Circuit switching and Time-domain Optical Sub-wavelength Switching Technologies: Evaluations on the Power Consumption

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Introduction

- Fast increase of traffic and of the energy consumption in networks is becoming a critical issue
- Transport networks particularly stressed since energy increases proportionally to the traffic
- Necessary to look for new switching technologies more energy efficient:
  - Larger traffic aggregation
  - Use of transparent transmission
Circuit switching solutions

- **Opaque circuit switching**
  - All traffic processed electronically at each node
  - Expensive and energy consuming

- **Transparent circuit switching**
  - Direct connection between sources and destinations using optical logical channels (lightpaths)
  - No electronic processing required, but scarce aggregation capability

- **Translucent circuit switching**
  - Different demands groomed in the same lightpath and multi-hop paths
  - Limited electronic processing, better aggregation capability
Sub-wavelength switching technologies

- Transparent switching of traffic at a granularity finer than the wavelength
  - Sharing of the interfaces in the time domain
  - Same transmitter/receiver can send/receive from several nodes

Circuit paradigms

Sub-wavelength technology

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The goal of our study

- Several technologies have been already introduced
- Not our purpose to propose new sub-wavelength technologies or to find which is the most performant
- Our target is to dimension the network…
  - Retrieve transmitters and receivers required to sustain a given traffic
- … and to compare them in terms of required resources and power consumption with respect to current switching solutions
Our sub-wavelength technologies

- **Wavelength routed**
  - Destinations have uniquely assigned one or more wavelengths
  - Transmitter tunes the wavelength according to the destination
  - No intermediate route processing

- **Two main categories of subwavelength technologies:**
  - Lossy and loss less
Categories of sub-wavelength technologies

- Lossy:
  - No reservation and coordination among nodes for the transmission
  - Bursts can compete for the same resources
  - Contentions can happen and bursts have to be discarded

- Loss-less:
  - Complete reservation of the resources
  - Successful transmission of data is guaranteed
  - Reservation scheme of the resources depends on the technology
Optical Burst Switching (OBS)

- Lossy technology
- Inspired by Label OBS\(^1\)
- A source node sends burst by properly tuning the transmission wavelength according to the destinations

Time-domain Wavelength Interleaved Network (TWIN)\(^1\)

- Loss-Less
  - Transmission scheduled according to time slots
  - Scheduling performed using a request-grant scheme
  - Grant blocking at the source

- Any physical topology

Packet Optical Add Drop Multiplexer (POADM)\textsuperscript{1}

- Loss-less:
  - Time slotted, scheduling performed using a distributed reservation scheme
- Only ring topology

Scenario

- Analysis performed considering a ring of 10 nodes and uniform traffic

- Circuit switching technologies:
  - **Opaque and full transparent**: dimensioning retrieved using analytical formula
  - **Translucent**: a meta-heuristic minimizing number of Tx and Rx has been utilized to obtain the dimensioning

- Sub-wavelength switching technologies
  - Modeled using Omnet++ Network Simulation Framework
  - Simulations used to determine the dimensioning
Power consumption model

- We just consider power consumption of network interfaces (Tx and Rx) operating at 10 Gbps

- Circuit switching technologies:
  - We estimate that conventional Tx and Fixed Rx, consume respectively 22 W and 18 W

- Sub-wavelength switching technologies
  - Burst mode receivers have a power consumption equal to the one of the Fixed Rx
  - Tx including a fast tunable laser consume 26 W, at most 4 W more than Fixed Tx due to faster electronic control circuitry
Dimensioning of the resources

- **X-axis:** total amount of traffic received at a node from all other nodes
- **Y-axis:** number of Tx and Rx per node
- **Opaque:**
  - Required resources steeply increase
  - Bad performance due to electronic processing of all the traffic
Dimensioning of the resources

- Transparent:
  - Good performance only for throughput close to the transmitter capacity
  - As soon as the per node traffic rate is over the transmitter capacity, the required resources increase steeply
  - Not likely operational scenario, great effort required to upgrade system
**Dimensioning of the resources**

- **Translucent:**
  - Always performing better with respect to opaque and transparent
  - Select the best trade-off between opaque switching and direct optical transmission

- **OBS:**
  - Over-dimensioned in order to recover the losses, it may be fine just for very low loads
Dimensioning of the resources

- TWIN and POADM:
  - Both achieve similar results, increase of required resources is smooth
  - Near the Tx capacity perform slightly worse with respect to Transparent and Translucent circuit switching
Power consumption savings

- Power consumption savings of sub-wavelength technologies with respect of translucent circuit switching
- OBS can not achieve any savings
- POADM and TWIN:
  - decrease the power consumption at low loads
  - at high load the larger power consumption of the fast tunable transmitters makes translucent more energy efficient
Conclusion

- We have retrieved the dimensioning in a simple network scenario for different switching technologies and traffic loads.

- Among circuit switching, translucent is the best performing.

- Lossy sub-wavelength technologies are not scalable.

- Loss less technologies show interesting performance for low traffic scenario achieving significant power consumption savings.
Future work

- Perform a more detailed power consumption analysis
  - Different node architecture of each technology
  - Sub-wavelength technologies have a limited need of electronic switching, involving further power savings

- Dimensioning of mesh networks
  - POADM can be implemented considering the network as a logical ring

- Not uniform traffic scenario
Thank you!

Any question?

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