Efficiency-Oriented Design Automation for Wavelength-Routed Optical Network-on-Chip (WRONoC)

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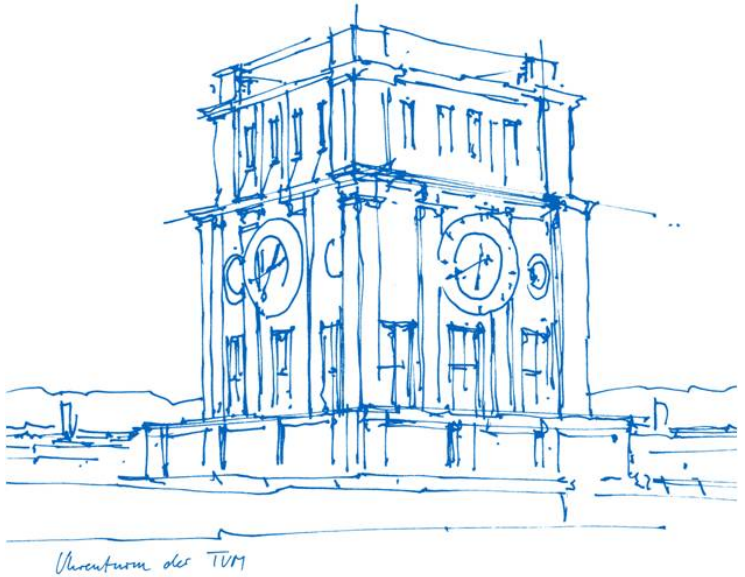

Outline

- Need of efficient WRONoC design
- Efficiency-oriented WRONoC design automation
  - Design step separation: topology generation followed by physical design
  - Comprehensive template-based synthesis
  - Subtraction from fully-connected router
- Conclusion

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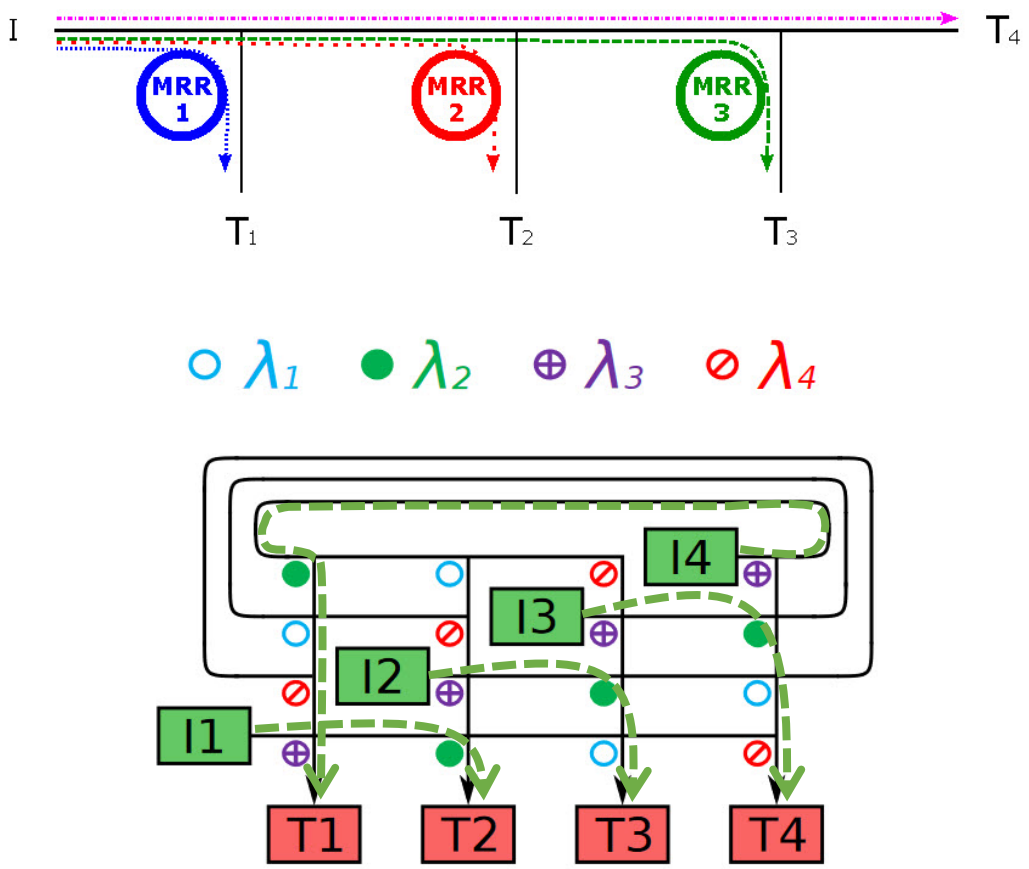
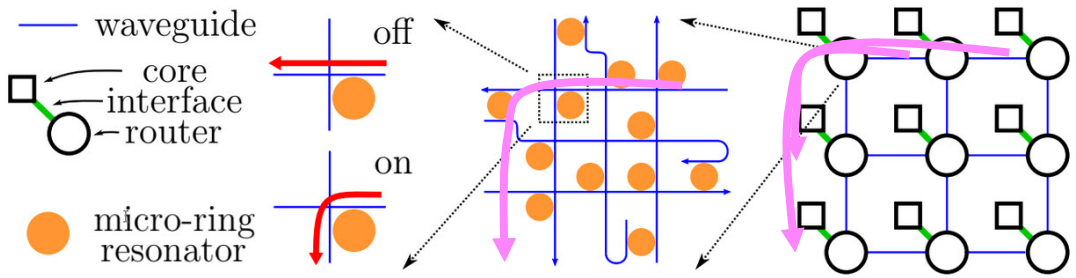
WRONoC Working Mechanism

- Usage of microring resonators (MRRs) for multiplexing and demultiplexing
- Dedicated signal path determined in design phase for each tuple (initiator, target, wavelength)
- No path overlap between signals with the same wavelength → enable all-to-all simultaneous communications

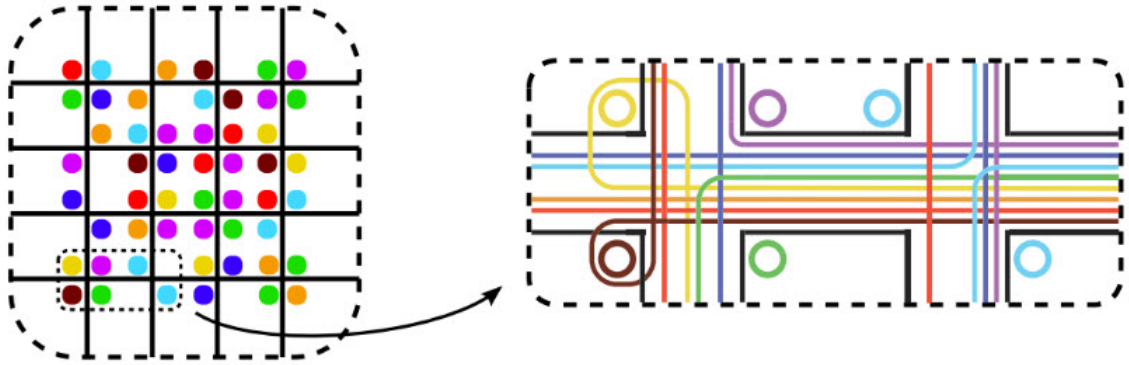


Passive WRONoC vs Active ONoCs

- Advantages:
  - No control resource
  - No scheduling effort
  - No congestion control
  - No signal path construction → no uncertain signal delay
- Disadvantages:
  - Extensive usage of MRRs (1 MRR serves constant #paths) → **Scalability issue!** → suitable for application-specific usage → design optimization to save resources



Active ONoCs



Passive WRONoCs

WRONoC Design Features

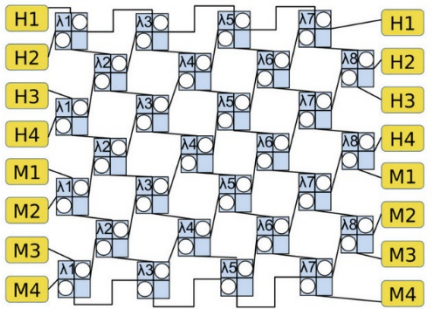
Topological features:

- Waveguide connection structure
- MRR topological locations
- MRR resonant wavelengths
- Signal wavelength assignment
- Signal path routing

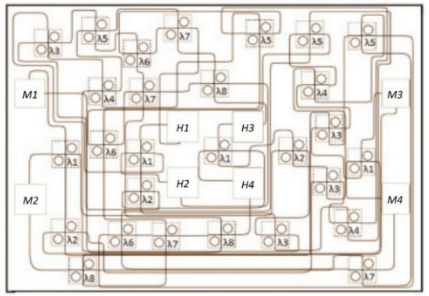
Physical design features:

- Waveguide routing
- MRR placement

source: *Engineering a Bandwidth-Scalable Optical Layer for a 3D Multi-core Processor with Awareness of Layout Constraints, NOCS'12*, Luca Ramini, Davide Bertozzi and Luca P. Carloni.



Manual topology



Manual layout

- All these need to be done during the design phase → **Challenges of efficiency!**
- Application-specific optimization **& Beyond human capability!**

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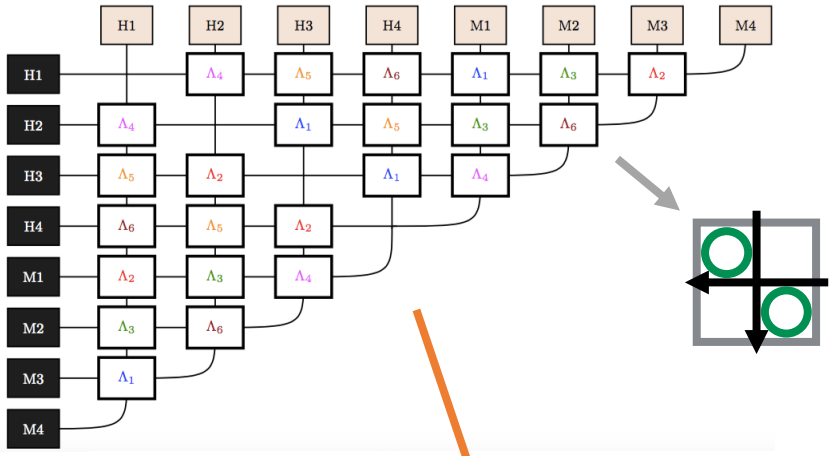
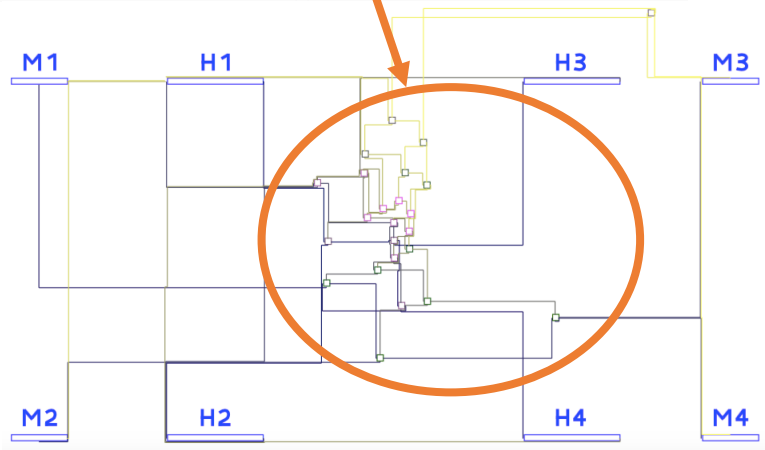
Design Step Separation

- Topology generation and then physical design – conventional and intuitive
- Advantages:
  - Intermediate solution, i.e. topology, is observable
  - Fast
- Disadvantages:
  - Mismatch of node positions → long waveguide detours and many waveguide crossings

Automatically-synthesized topology





Automatically-synthesized layout

source: *CustomTopo: A Topology Generation Method for Application-Specific Wavelength-Routed Optical NoCs, ICCAD'18*, Mengchu Li et al.

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Comprehensive Template-Based Synthesis

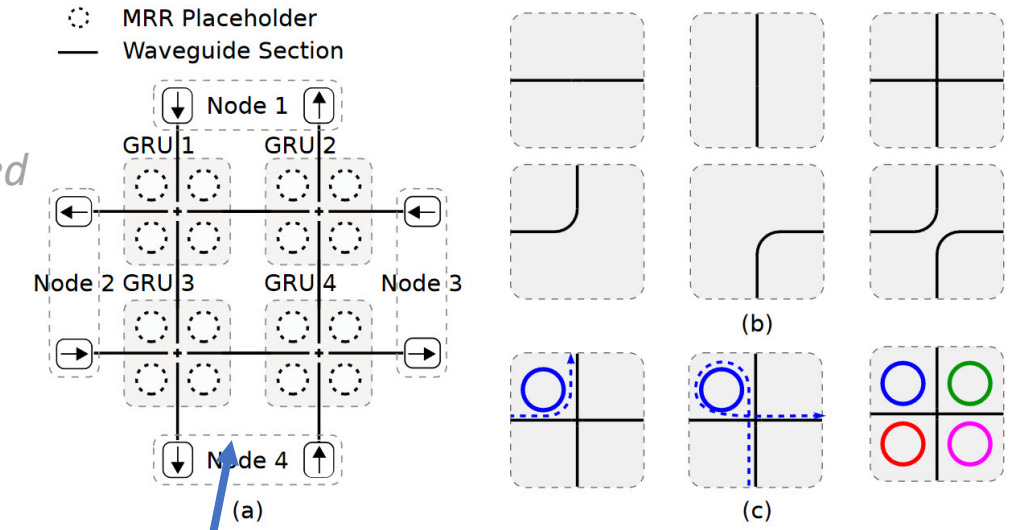
Topological features:

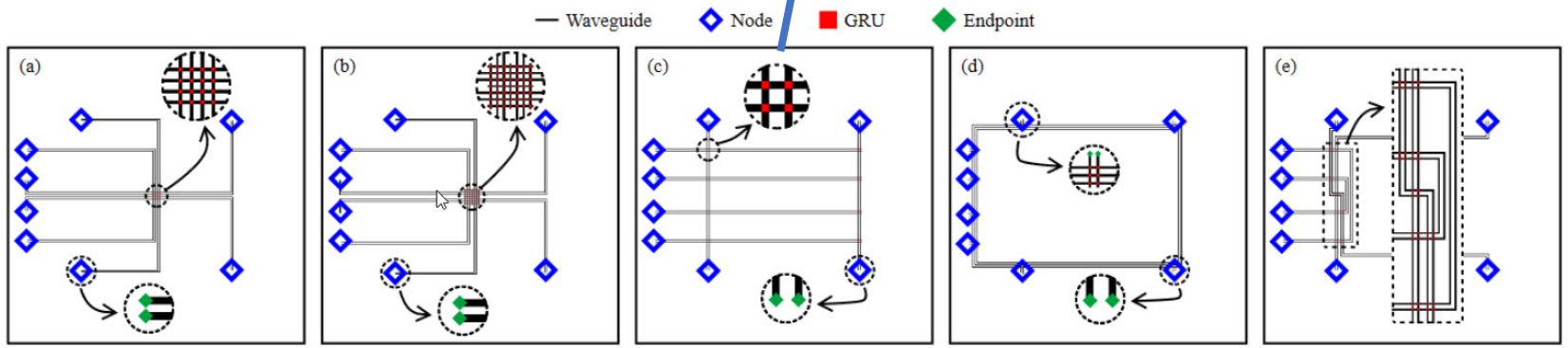
- Waveguide connection structure
- MRR topological locations
- MRR resonant wavelengths
- Signal wavelength assignment
- Signal path routing

to be determined

Physical design features:

- Waveguide routing *fixed*
- MRR placement *placeholders*





source:
PSION+: Combining logical topology and physical layout optimization for Wavelength-Routed ONoCs, TCAD'20, Alexandre Truppel et al.

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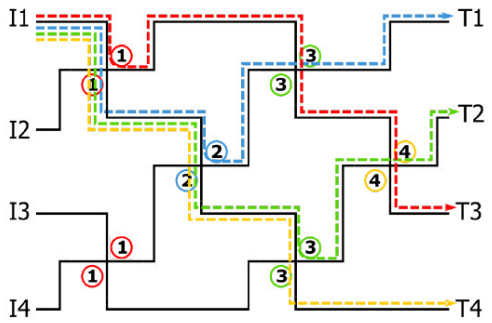
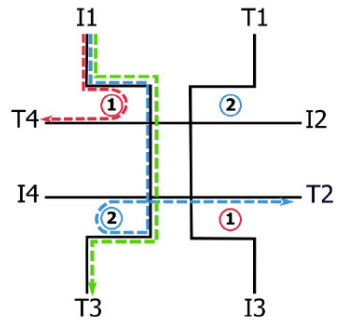
Subtraction from Fully-Connected Router

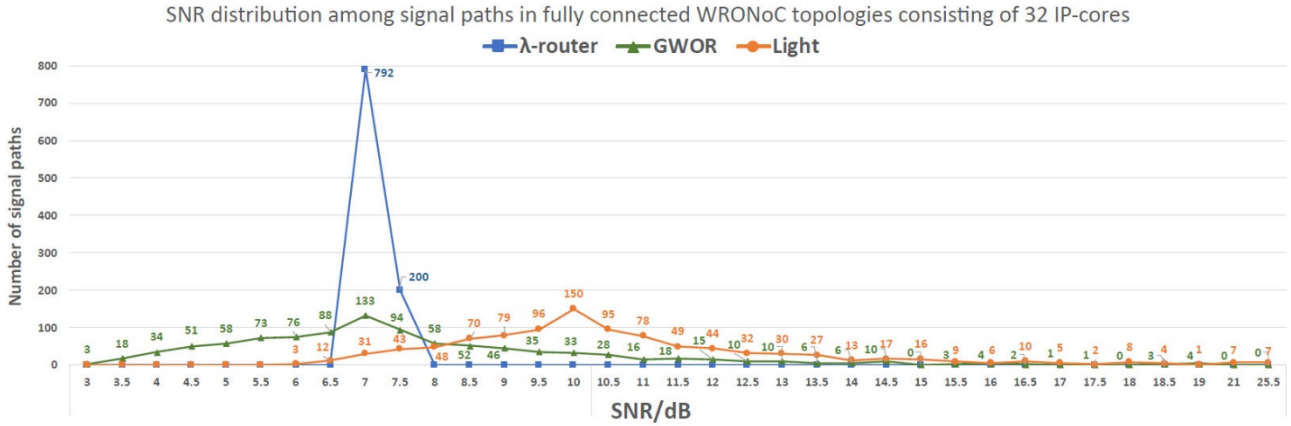
- Optimization by signal path binding
- **Key** requirements:
  - Physical-design aware and friendly
  - Wide range of SNR distribution

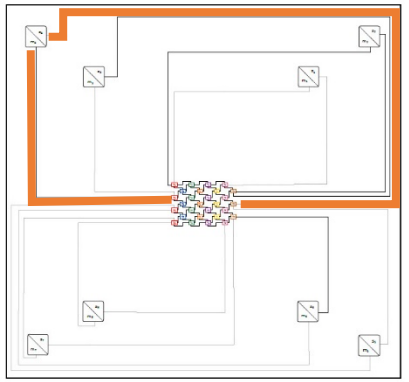


4×4 λ-router

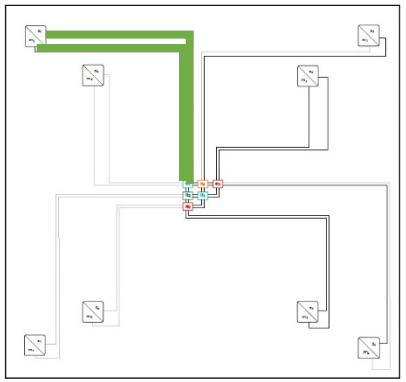


4×3 Light





(a) An 8×8 λ-router



(b) An 8×7 *Light* topology

source: *Light: A Scalable and Efficient Wavelength-Routed Optical Networks-On-Chip Topology, ASP-DAC'21*, Zhidan Zheng et al.

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Conclusion

- Optimization of application-specific WRONoC is worthwhile but difficult
- Being efficient is the prerequisite of WRONoC design automation tools
- The following methodologies are worth further exploration for efficient WRONoC design automation:
  - Design step separation: topology generation followed by physical design
  - Comprehensive template-based synthesis
  - Subtraction from fully-connected router
- Staying efficient will be more challenging considering the following aspects:
  - More design features, e.g. power distribution network
  - More optimization metrics, e.g., crosstalk and bandwidth

Many thanks to my colleagues: Mengchu Li, Alexandre Truppel, Zhidan Zheng, and Prof. Ulf Schlichtmann

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