Design Space Exploration of Optical Interfaces for Silicon Photonic Interconnects
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Design Space Exploration of Optical Interfaces for Silicon Photonic Interconnects

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• Multi-cores + Data intensive applications (memory accesses, data exchanges)
  • \( \Rightarrow \) high requirement for data communication

Challenges: higher **performances**, higher **power efficiency**, higher **integration**

Source: Moustafa Mohamed, et al., CODE-ISSS’11.(slides)
Context: Optical interconnect

- Multi-cores + Parallel applications + memory needs + ...
  - high requirement for data communication
- Classical NoC → bottleneck !!
- Need for more efficient communication infrastructure
  - Optical NoC could be a solution

- Silicon Photonics
  - High throughput: Wavelength Division Multiplexing, WDM
  - Lower dynamic energy
  - Lower latency

- We need design space exploration, in particular for Optical interface !!
Context: Needs for Design Methodologies

Easily programmable and power efficient processors

Key enabler: Design methodologies

Focus of Design Space Exploration for 2 parts of the interface

• channel allocation

• laser power management

Key enabler: Emerging technologies

DGFET

Silicon photonics

3D
Outline

- Context and problematic
- DSE of waveguides and wavelengths allocation
- DSE of laser power management
- Conclusion
Silicon Photonics Interconnects

Rx

Tx

ONI: Optical Network Interface

Micro-resonators

CMOS-compatible VCSEL
(Vertical-Cavity Surface-Emitting Lasers)

Source:
Communication schemes

IP source

Waveguide

ONI: Optical Network Interface

ONIa

ONIb

ONIc

Req λ1

NACK

Req λ2

Req λ2

ACK

Transmission

IP target

Optical layer

TSV

Electrical layer

IP core / cluster

Control network

Router

Router

Router

Electrical layer

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18-mar-16
Channel size design tradeoff

Channel size: number of waveguides and wavelengths per request, i.e. bandwidth

Best design option?

data transfer time (optical domain) versus request latency (electrical domain)
Simulation parameters

- **Models based on Gem5**
  - Quasi-cycle accurate simulator
  - Integration of C++ models of optical components
  - Based on Garnet NoC

- **Simulation characteristics**
  - Ring-based optical interconnection
  - 8-tiles (ARM, 4-KB L1 cache) 32 bits channel width
  - 2 architectures:
    - 4 waveguides, 16 wavelengths for each waveguide
    - 16 waveguides, 16 wavelengths for each waveguide
  - Modulation speed: 10Gb/s
  - Real application traffic (SPLASH-2)
### Controller Synthesis Results

- 28nm FSDOI technology (Synopys Design Vision environment)

<table>
<thead>
<tr>
<th>Network size</th>
<th>4 waveguides</th>
<th>16 waveguides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel size (wg, wl)</td>
<td>Area (um²)</td>
<td>Power (mW)</td>
</tr>
<tr>
<td>(16,16)</td>
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<td>NA</td>
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<td>(8,16)</td>
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<td>21385</td>
<td>5.33</td>
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</tbody>
</table>

**Simple controllers**

**More complex controllers**

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Results: SPLASH-2 benchmark

Best channel size: 1 waveguide, 8 wavelengths

Sepúlveda15] Communication Aware Design Method for Optical Network-on-Chip
J.Sepúlveda, S.Le Beux, J.Luo, C.Killian, D.Chillet, H.Li, I.O’Connor, O.Sentieys
Outline

- Context and problematic
- DSE of Waveguides and wavelengths allocation
- DSE of laser power management
- Conclusion
Impact of the waveguide sharing

- Communication between 2 pairs of Ips
  - One wavelength for each communication
  - No conflict between communications

- Laser power at nominal value
Impact of the waveguide sharing

- Communication between 2 pairs of Ips
  - One wavelength for each communication
  - Temporal and spatial conflicts in the waveguide

- Laser power at nominal value
  - SNR ↘ BER ↗
Impact of the waveguide sharing

- How can we manage SNR and BER?

- Laser power can be
  - SNR
  - BER

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18-mar-16
Impact of the waveguide sharing

How can we manage SNR and BER?

Laser power can be
- SNR
- BER

Or ECC can be included in the communication channel
- SNR = BER
- but BW

Impact of the waveguide sharing

- **Strategy**
  - How to find a good tradeoff between
    - management of laser power
    - introduction of codec in the channel
  - Could be supported by the allocation protocol
    - req. and ack. messages can help to estimate the loss in the optical channel
Outline

• Context and problematic

• DSE of Waveguides and wavelengths allocation

• DSE of laser power management

• Conclusion
Conclusion and future works

- Optical NoC Interface design
  - critical issue in silicon photonics interconnects → need DSE at different levels
    - low level DSE/management
      - laser power and ECC
    - high level DSE/management
      - channel allocation / allocation protocol

- Future works
  - tradeoff between Electric vs Optic energy performances
    - on-line strategy for channel allocation
  - thermal aware design method
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Thank you !

Questions ?