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 simplification
  - 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
**Goal**: better synergy between the mature electronic technologies and the new optical technologies (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 transparent
    - 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
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
- **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.
- Encoders and decoders
- Fixed Output Wavelength Converters
- WOBS 2008 in London, U.K.
- 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; $\alpha_{on-HP} = \alpha_{on-LP} = 1.2$
- JET reservation mechanism: extra-offset for HP bursts = 18 $\mu$s
- Edge nodes: time assembly algorithm with $T_{max} = 2 \mu$s
- LA-FFVF scheduling algorithm
- Control packet size = 16 bytes
□ 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
- 128x128 seems the limit
- $M=4$, $N=32$
- 128 wghts 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. Casoni, E. Luppi, U. Manzoli, M. L. Merani,  
“M_OBS_SIM: a Powerful Modular Optical Burst Switched (OBS) network SIMulator”,  
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