System Design and Evaluation of a Large Photonic Switch based on Optical Codes for OBS Networks

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Outline

- Introduction: Optical Burst Switching scenario
- Switching architectures based on TWC
- Optical Codes
  - encoders/decoders
- Proposed photonic switch architecture
  - code based
- Proposed multi-stage architecture
  - Clos based
- Numerical results
  - Multi-stage vs. monolithic
  - Burst blocking probability
  - Complexity/costs
  - Simulation through our C++ M_OBS_Sim tool
- Conclusions

Optical Networks: Evolution

- DWDM technique
  - **Transmission rate in the range of Tbit/s**
- Architectural semplification
  - **From IP over ATM over SONET over WDM to IP over WDM**
- Need to exploit in an effective way the huge transmission bandwidth with IP traffic
  - **Wavelength Routing**
    - ✓ all-optical data network
    - ✓ Low flexibility for IP traffic
  - **Optical Packet Switching**
    - ✓ Ideal transfer mode for IP traffic
    - ✓ Severe technological constraints → not feasible in the short/middle term
      - Optical components immature
      - Optical buffers

Optical Burst Switching

Goal: better sinergy between the mature electronic technologies and the new optical tecnologies (mid-term solutions)

- **Switching granularity between WR and OPS**
  - *Burst concept:* aggregation of IP packets with common features (e.g. destination and QoS), considered as the basic optical unit
- **Time and space separation of data and control (header) fields**
  - Control packet employs dedicated channel and precedes the relative data burst
    - ✓ All-optical network, buffer-less and data trasparent
    - ✓ Hybrid opto-electronic network for control signals (*out-of-band signaling*)
  - Simplification of the electronic processing of the control packets at intermediate nodes
  - Reduction of the opto-electronic functionalities required to router

Switching Architectures with WC

Contention resolution through:

- Wavelength conversion: optoelectronic devices
  - Tunable Optical Wavelength Converters (TOWC)
    - From any input wavelength to any output wavelength (any-to-any)
    - Tunable lasers
  - Fixed Output Wavelength Converters (FOWC)
    - From any input wavelength to one output wavelength (any-to-one)
    - Fixed wavelength laser

- Share-per-Node
  - Shared bank of TOWC employed by any incoming burst on any wavelength
- Share-per-Input-Link
  - Shared bank of TOWC employed by bursts on the same fiber
- Share-per-Output-Link
  - Shared bank of TOWC employed by bursts addressed to same output

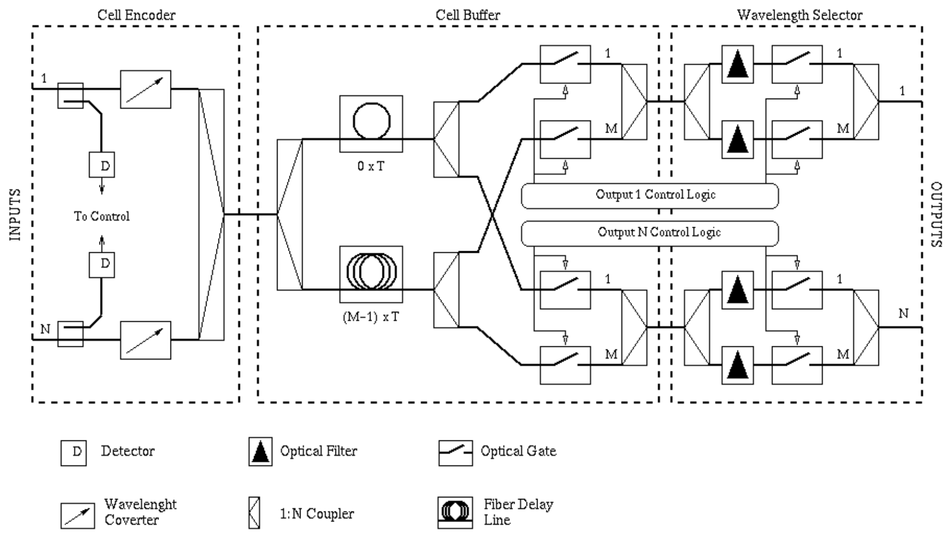
Optical Codes in Switches

- **Issue**: minimize the processing time of the burst control packet
- Possible approach: use of optical codes combined with MPLS/GMPLS
- Optical codes associated to labels
- To this end some optical devices have been proposed and evaluated: multiple plane encoders/decoders
- With such devices a packet processing rate of 13 gigapackets/s can be reached

Switching methods

- **OASIS switch (1995-96)**
  - **Incoming packets converted to wavelengths associated to the addressed output**
  - **Fiber delay lines for contention resolution**

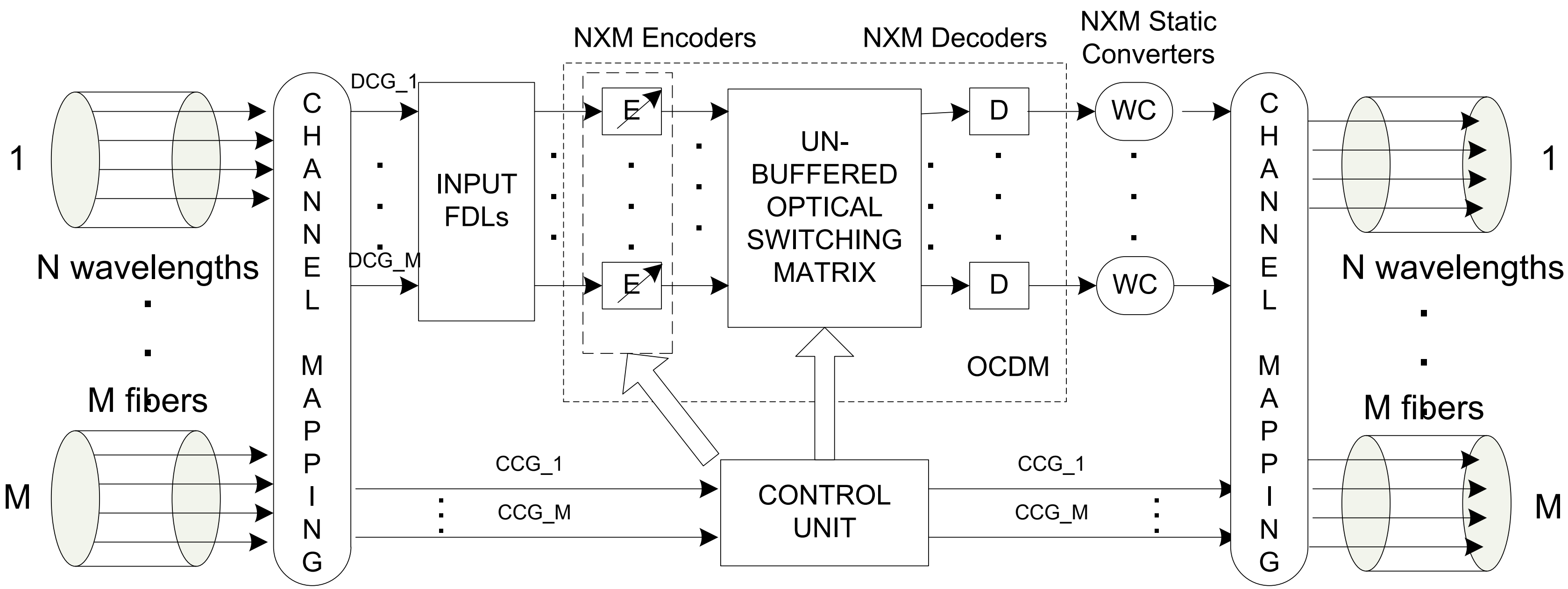
- **KEOPS project (1998)**
  - **Incoming packets converted to wavelengths associated to the input link**
  - **Fiber delay lines for contention resolution**



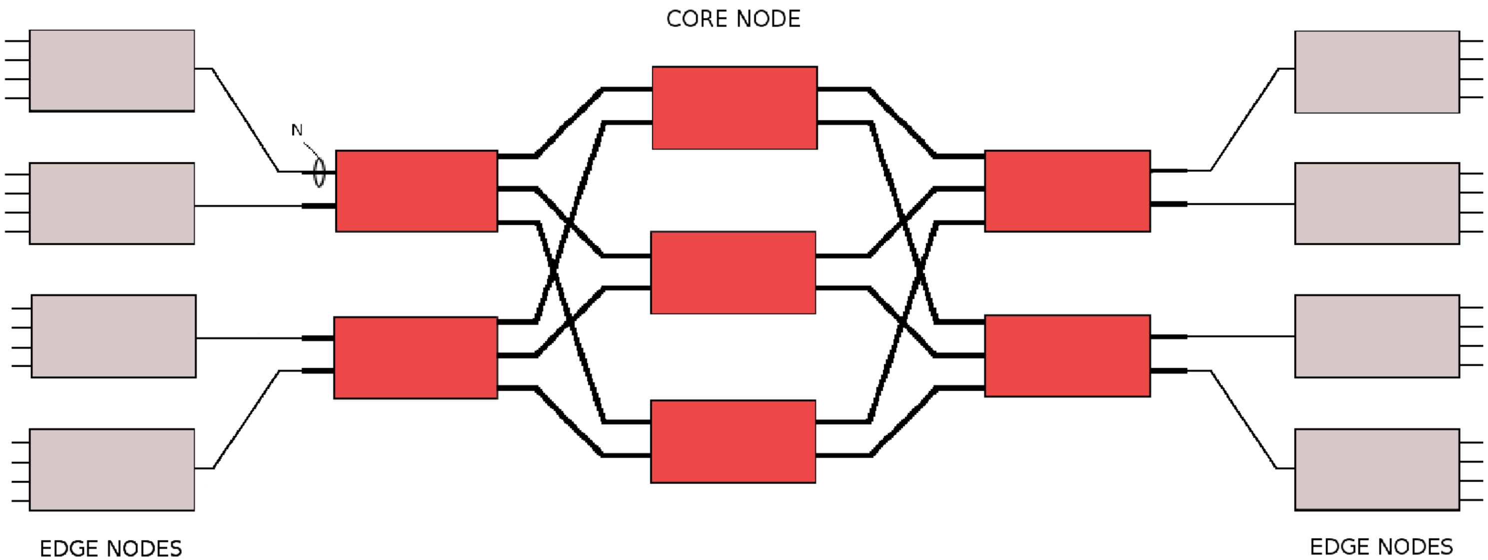
Proposal:
Switching bursts by encoding them as a function of the requested output, i.e., to associate a code to each output wavelength

New Code based OBS core router

- Encoders and decoders
- Fixed Output Wavelength Converters
- WOBS 2008 in London, U.K.

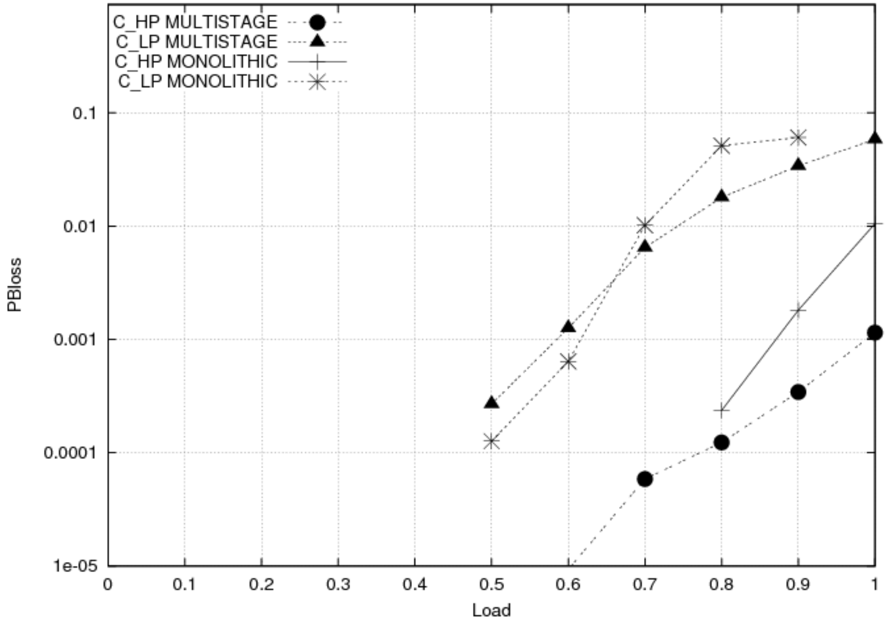


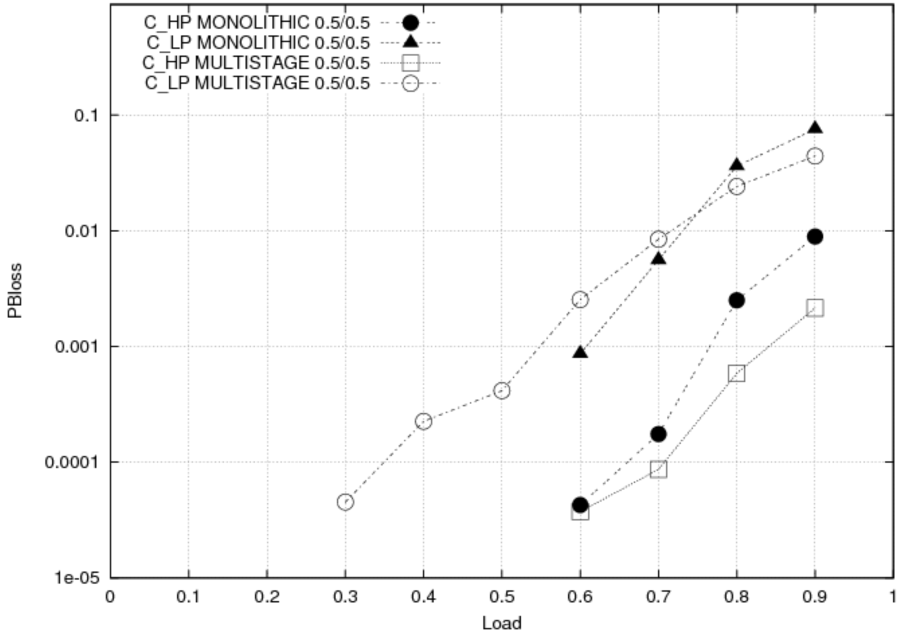
3 stage CLOS switch



- Link rate (each wavelength) = 10 Gbit/s
- Incoming traffic: two classes of service (p_{HP} and p_{LP}), M/Pareto
  - with basic packet size = 512 bytes; $\alpha_{on\text{-}HP} = \alpha_{on\text{-}LP} = 1.2$
- JET reservation mechanism: extra-offset for HP bursts = 18 μs
- Edge nodes: time assembly algorithm with Tmax = 2 μs
- LA-FFVF scheduling algorithm
- Control packet size = 16 bytes

Numerical Results

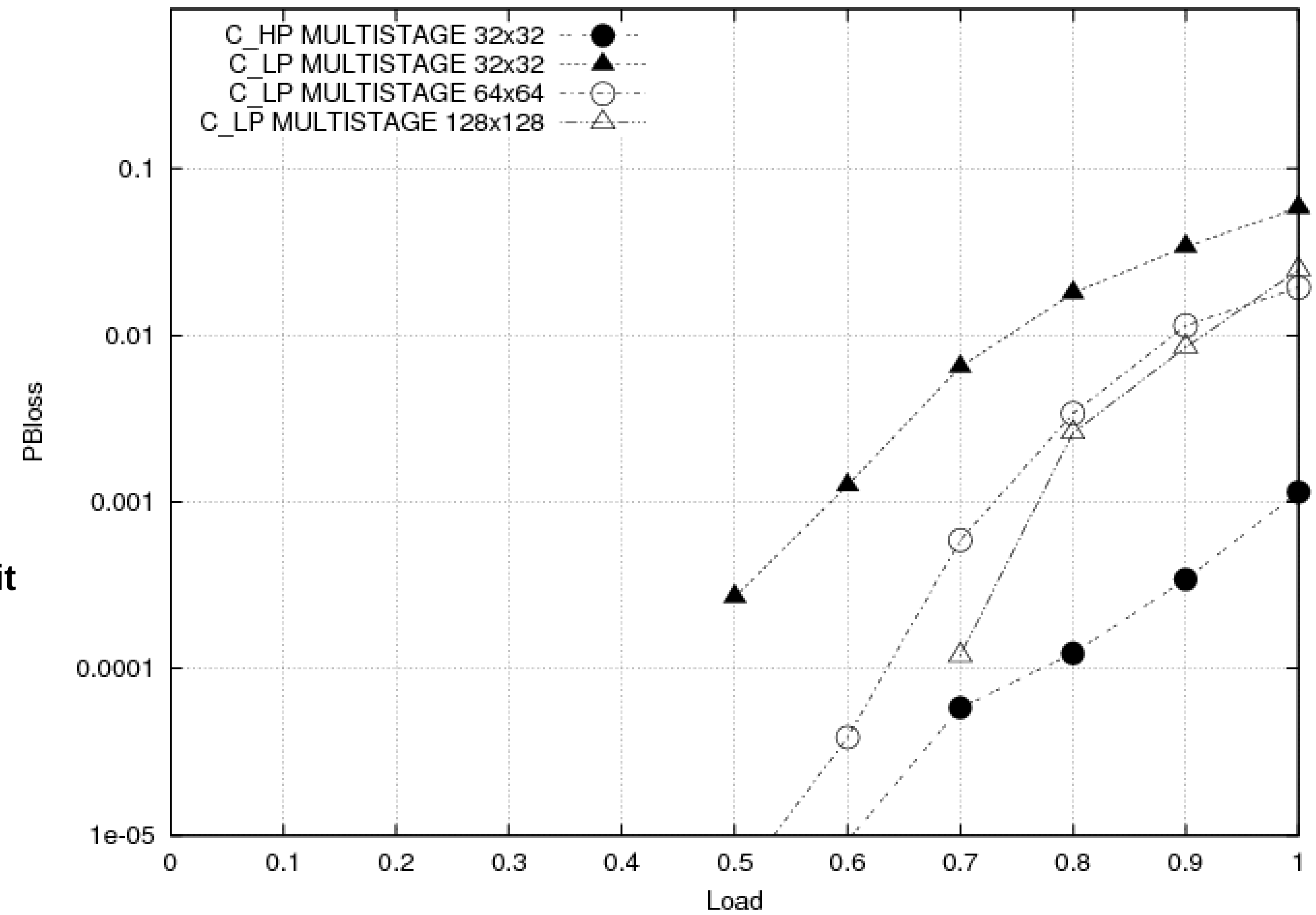




- 32 x 32 switches
- Incoming traffic into edge nodes is M/Pareto
- 3 stage seems to perform slightly better than monolithic
- 0.7 load can be sustained with loss = 10-4 for HP and 10-2 for LP bursts or
- 0.55 load to have loss < 10-5 for HP and 10-3 for LP bursts

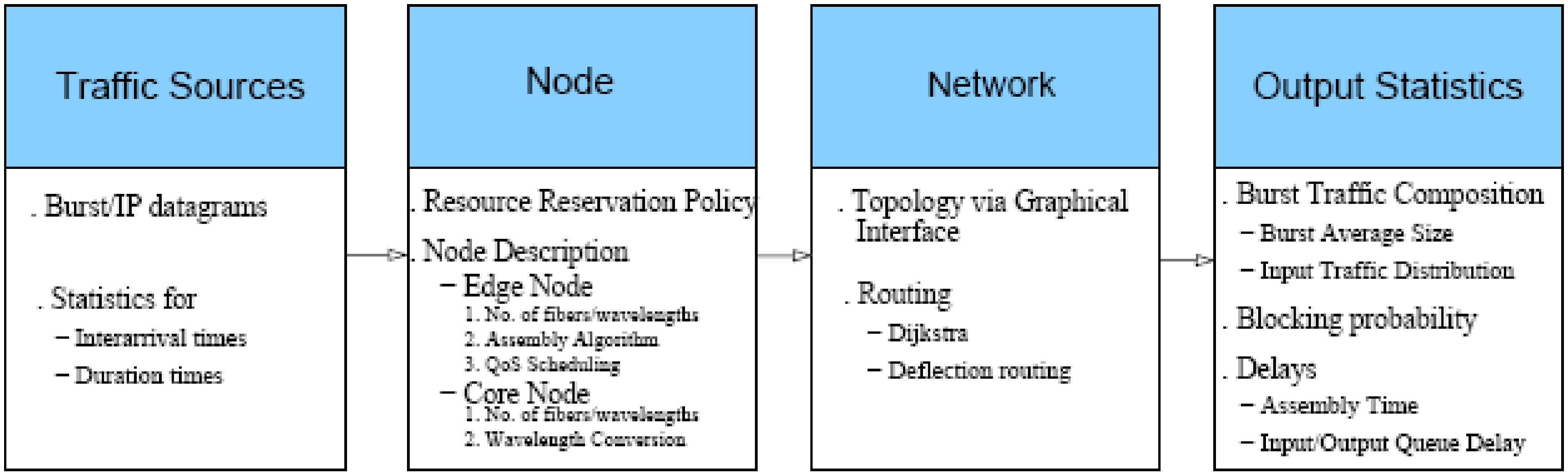
Numerical Results

- 128x128 seems the limit
- M=4, N=32
- 128 wlghts at 10 Gbit/s
- 1.2 Terabit/s as total
- For loads < 0.6 no loss



3-stage Clos is a Terabit Switch basically non blocking for load < 0.6

M_OBS_Sim: LOGICAL SCHEME



(demo available at **http://www.dii.unimore.it/~mcasoni**)

M.Casoni, E.Luppi. U.Manzoli, M.L. Merani,
"M_OBS_SIM: a Powerful Modular Optical Burst Switched (OBS) network SIMulator",
Simulation Modelling Practice and Theory, vol. 14 (2006), pp. 874–883, *Elsevier Journal*

Conclusions

- A novel multi-stage switching architecture based on optical codes has been proposed and evaluated for core nodes in OBS networks
- Optical codes have been used for coding incoming bursts as a function of the selected output wavelength to perform the switching function
- Encoders and decoders are used
- The proposed multi-stage architecture has been compared with a monolithic switch
- Performance evaluation in terms of burst blocking probability

Main result:

3-stage Clos is a Terabit Switch basically non blocking for load < 0.6

Current work:

evaluation of power consumption and comparison with other switching architectures

THANK YOU FOR YOUR ATTENTION

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… suggestions are very very welcome