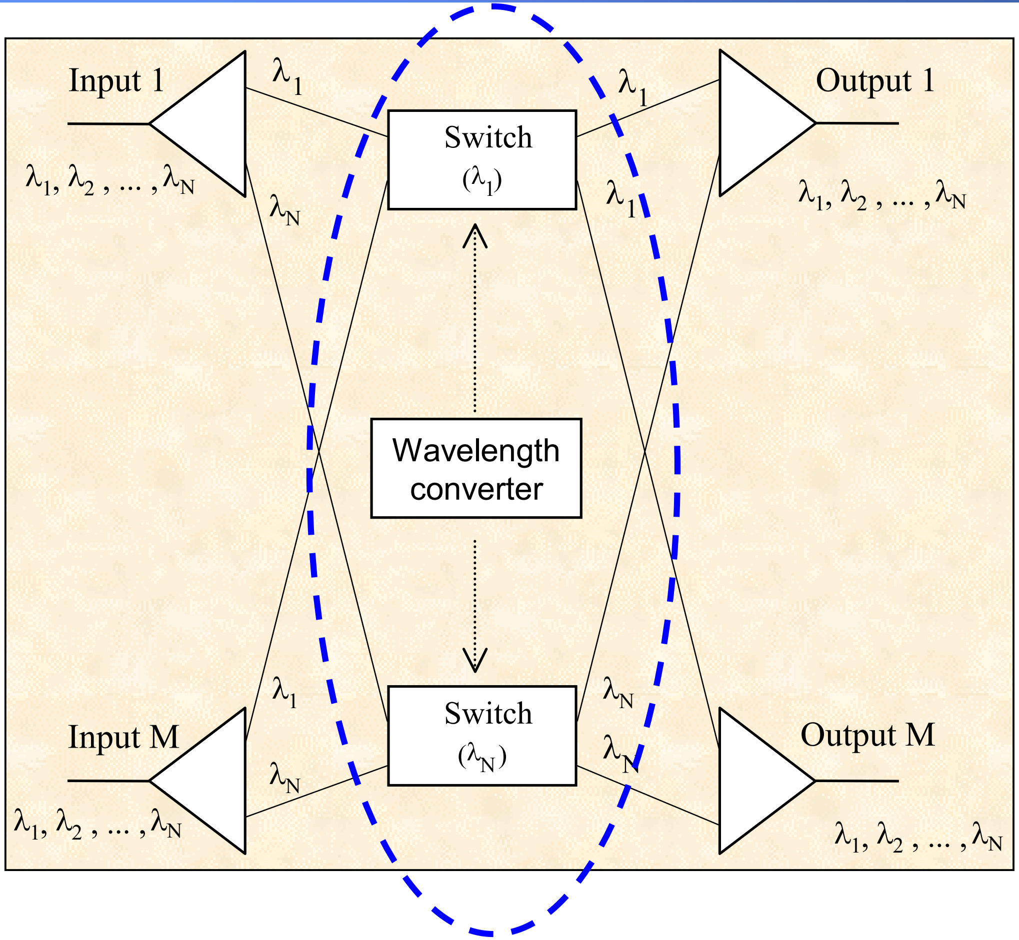
• exponential distribution for OFF periods

• Pareto distribution for ON periods of the 3 classes

$$F(x) = \Pr[X \leq x] = 1 - \left(\frac{k}{x}\right)^{\alpha}$$

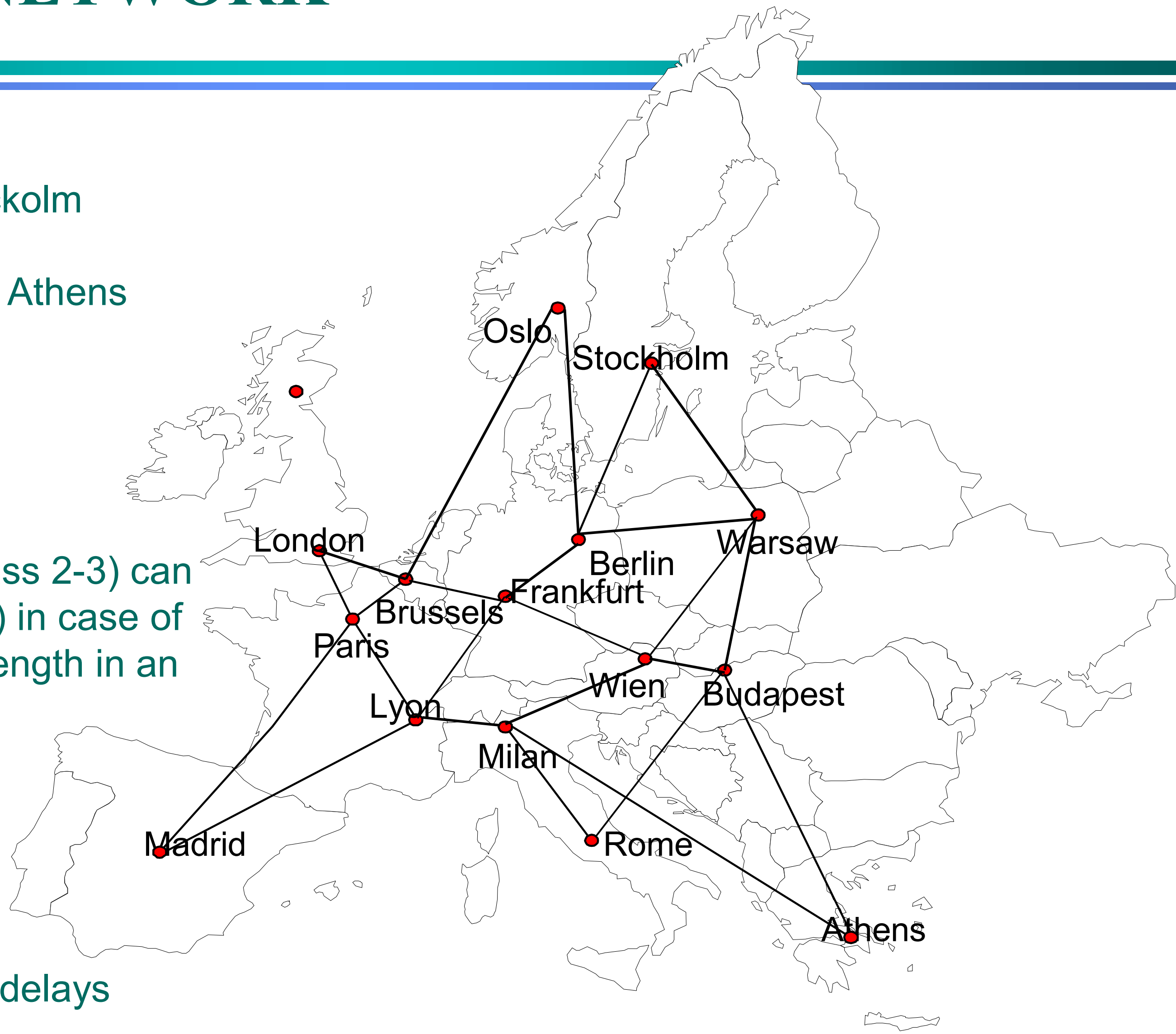
LIMITED SET OF WAVELENGTH CONVERTERS

- *Class 1 bursts* (high)
  - ✓ time sensitive,VoIP, ACKs
  - ✓ extra-offset
  - ✓ use of converters: YES
- *Class 2 bursts* (medium)
  - ✓ loss sensitive, made of 576 bytes
  - ✓ no extra offset
  - ✓ use of converters: YES
- *Class 3 bursts* (low)
  - ✓ loss sensitive, made of 1500 bytes
  - ✓ no extra offset
  - ✓ use of converters: NO



REFERENCE NETWORK

- *Sources*: London, Oslo, Stockolm
- *Destinations*: Madrid, Rome, Athens
- *Routing*: Dijkstra modified
  - ✓ loss sensitive data (class 2-3) can be deflected (rerouted) in case of unavailability of wavelength in an output fibre
  - ✓ variable edge-to-edge delays



REFERENCE SETTING EXAMINED

- Burst Assembly function and OBS Network investigated through an *ad-hoc* event driven C++ object oriented simulator
- Edge router and Burst Assembler parameters
  - ✓ p_1=0.6 (0.3 for VoIP and 0.3 for small size packets), p_2=0.2 (576 bytes datagrams) and p_3=0.2 (1500 bytes)
  - ✓ T_{max} = 20 ms
- Core router and network traffic parameters
  - ✓ M=4 incoming/outgoing fibers; N=8 wavelengths per fiber at 10 Gbit/s;
  - ✓ ON-OFF sources with exponential OFF periods and Pareto ON periods with α_{on}=1.2
  - ✓ Service class differentiation through
    - ➢ extra-offset for class 1 bursts only
    - ➢ differerent permissions of employment of a set of 20 wavelength converters
    - ➢ different routing for classes 2 and 3 loss sensitive data (deflected)

ASSEMBLY TIME FOR CLASS 3 BURSTS

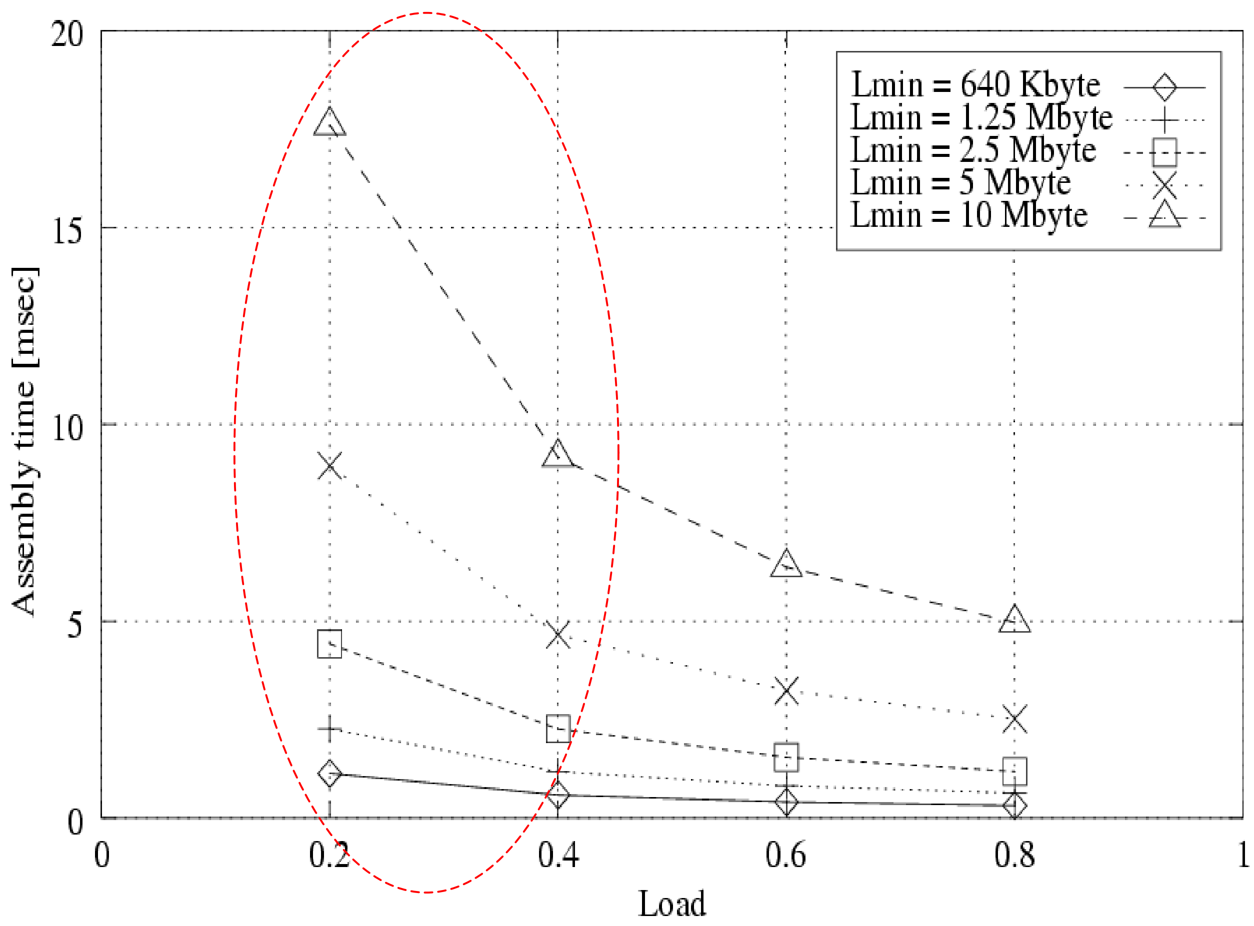
Loss sensitive data

- ✓p_1=0.6
- ✓ p_2= p_3= 0.2

- ✓ T_{max} = 20 ms

Light loads (<0.4):

By properly setting L_{min} is possible to control the assembly time and the size of bursts injected into the network



BURST BLOCKING PROBABILITY vs. OFFERED LOAD

Single node

✓ ON-OFF sources with exponential OFF and Pareto ON periods with $\alpha_{on}=1.2$

✓$p_1=0.2$, $p_2=0.5$ and $p_3=0.3$

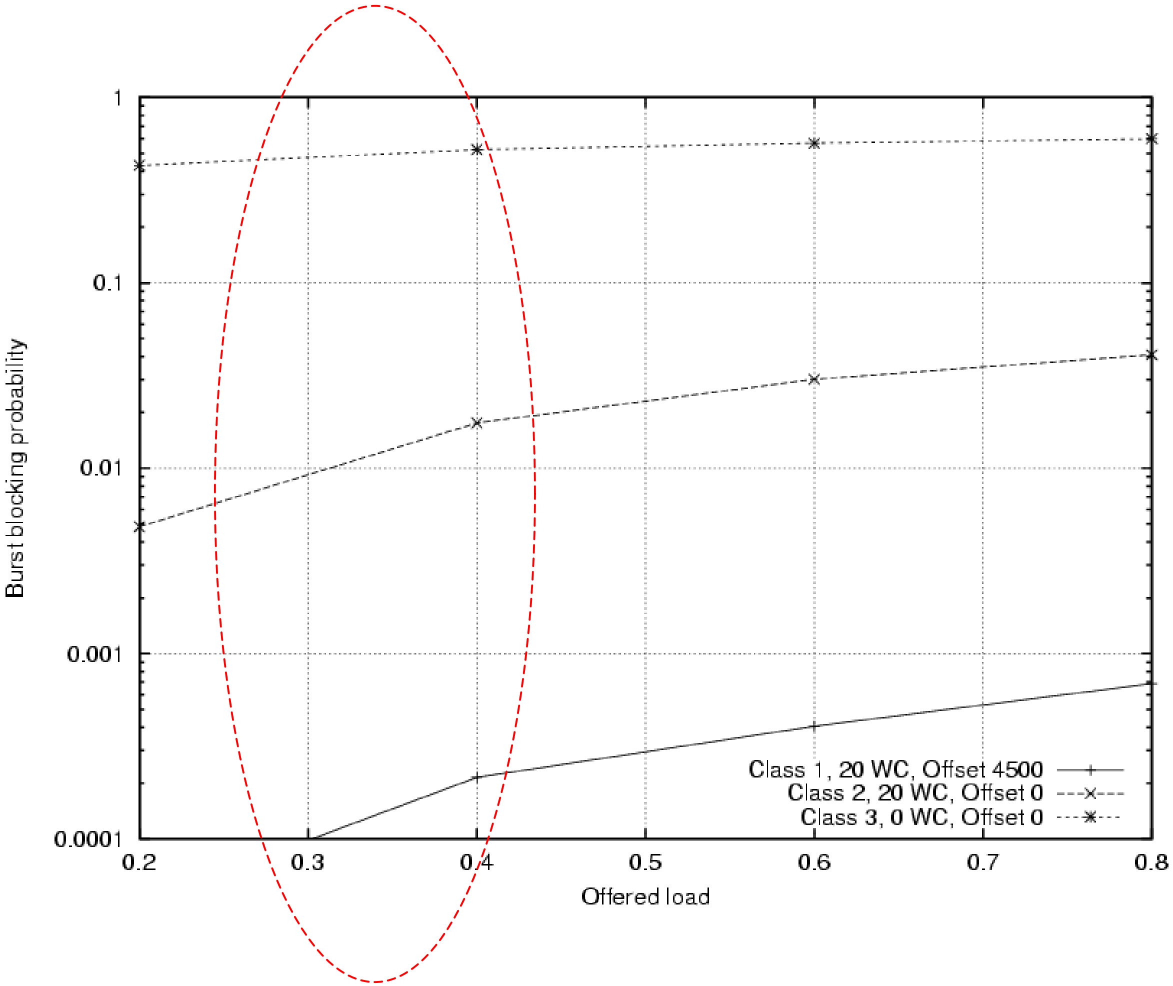
✓ extra-offset class 1 bursts=3.6μs

✓ Set of 20 WCs used by class 1 and 2 only

Performance:

✓ class 1 always < 10^{-3}

✓ service differentiation



TOTAL END-TO END BURST BLOCKING PROBABILITY

Pan European Network

✓ ON-OFF sources (London, Oslo, Stockolm) with exponential OFF and Pareto ON periods with $\alpha_{on}=1.2$

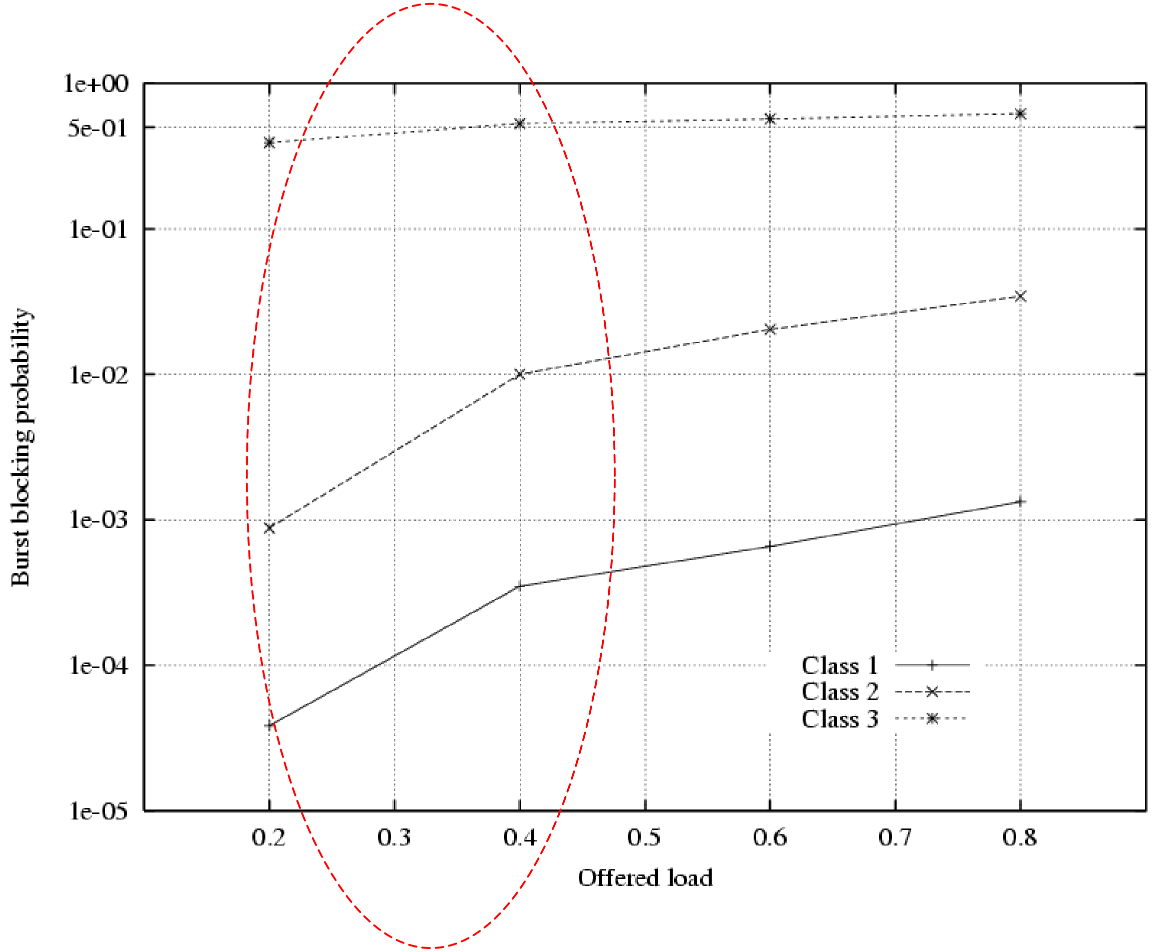
✓ $p_1=0.2$, $p_2=0.5$ and $p_3=0.3$

✓class 1 bursts extra-offset =6µs

✓ Set of 20 WCs used by class 1 and 2 only

✓ classes 2 and 3 deflected and re-routed in case of blocking on outputs

Performance for Oslo-Rome traffic



EDGE-TO-EDGE DELAY (HOPS)

Pan European Network

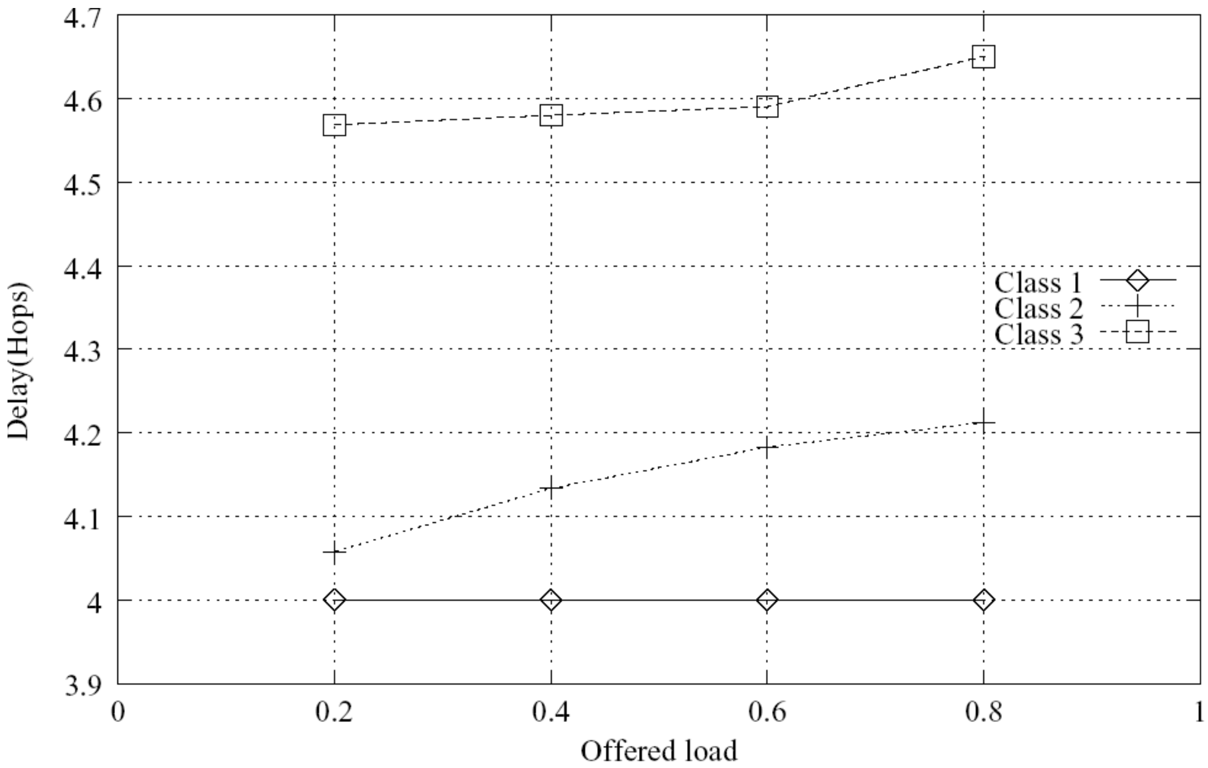
✓ ON-OFF sources (London, Oslo, Stockolm) with exponential OFF and Pareto ON periods with α_{on}=1.2

✓classes 2 and 3 deflected and re-routed in case of blocking on outputs

Performance for Oslo-Rome traffic

✓ Class 1: fixed delay

✓ Classes 2-3: variable delays



CONCLUSIONS

- Investigation of a OBS Network
  - JET resource reservation mechanism
- QoS differentiation through
  - Different extra-offset settings
  - Different employment of a limited set of wavelength converters
  - Different routing (deflection)
- "Realistic" traffic patterns
- Study of Access Network
  - assembly function
- Study of a Pan European Network
  - burst blocking probabilities
  - edge-to-edge delays

- Extreme attention must be paid in the burst assembly algorithm in order to be efficient and not to penalize loss sensitive data
- A simple approach for service differentiation (extra-offset+converters management+class based routing) seems to be effective to provide insights for traffic and network engineering

THANK YOU FOR YOUR ATTENTION

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… suggestions are welcome