On the Performance of TCP over OBS Networks with Different QoS Classes

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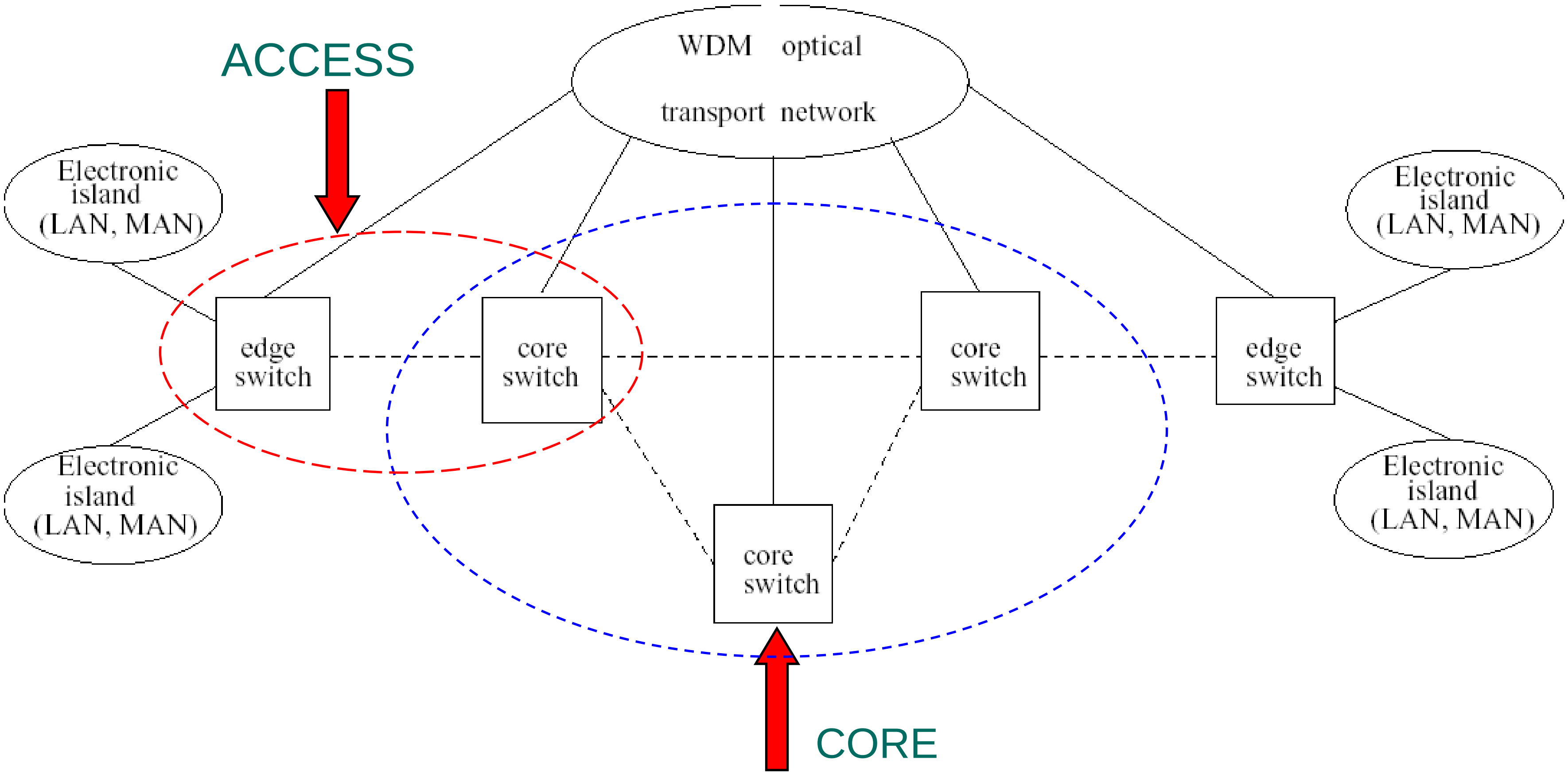
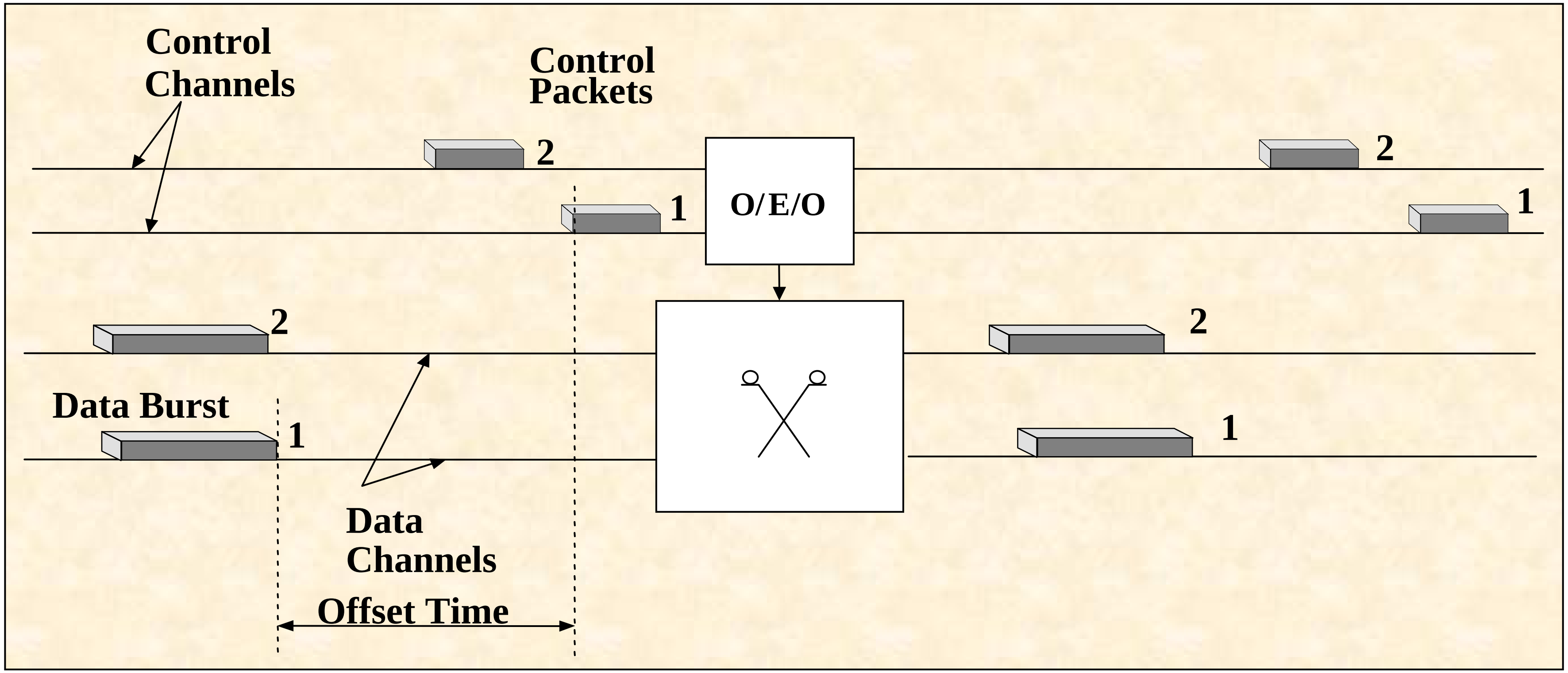
OUTLINE

- Introduction: Optical Burst Switching Scenario
- Goal: development of
  - ✓ analytical and
  - ✓ simulation tools for OBS nodes and networks
- Case Study: Pan-European Network (Cost 266 simplified)
- Numerical results
  - single node (analysis)
  - reference network (simulation)
- Conclusions

INVESTIGATED OBS SCENARIO



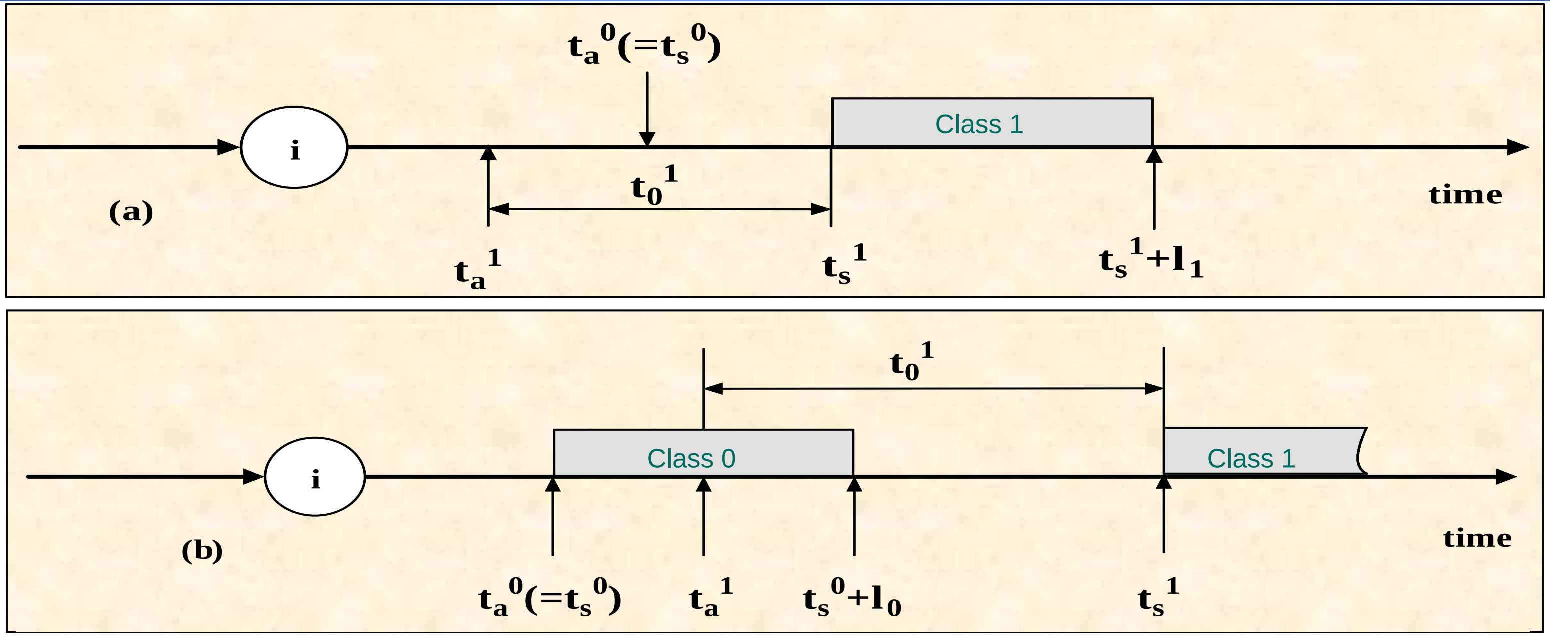
OPTICAL BURST SWITCHING (OBS)



- 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

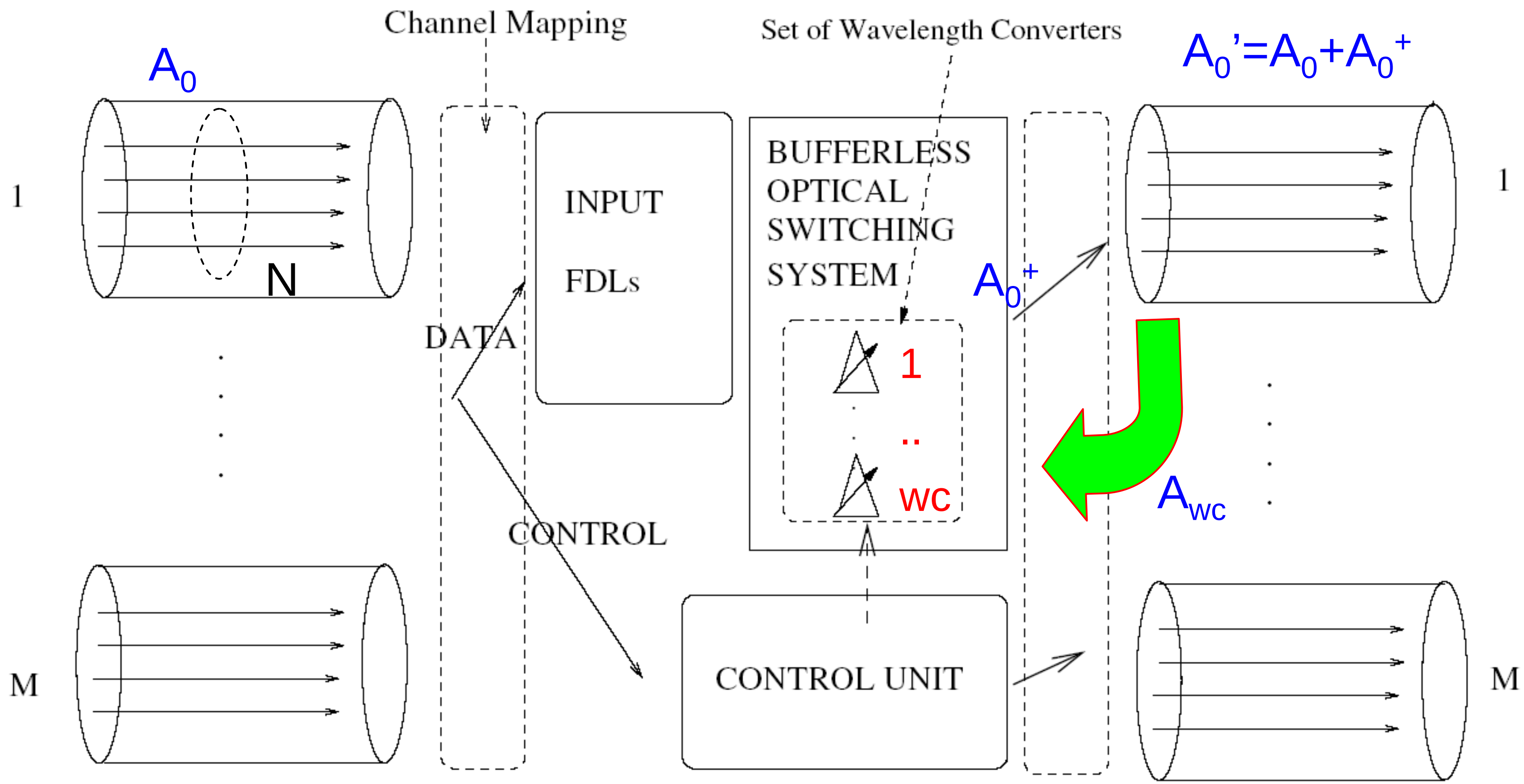
Good trade-off efficiency-feasibility ➡ Mid-term solution

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

CORE ROUTER



Channel Mapping
Set of Wavelength Converters
A0
A0'=A0+A0+
1
N
INPUT
FDLs
BUFFERLESS
OPTICAL
SWITCHING
SYSTEM
A0+
1
..
WC
Awc
DATA
CONTROL
CONTROL UNIT
M
1
M

OBS Node Analysis: Assumptions

- bufferless node
- equal traffic on each incoming wavelength
- the burst arrival process to the core router is modelled by a Poisson process, whereas the burst duration is arbitrary
- all outputs are chosen with equal probability

BURST BLOCKING PROBABILITY

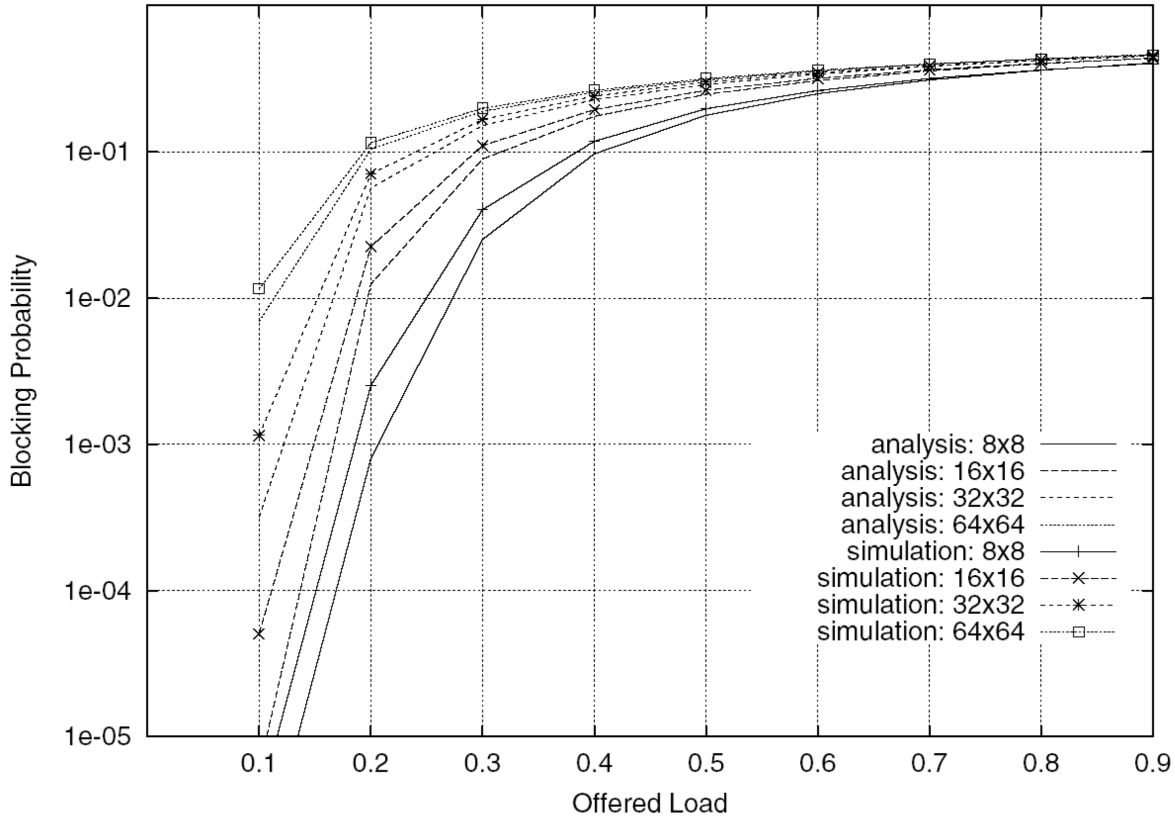
$$P_b = \Pr\{\lambda_j\_busy\} \cdot \{\Pr\{no\_wc\_free\} + \Pr\{wc\_free\} \cdot \Pr\{all\_remaining\_(N-1)\_\lambda s\_busy\}\}$$

$$\Downarrow$$

$$P_b = \frac{A_0^{'}}{1 + A_0^{'}} \cdot \left\{B\left(wc, A_{wc}\right) + \left[1 - B\left(wc, A_{wc}\right)\right] \cdot B\left(N-1, \left(N-1\right) \cdot A_0^{'}\right)\right\}$$

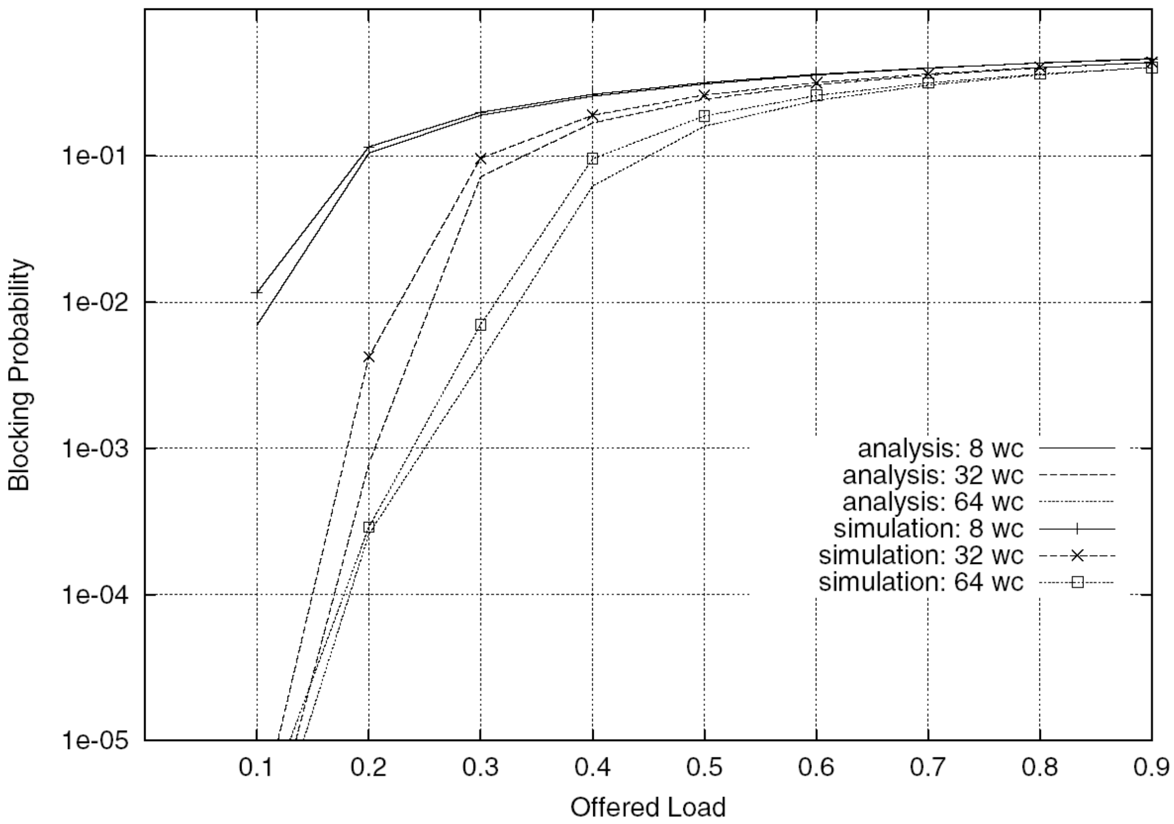
BURST BLOCKING PROBABILITY (1)

- N = 8 wavelenghts
- M = 8, 16, 32, 64
- wc = 8

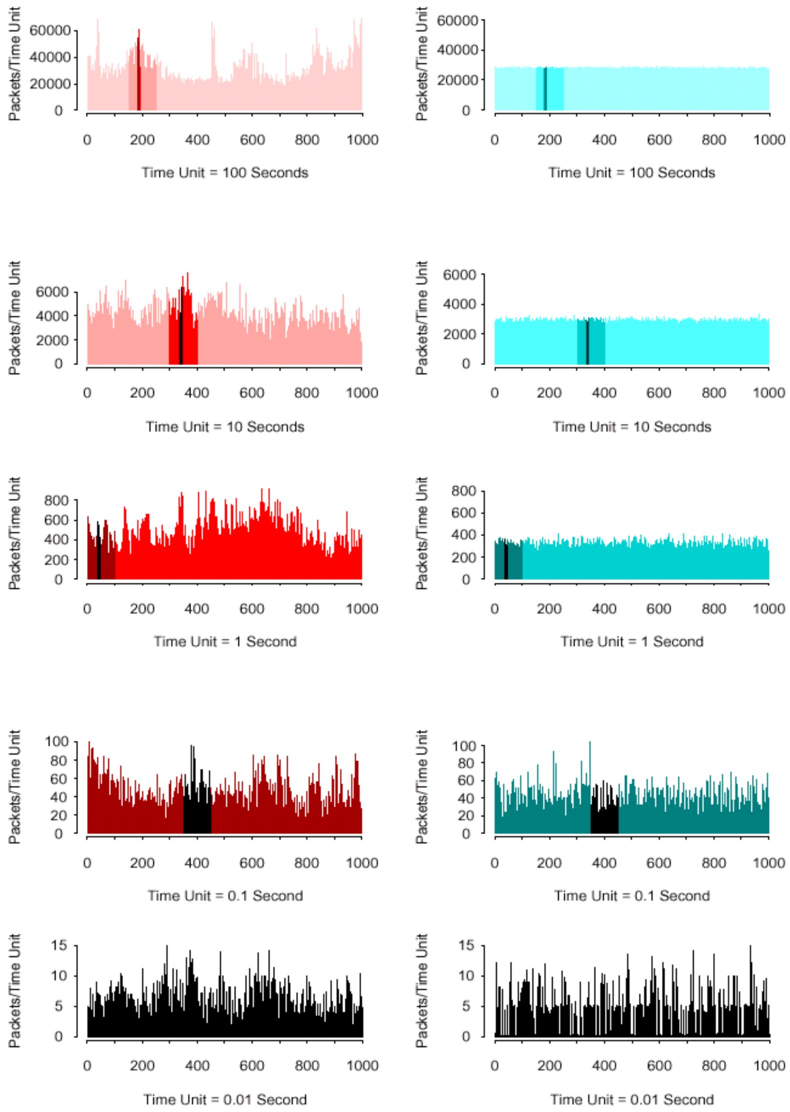


BURST BLOCKING PROBABILITY (2)

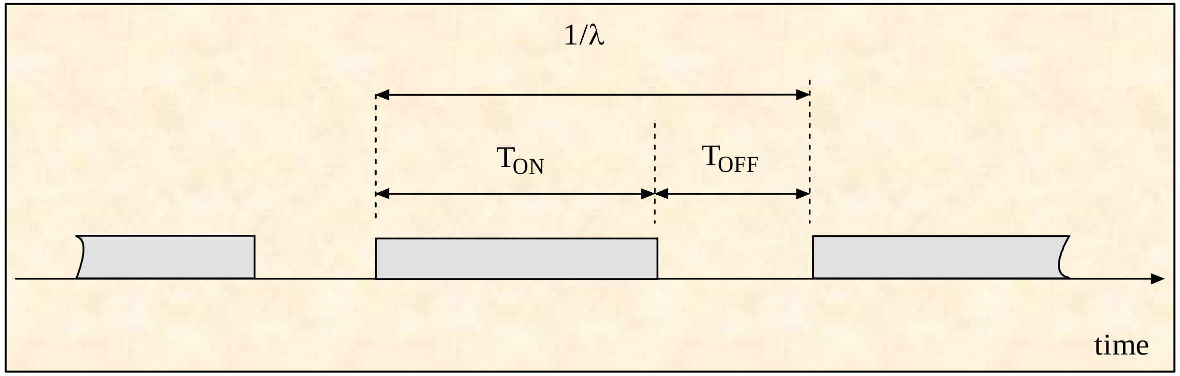
- N = 8 wavelenghts
- M = 64
- wc = 8, 32, 64



SELF-SIMILAR NATURE OF INTERNET TRAFFIC



TRAFFIC SOURCES



ON-OFF sources:

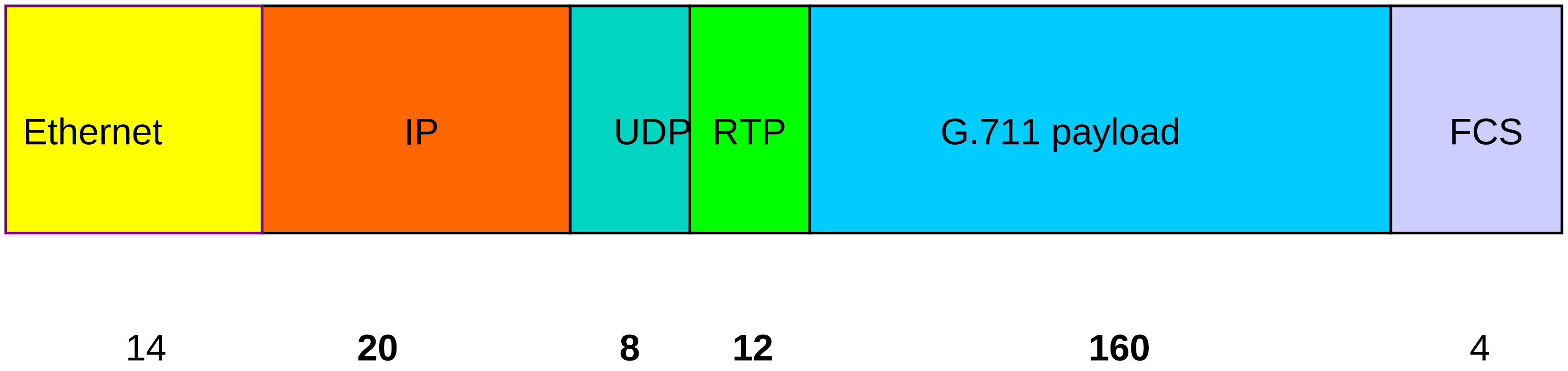
- exponential distribution for OFF periods
- Pareto distribution for ON periods of the 3 classes

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

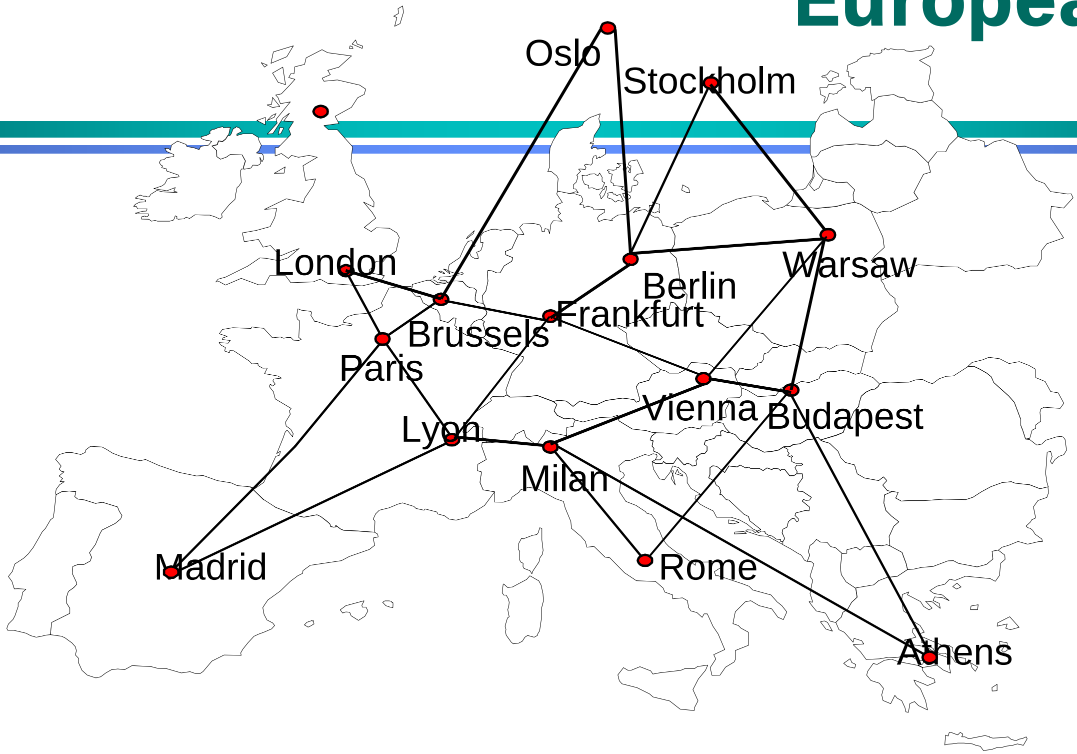
Voice over IP (G.711)

Total frame length:

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



European Network

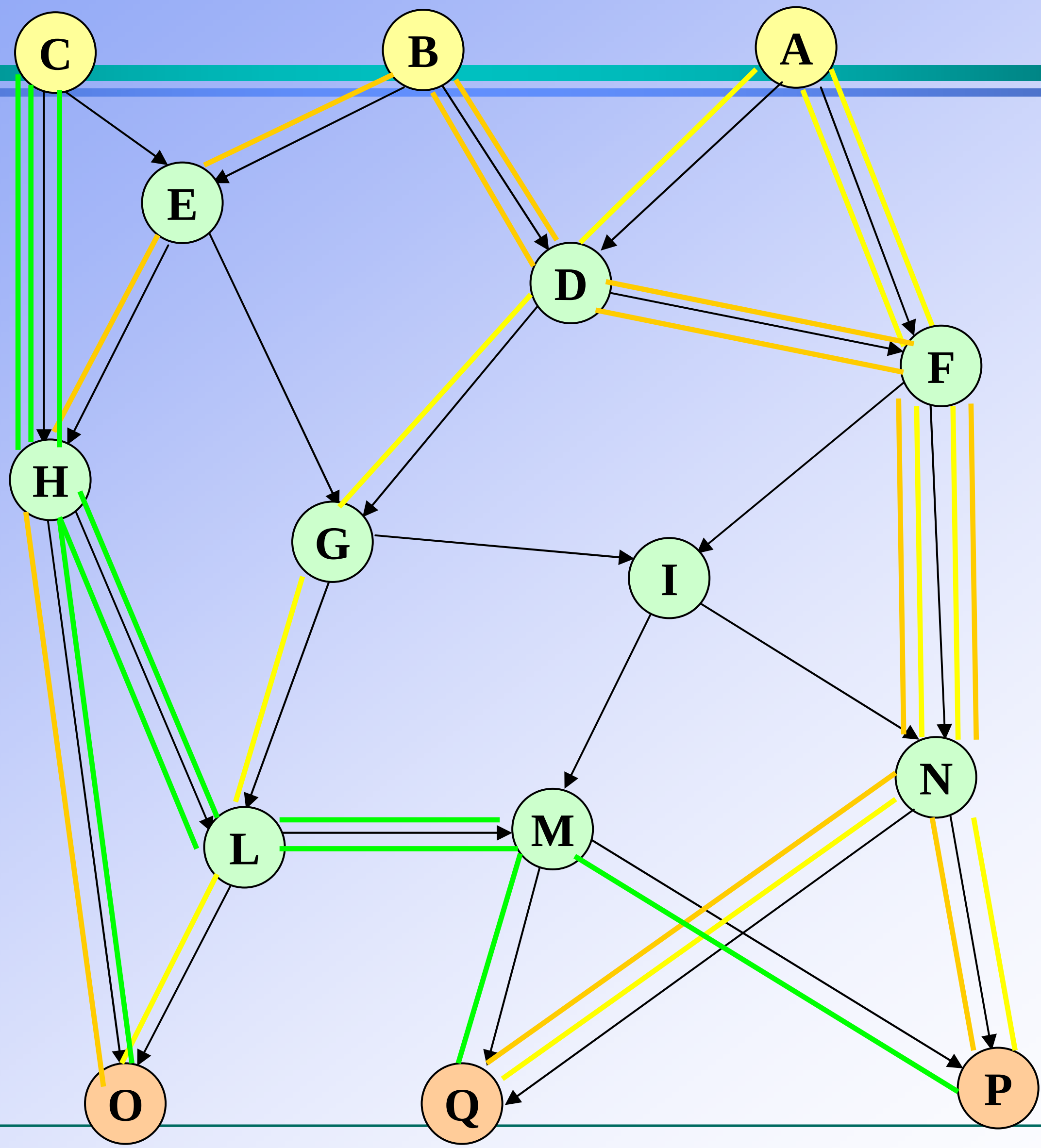


Routing: Dijkstra

16 λs per fiber

QoS class for burst	Average Pareto ON period for incoming datagrams	Percentage	JET extra offset (8 μs) use	N. of shared wavelength converters	Deflection routing
Class 1	218 bytes	50%	Y	32	N
Class 2	10 Kbytes	20%	N	32	Y
Class 3	10 Kbytes	30%	N	0	Y

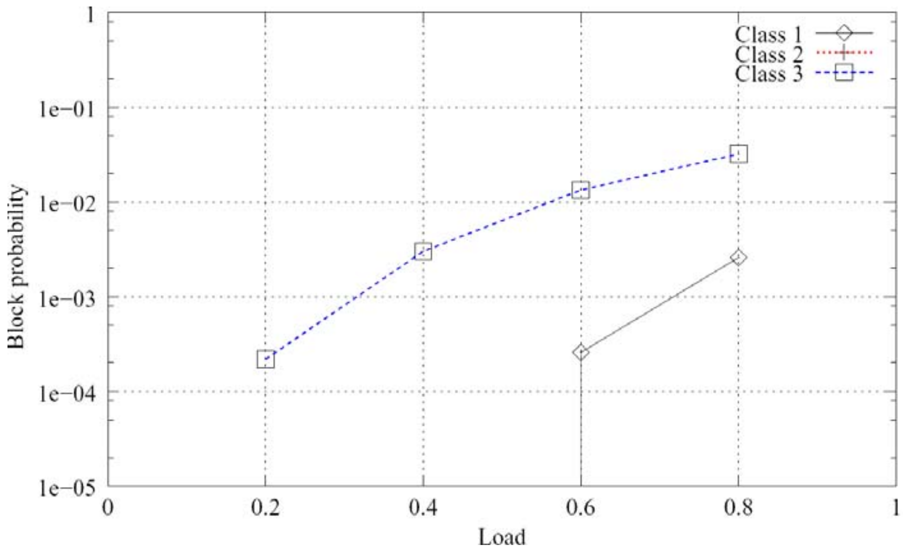
European Network

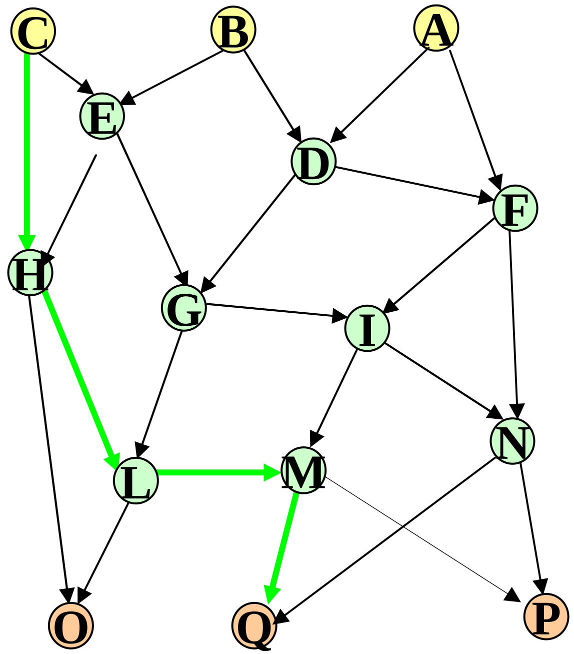


A – Stockolm
B – Oslo
C – London
D – Berlin
E – Bruxelles
F – Warsaw
G – Frankfurt
H – Paris
I – Vienna
L – Lyon
M – Milan
N – Budapest
P – Athens
Q – Rome
O - Madrid

MOBSim: Blocking Probability from London to Rome

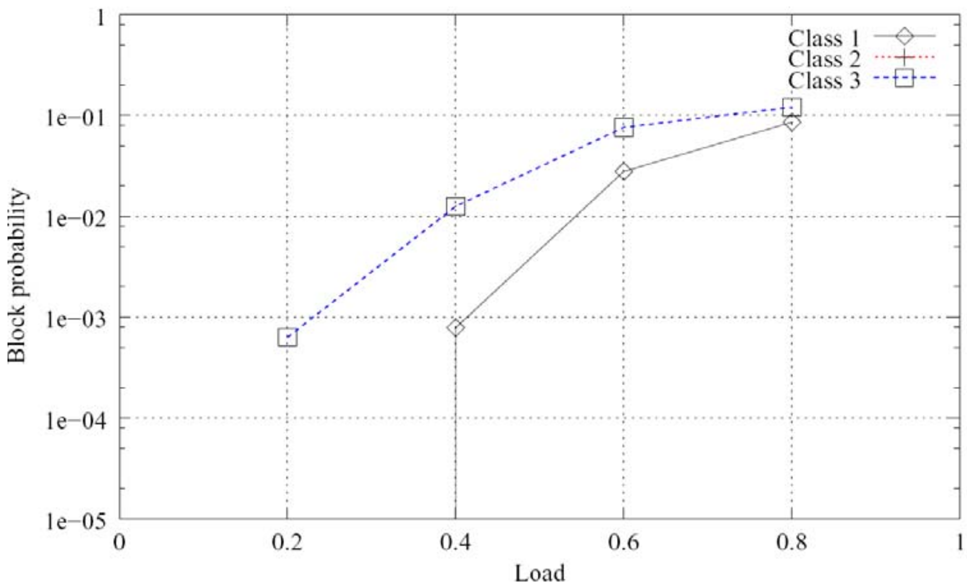
Tmax Lmin v.2 *

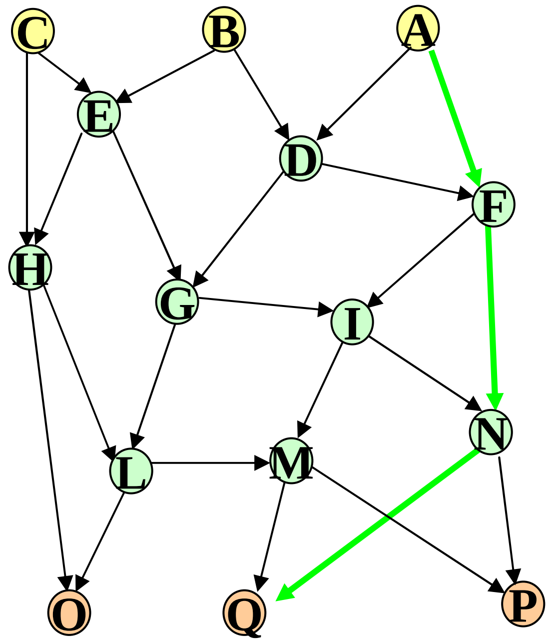




* M. Casoni, E. Luppi, M.L. Merani, "Impact of Assembly Algorithms on End-to-End Performance in OBS Networks with Different QoS Classes", *Proc. of* 3rd *International Workshop on Optical Burst Switching*, October 25 2004, San Josè (CA, USA).

MOBSim: Blocking Probability from Stockolm to Rome





Performance depend on the path: in case of severe congestion (node F) degradation can be remarkable

End to End Performance

TCP Reno:

$$Thr = \frac{MSS}{RTT\sqrt{\frac{2bp}{3}} + T_o \min\left(1, 3\sqrt{\frac{3bp}{8}}\right) p\left(1 + 32p^2\right)}$$

- Edge-to-edge one way delay:

$$T_{e2e1way} = T_{assembly} + N_{hops} \times T_{hop} + T_{disass}$$

- RTT $\approx$ 2 x $T_{e2e1way}$
- Assuming 800 km average link length ($T_{hop} \approx$ 4 ms) and N_{hops} in [3..5] then N_{hops} x $T_{hop} \leq$ 20 ms and $T_{assembly}$ depends on burst assembly (see e.g.*)
- Regarding p, assuming "slow" TCP sources implies that at most one segment per connection is in a generated burst: p $\approx$ burst blocking prob.

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TCP Throughput (1)

- T_o = 1 s; b = 2; MSS = 1500 bytes;
- p = 1%

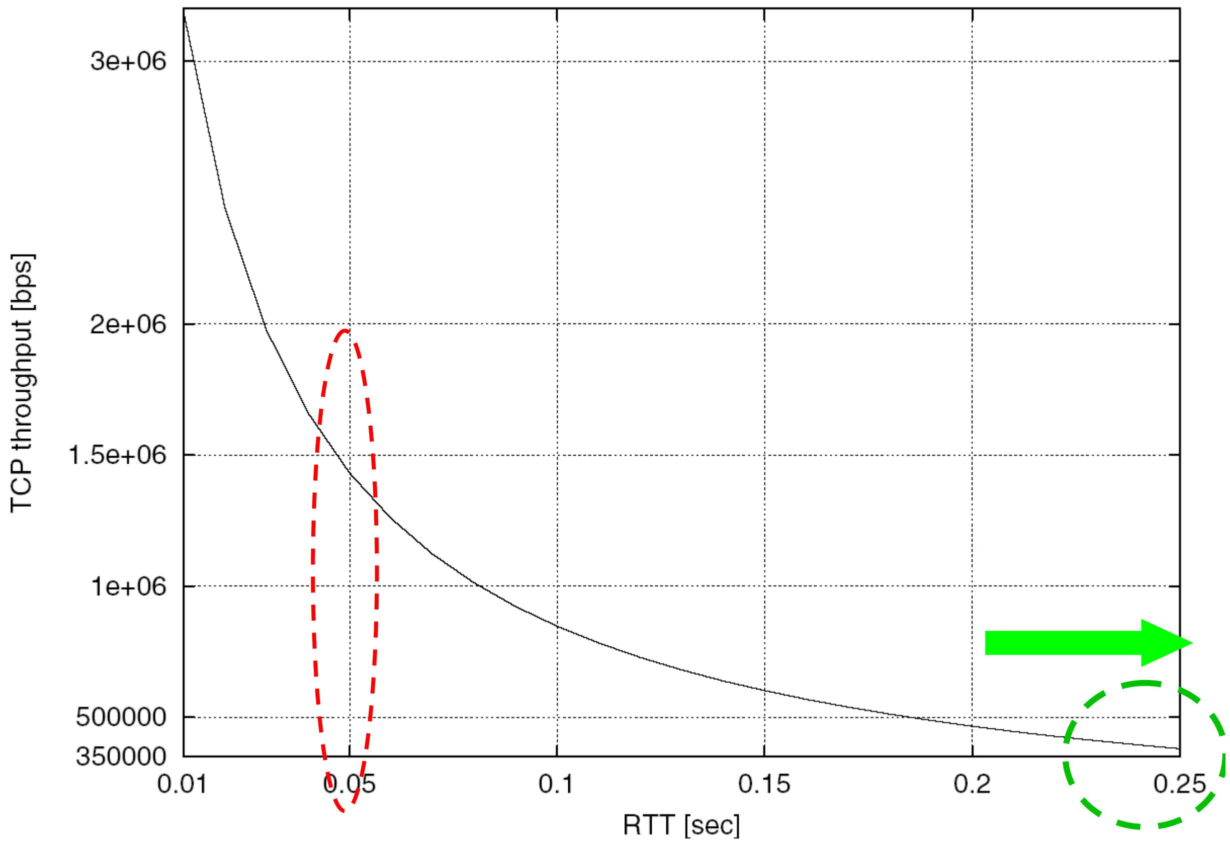
Effects of Burst Assembly :
(on *T_assembly*)

- ***Tmax Lmin***:

Class 2/3: RTT > 300 ms
(performance is “assembly driven”)

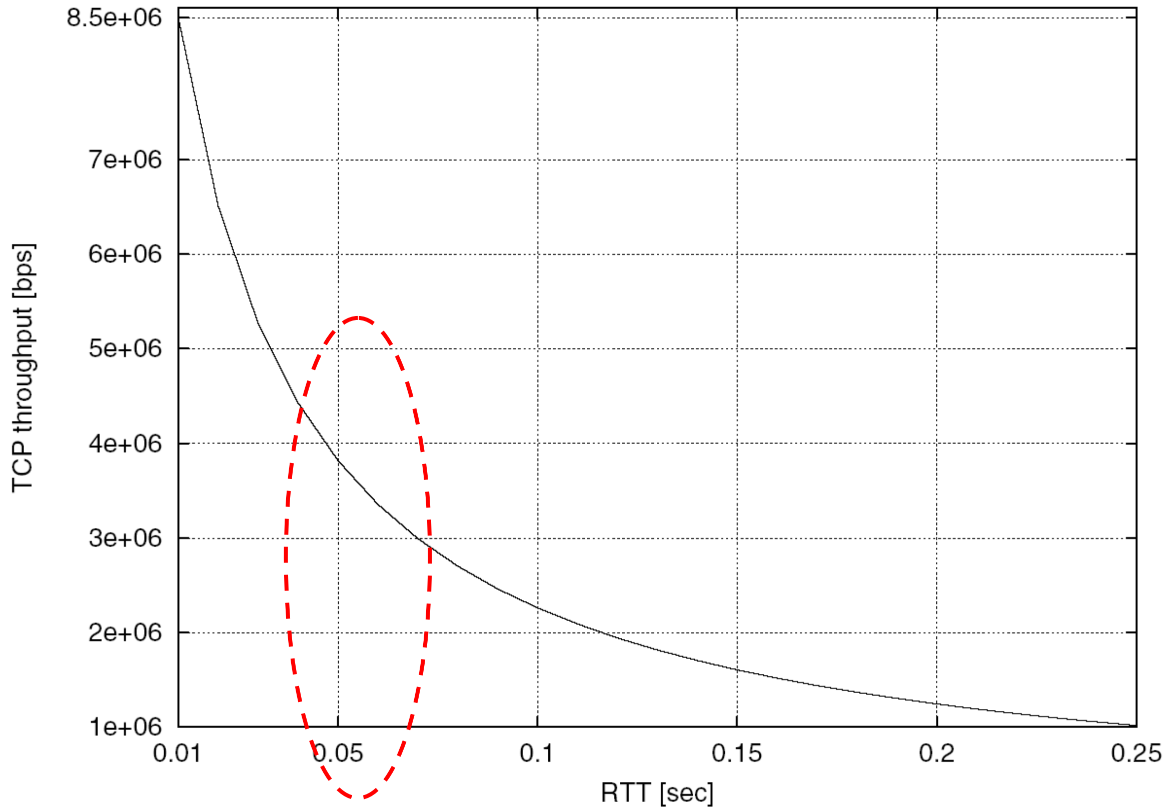
- ***Tmax Lmin v.2 (new)***:

Class 2/3: RTT ≈ 50 ms
(performance is “propagation driven”)



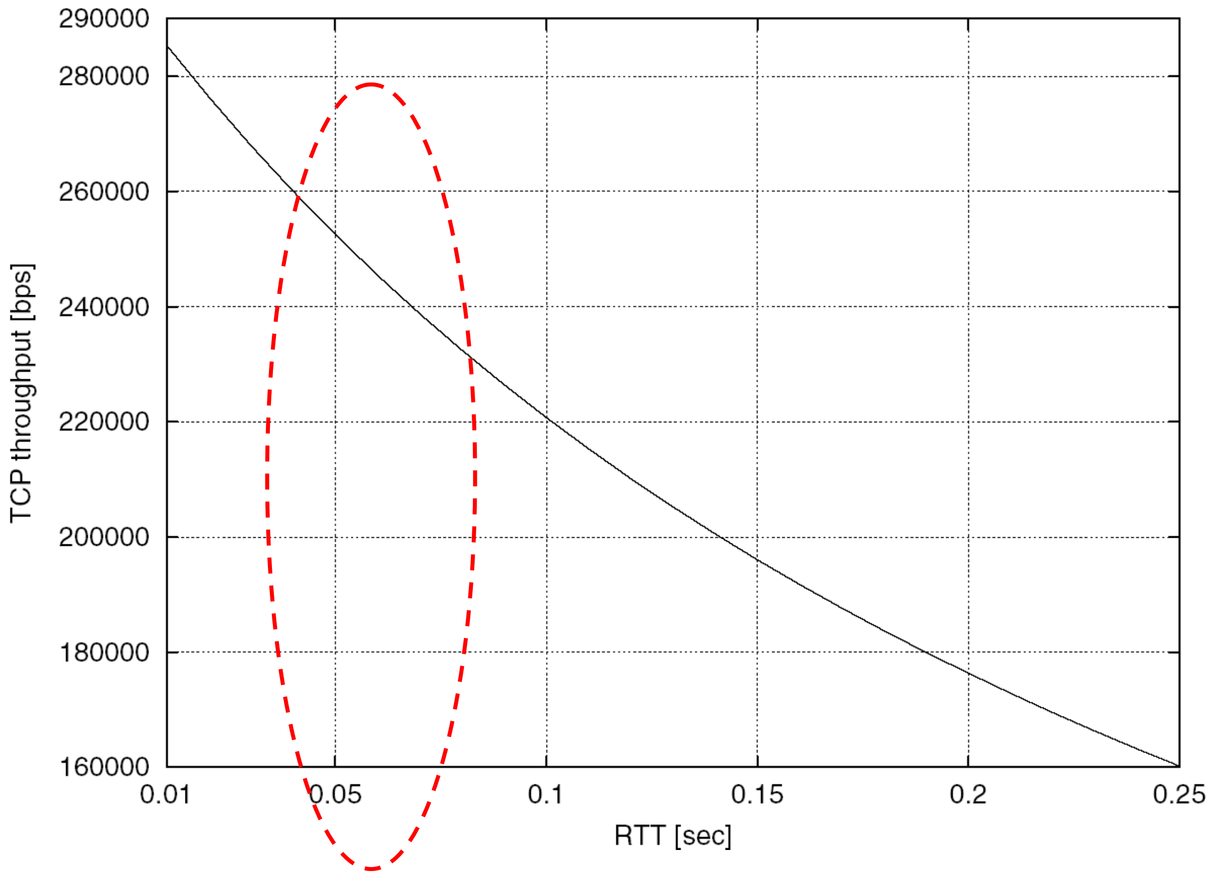
TCP Throughput (2)

- ✓ $T_o = 1$ s; b = 2;
- ✓ MSS = 4000 bytes;
- ✓ p = 1%



TCP Throughput (3)

- $T_o = 1$ s; b = 2;
- MSS = 4000 bytes;
- p = 10%



CONCLUSIONS

- JET as resource reservation mechanism

- bufferless OBS Node Analysis
  - ✓ Burst blocking probability formula

- Study of a Pan European Network, through MOBSim tool, free demo available at:

  http://www.dii.unimore.it/wonet/en/index.html

- QoS differentiation through
  - ✓ Different extra-offset settings
  - ✓ Different employment of a limited set of wavelength converters
  - ✓ Different routing (deflection)

  - ✓ “realistic” traffic patterns
  - ✓ burst blocking probabilities

- TCP performance: effects of burst assembly, segment size and loss

- 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 very very welcome