Optical Multicast Ring and Wavelength Reusable Routing for Optical Network on Chips (ONoC)

Feiyang Liu

Supervisors: Haibo Zhang, Zhiyi Huang, and Yawen Chen

Outline

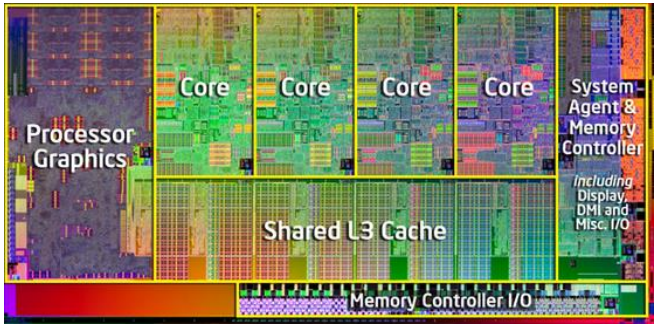
- **Background**
- Motivation
- Architecture and Communication
- Conclusions

Revolution on High-Performance Processor

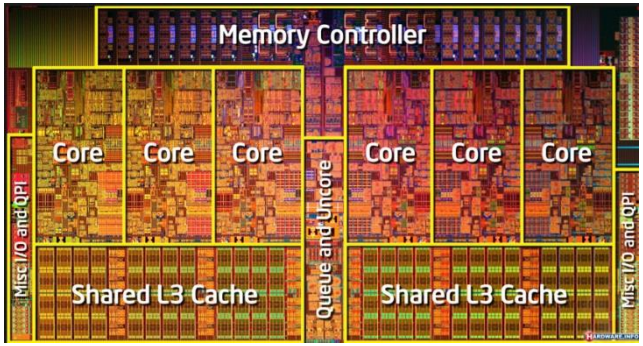
- How to improve the performance of our processors ?

✗ Increasing frequency, (<3.5 GHz).

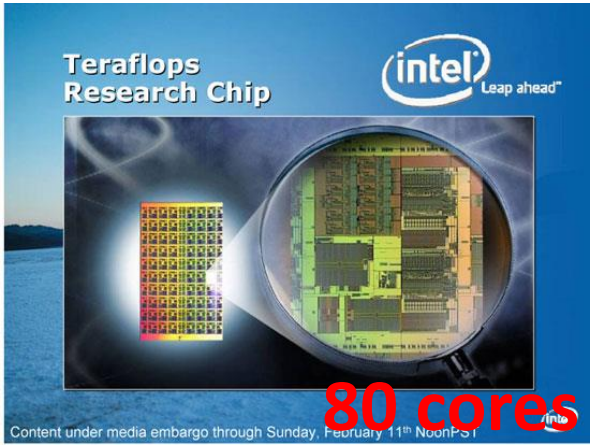
✓ Increasing cores (tens of --- hundreds of --- thousands of……).



Intel i7 2600K

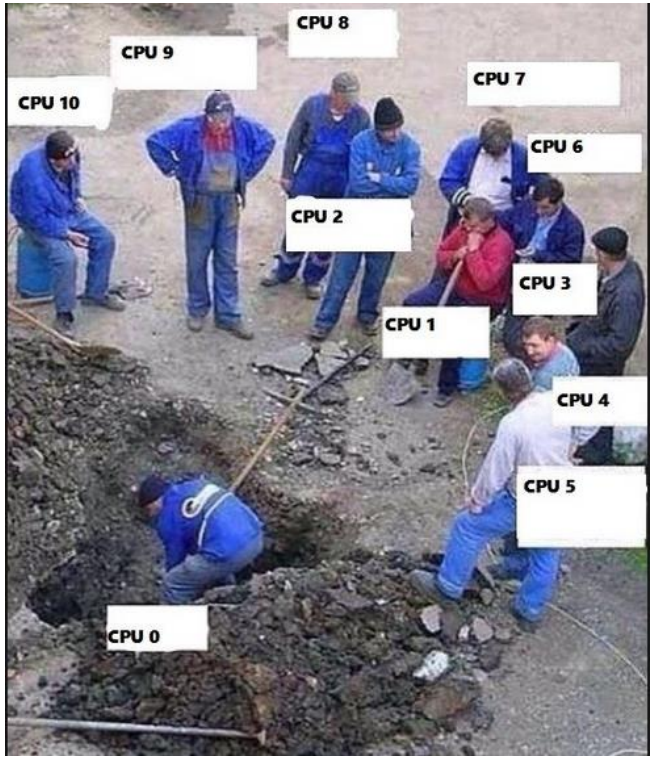


Intel i7 980X

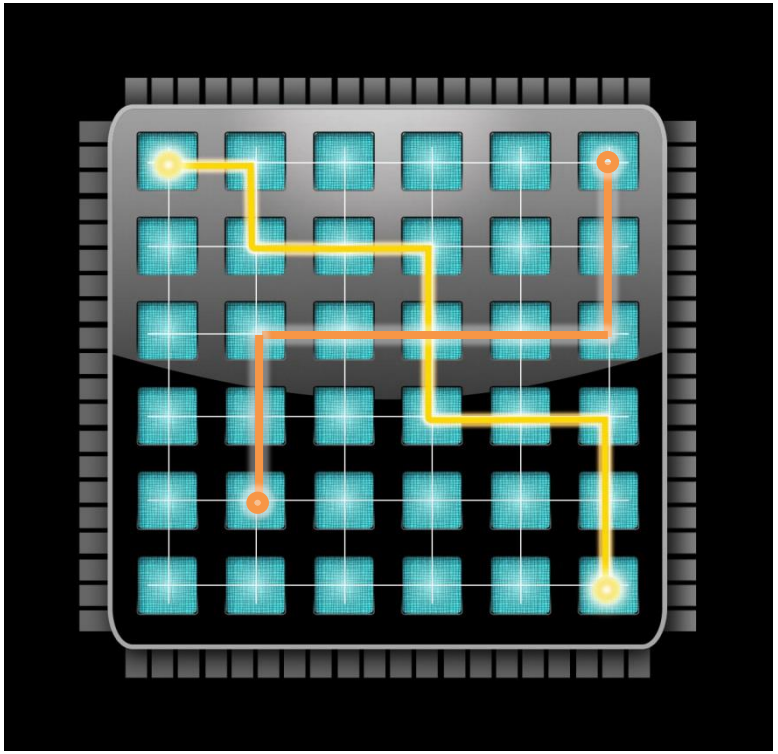


Communication Problem

- High-performance and efficient communication is a challenging problem.
- ***Optical Network on Chip*** (ONoC), silicon-based inter-core optical networking.



That happens with poor communication



Optical Network on Chip

ONoC Design

- Objective: *high-performance and efficient* inter-core communication.
- Solution: *network architecture and routing scheme.*

- **Advantages**:
  - Low transmission delay.
  - High bandwidth capacity.
  - Low energy dissipation.
  - Wavelength multiplexing.
  - Low crosstalk noise.

- **Disadvantages**:
  - No optical processing/buffering device.
  - Long optical path-setup delay.
  - Limited available wavelengths.
  - Low wavelength utilization with fixed wavelength allocation.
  - Electrical-optical conversion.

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Multicast Communication

- Multicast communication ***intensively exists*** in multicore systems.
- *in some cache coherence protocols, more than 30% traffic is multicast.*

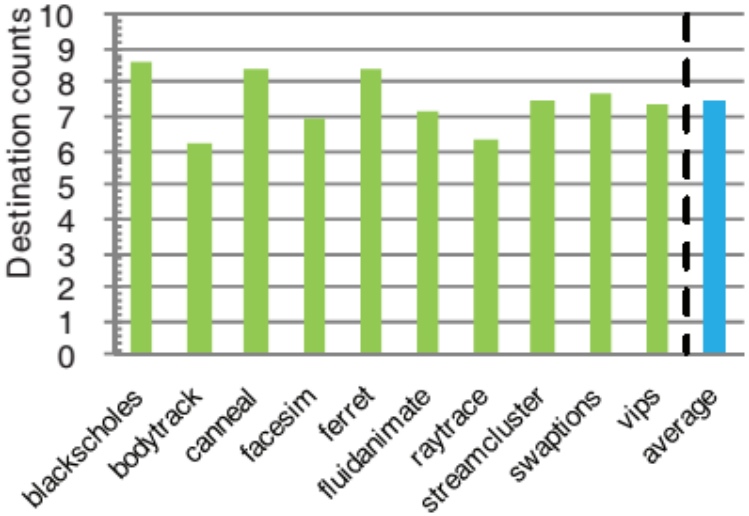
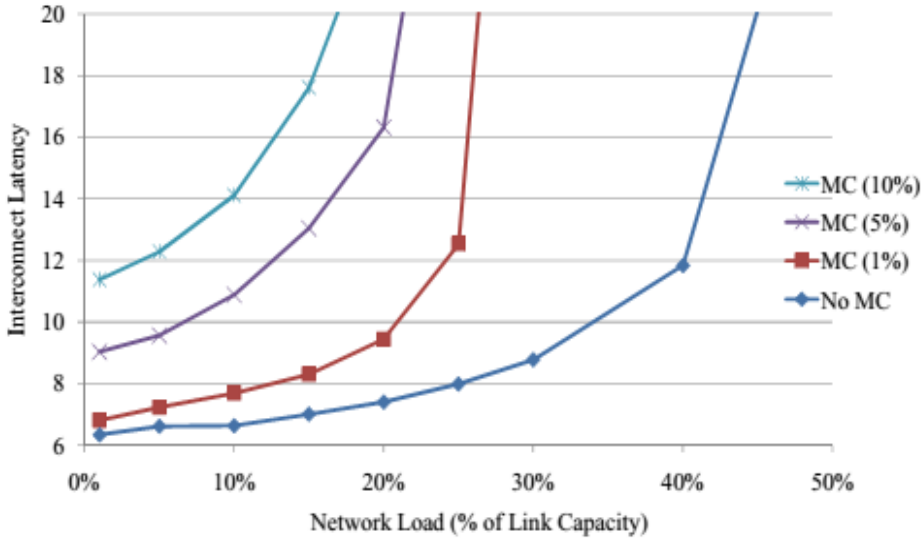


Figure 1. Average destinations per multicast for the PARSEC benchmarks.

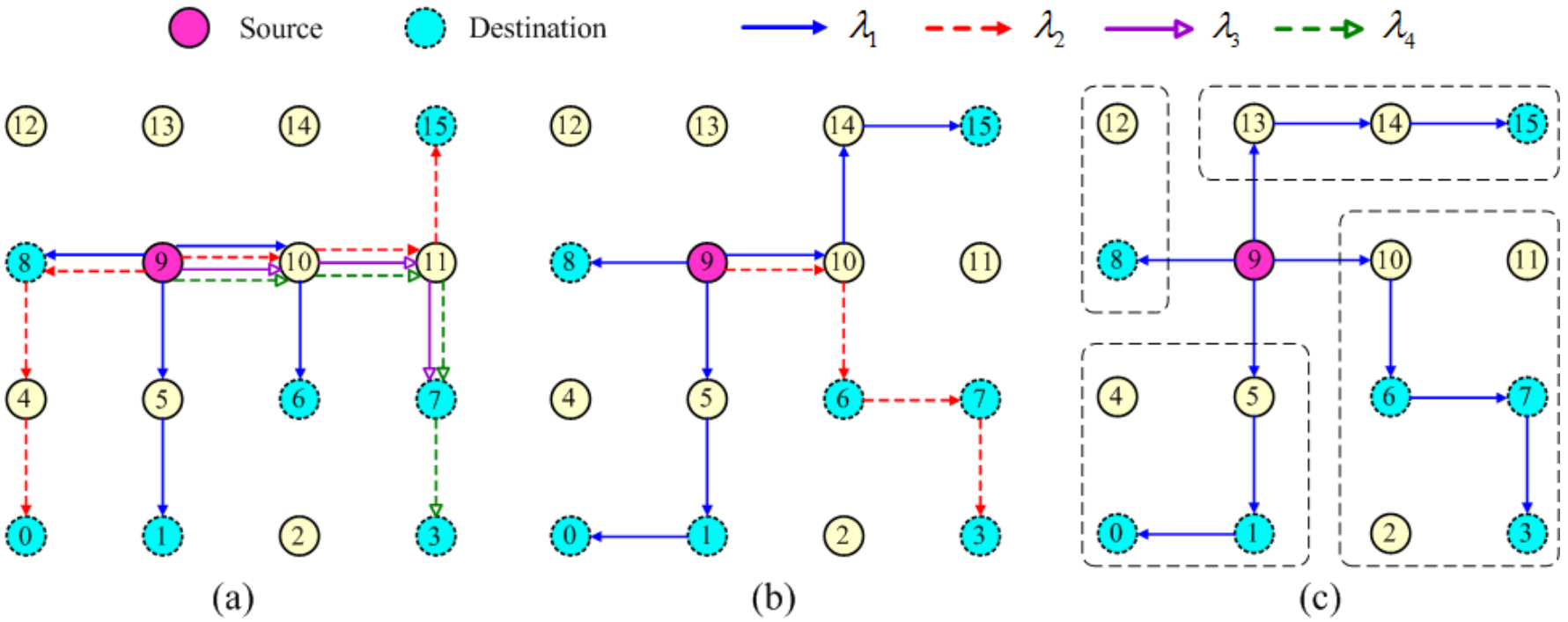
For 4*4 CMP running PARSEC traces (HPCA 2011)



Influence of multicast on packet delay, 4*4 NoC (ISCA 2008)

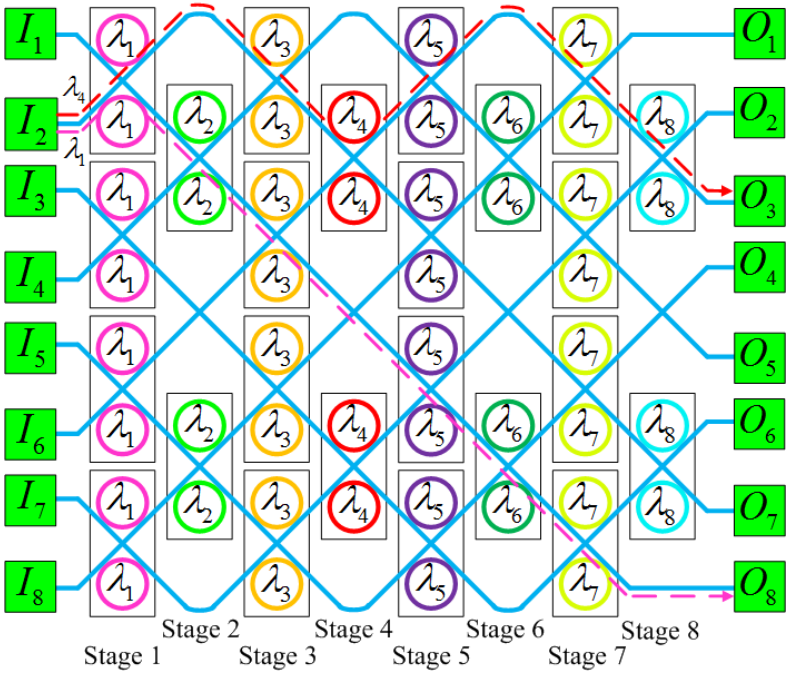
Replication-based Multicast Routing

- Send separate copy to every destination or a set of destinations.
- *e.g.*, unicast-based, tree-based, and path-based.
- Important drawback: ***Existing routing paths cannot be reused.***

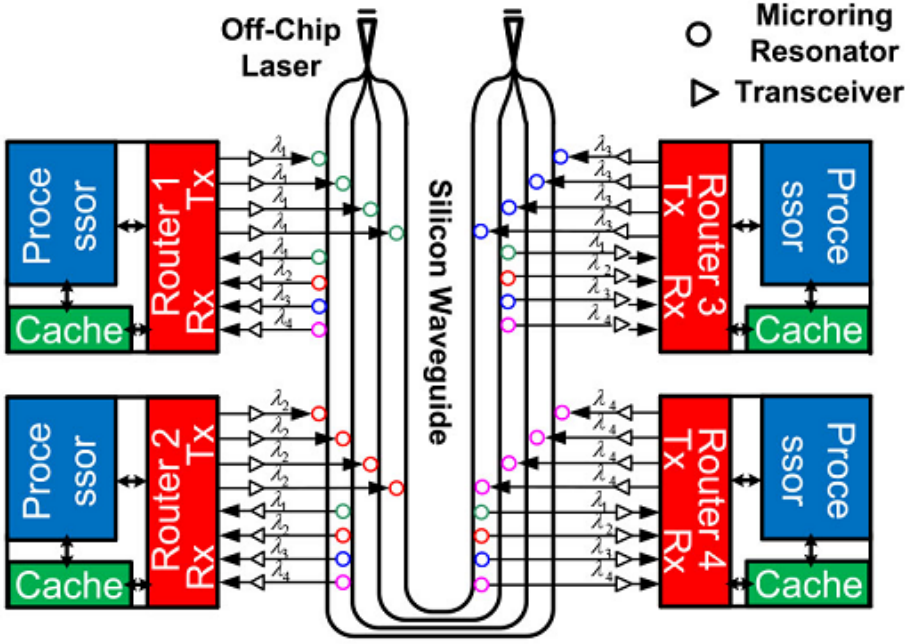


Multicast-Enabled Architecture

- ***Wavelength-routed*** ONoCs, static global connection and wavelength allocation.
- ***Limited scalability,*** due to constraints on available wavelengths.



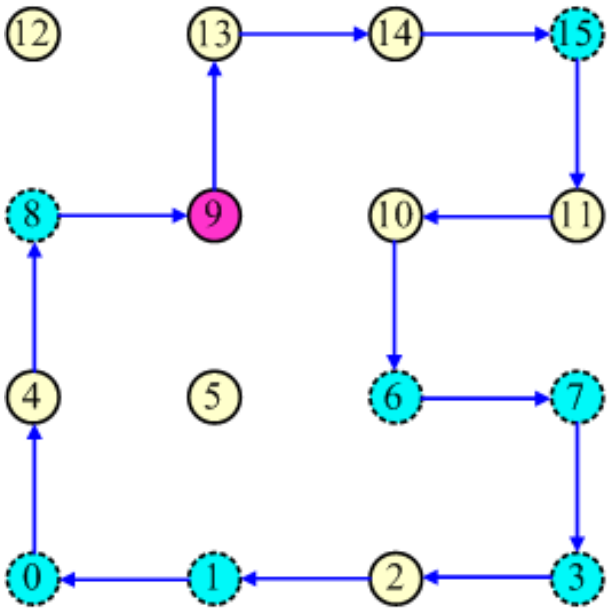
Optical Crossbar



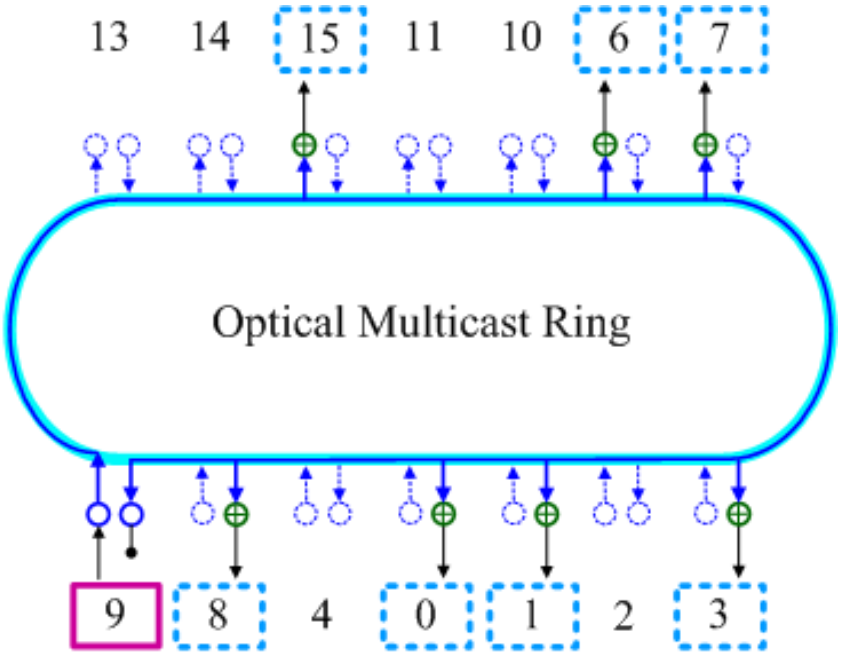
Global Optical Ring

Key Ideas

- ***Dynamical-established multicast ring***.
- ***Established ring reusing within multicast group***.
- ***Single-Write-Multiple-Read***.



(a)



(b)

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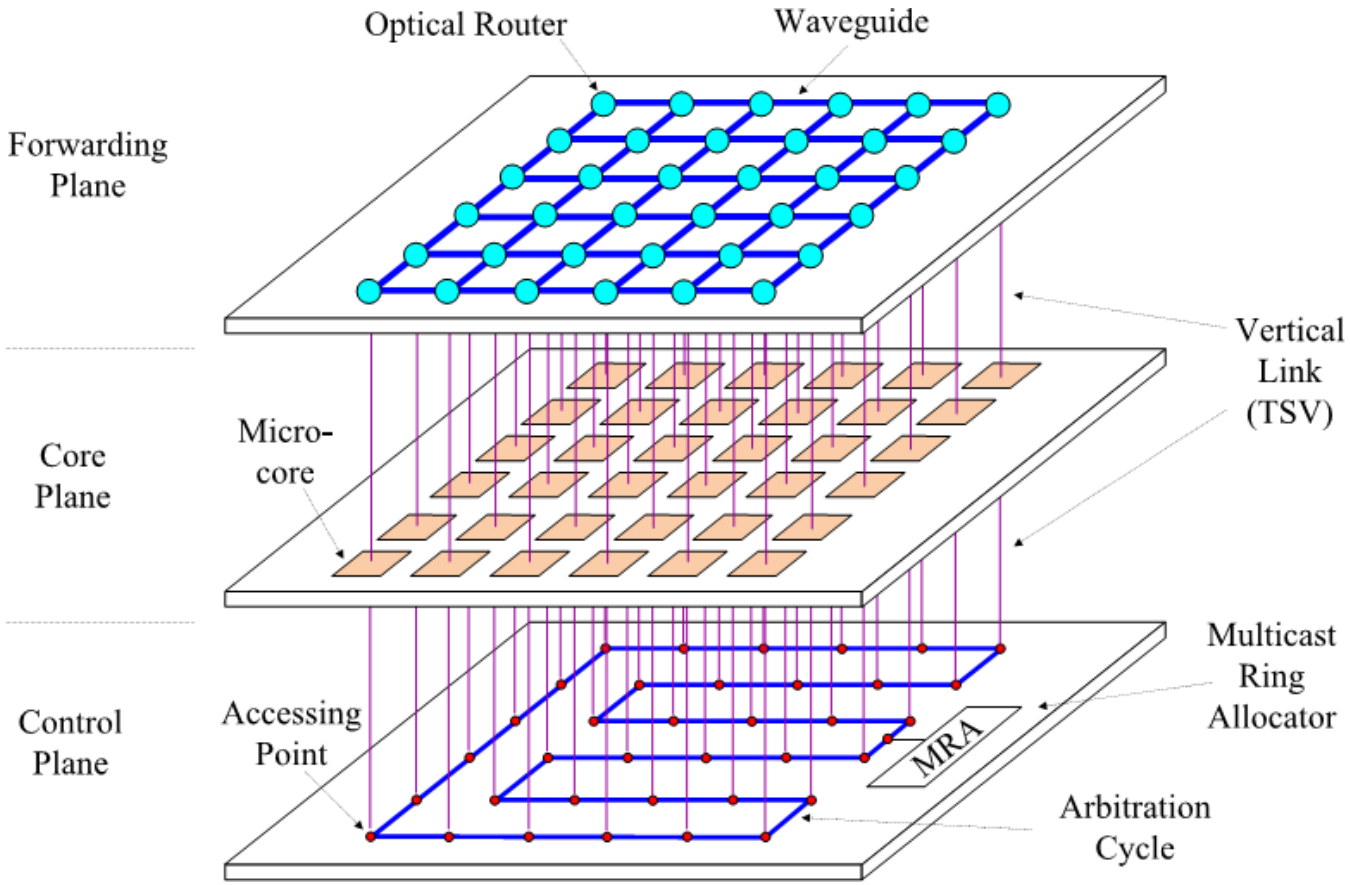
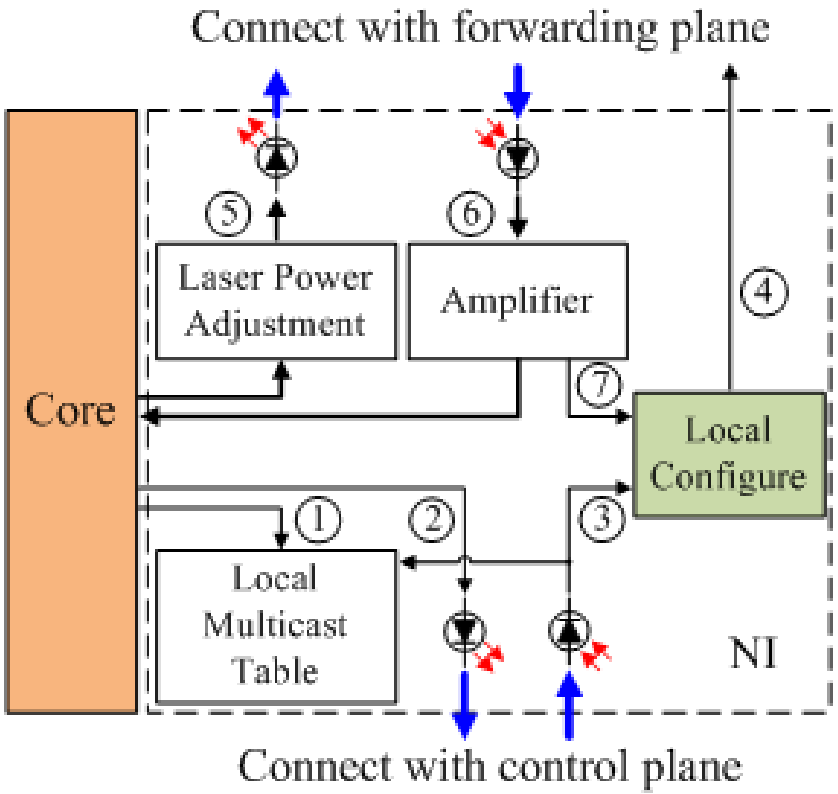
Architecture

- Borrow the idea of *Software Defined Networking*.
- Core plane, centralized control plane, optical forwarding plane.



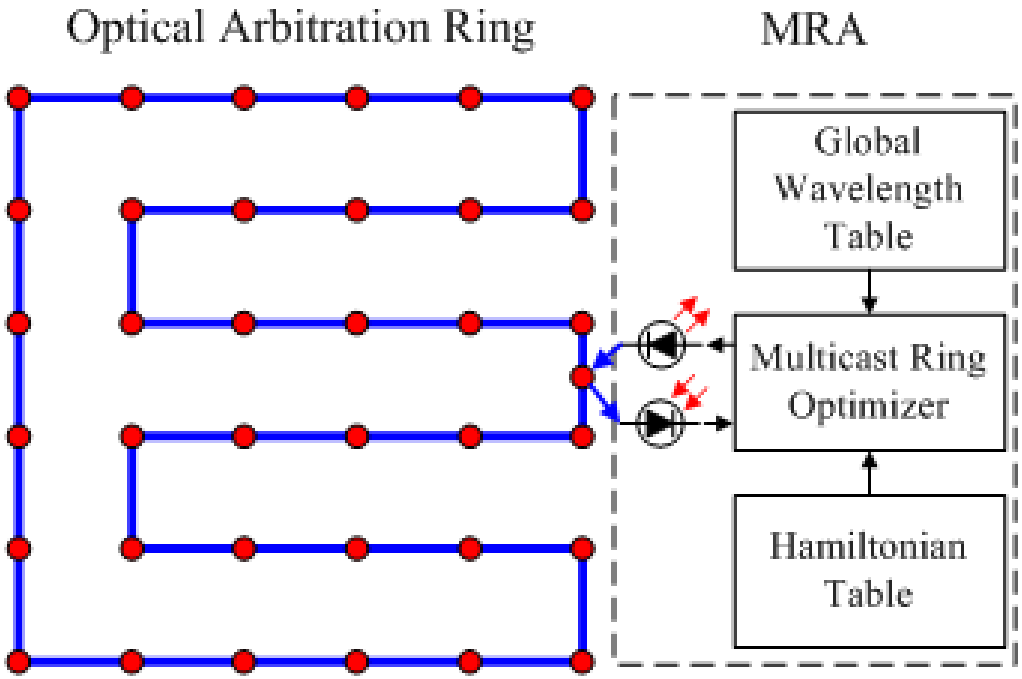
Network Interface

- The coordinator for multicast communication.
- Connecting with control plane for multicast ring establishment.
- Connecting with forwarding plane for optical transmission.



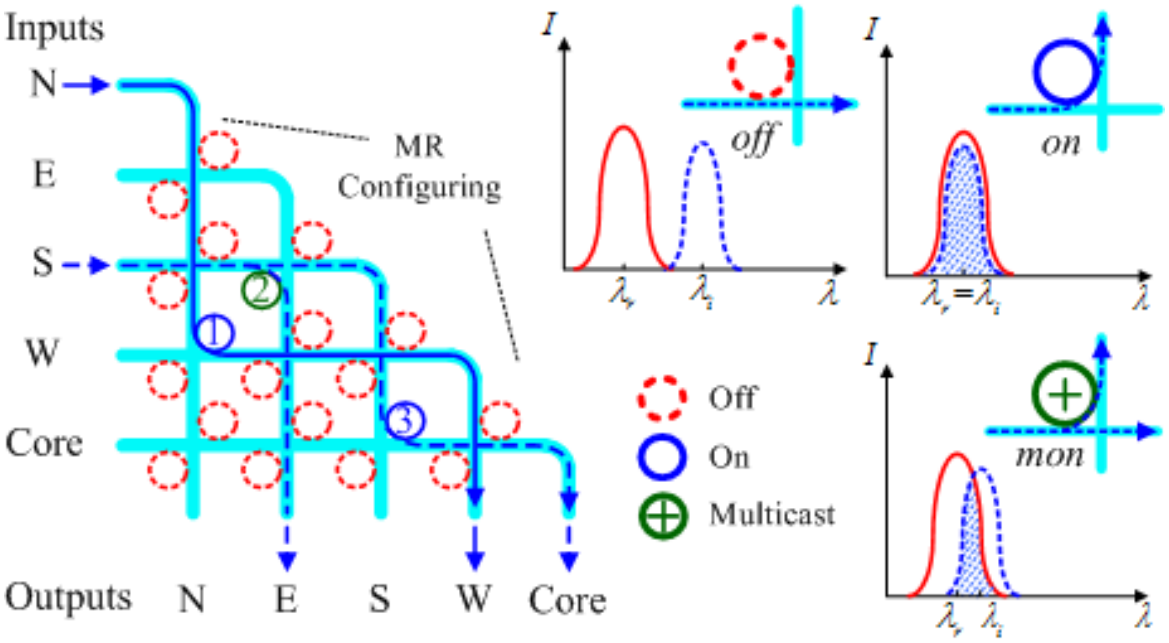
Control Plane

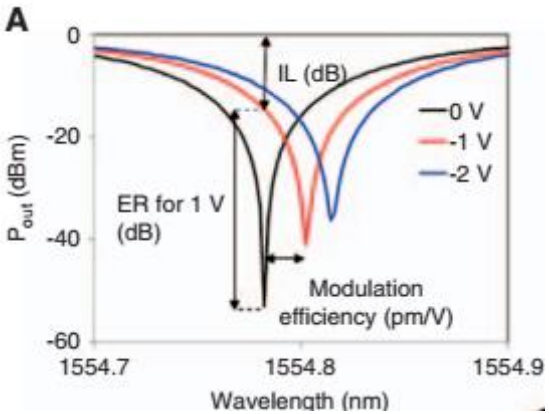
- ***Optical Arbitration Ring*** for collecting requests and distributing configuration packets. ⇒ Fast and Parallel.
- ***Multicast Ring Allocator*** for the centralized multicast ring discovery and wavelength allocation. ⇒ Global Optimal/Near-Optimal.



Forwarding Plane

- Multicast-enabled optical router
- Three states: ***off, on, multicast.***

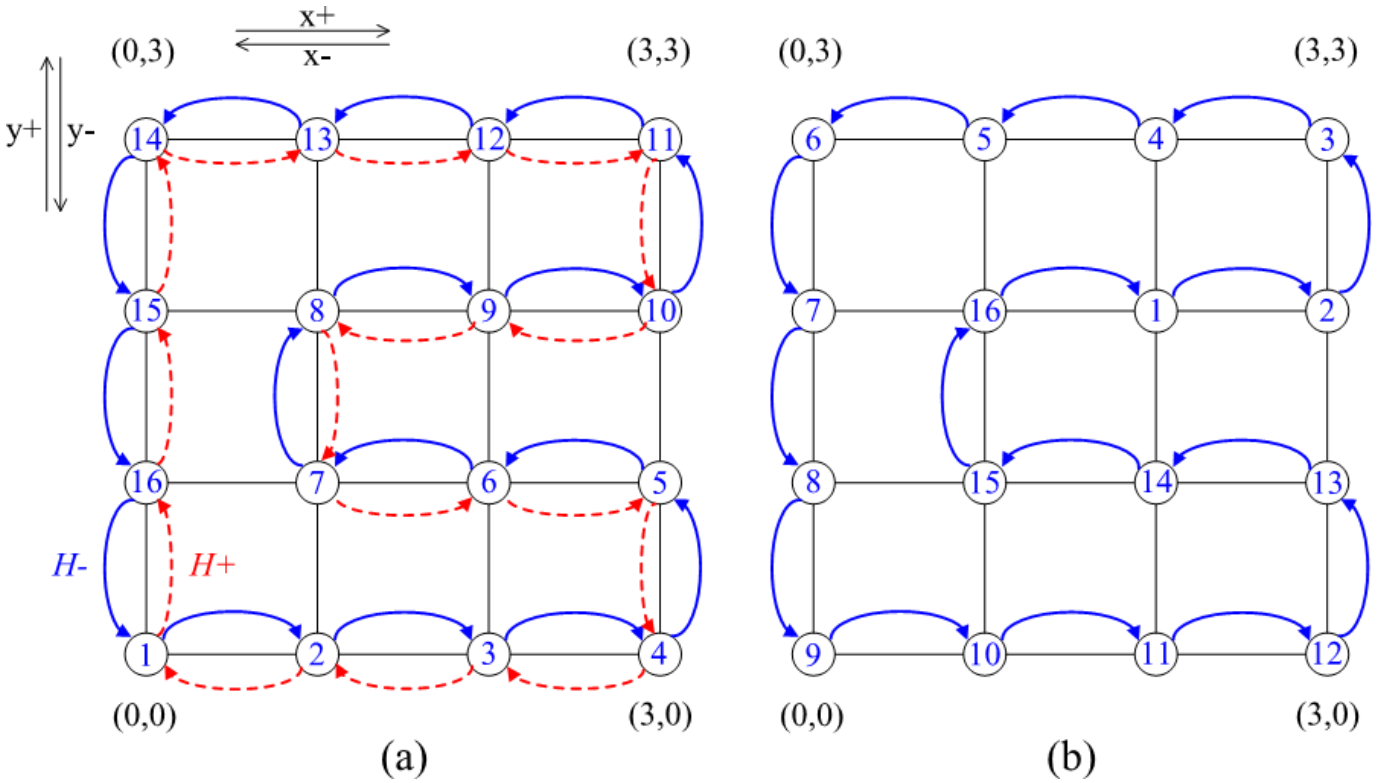




Multicast Ring Discovery

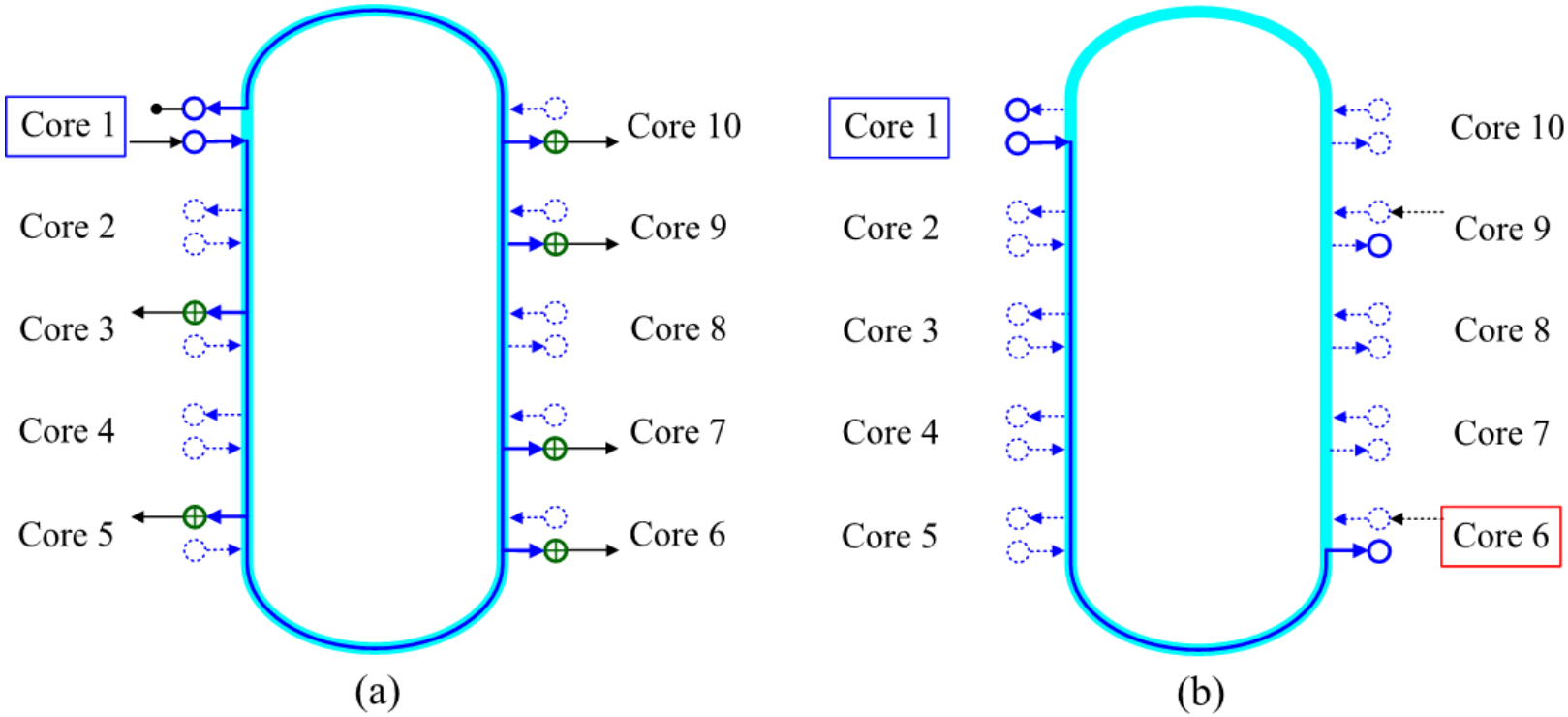
- Based on predefined Hamiltonian Cycle → ***Low computation complexity***.
- Optimized on the consideration of,
  - Minimal multicast ring length
  - Maximal wavelength utilization.

→ ***High capacity with limited wavelengths***



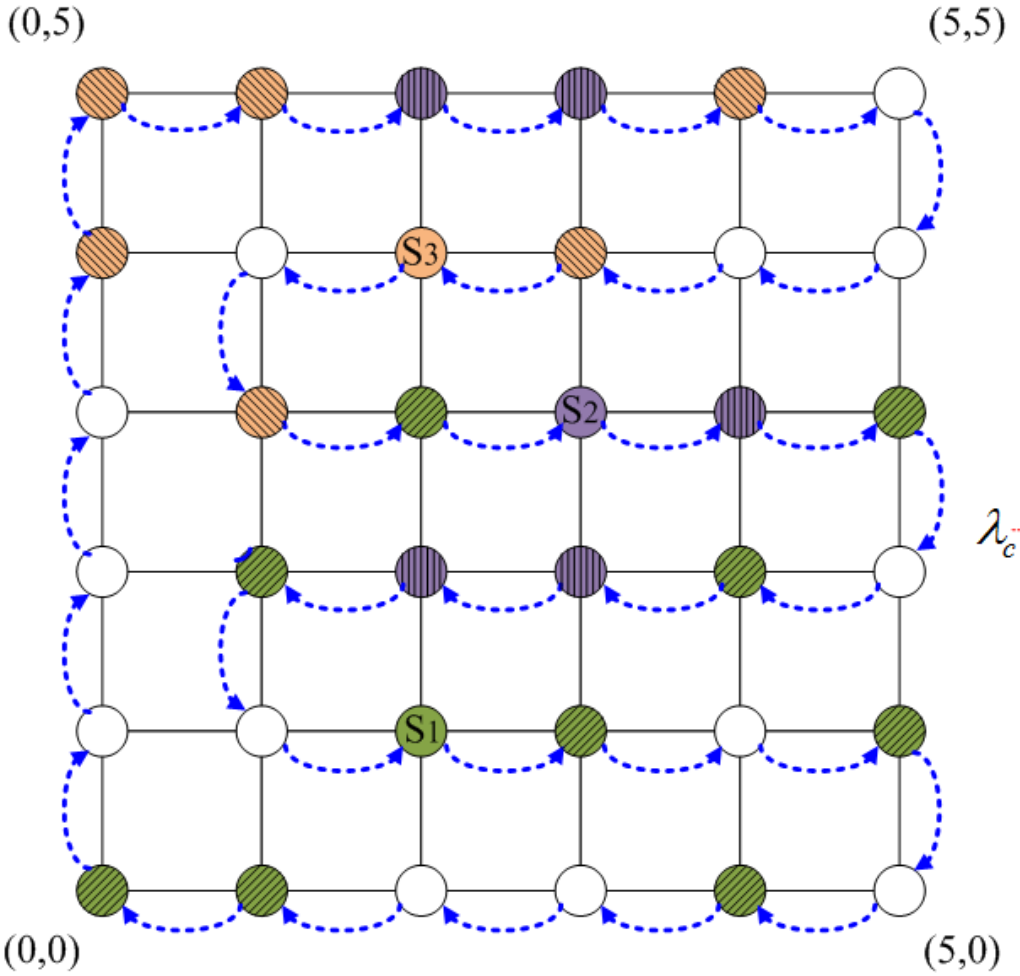
Multicast Ring Reuse

- Established multicast ring reused within the multicast group.
- Optical token arbitration.
- Interchange between routing and arbitration.



Multicast Routing Example

- Three multicast group and one common broadcast channel.



Multicast Group:

M_1 M_2 M_3

Wavelength:

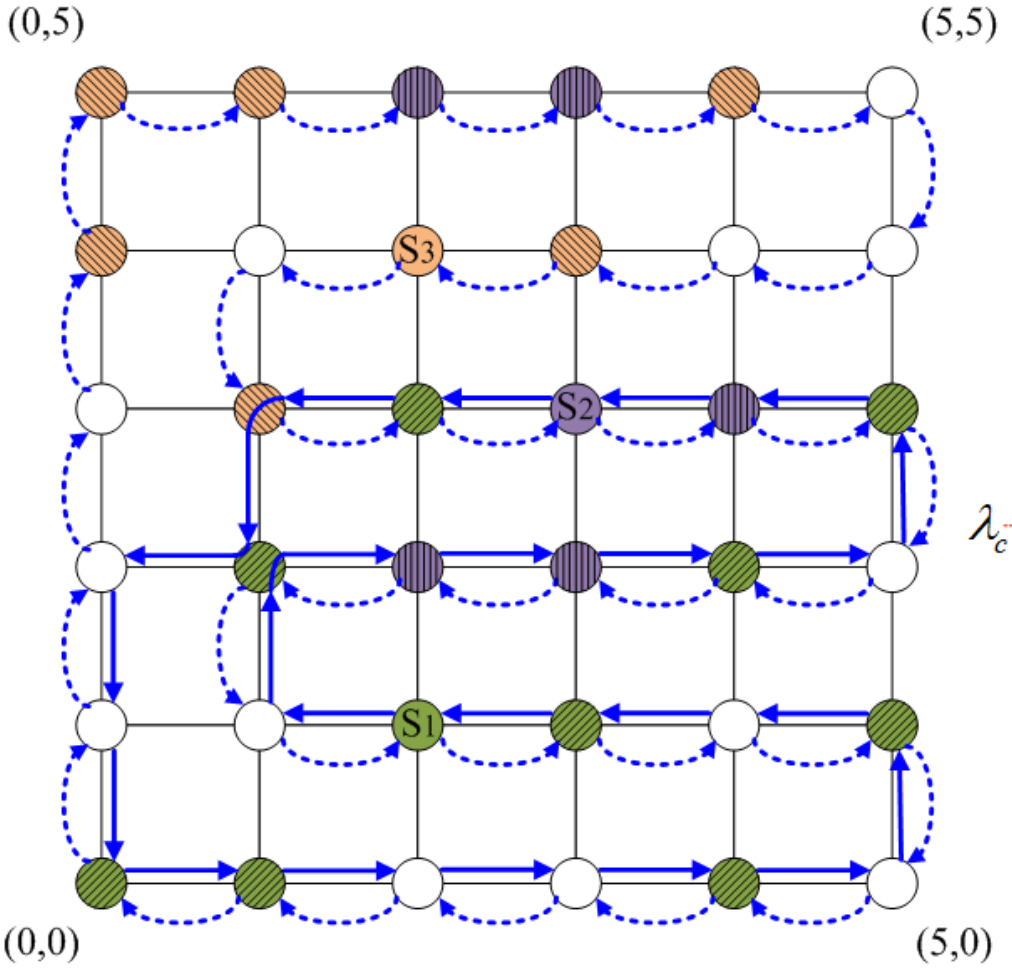
λ_1^+ λ_1^- λ_2^+

Wavelength Table:

λ_1^+	$\omega_{ij1} = 0, e_{ij} \in H^+$
$\lambda_c \rightarrow \lambda_1^-$	
λ_2^+	
λ_2^-	
⋮	⋮
$\lambda_{W_{\max}}^+$	
$\lambda_{W_{\max}}^-$	

Multicast Routing Example

- Routing for Multicast Group M1.



Multicast Group:

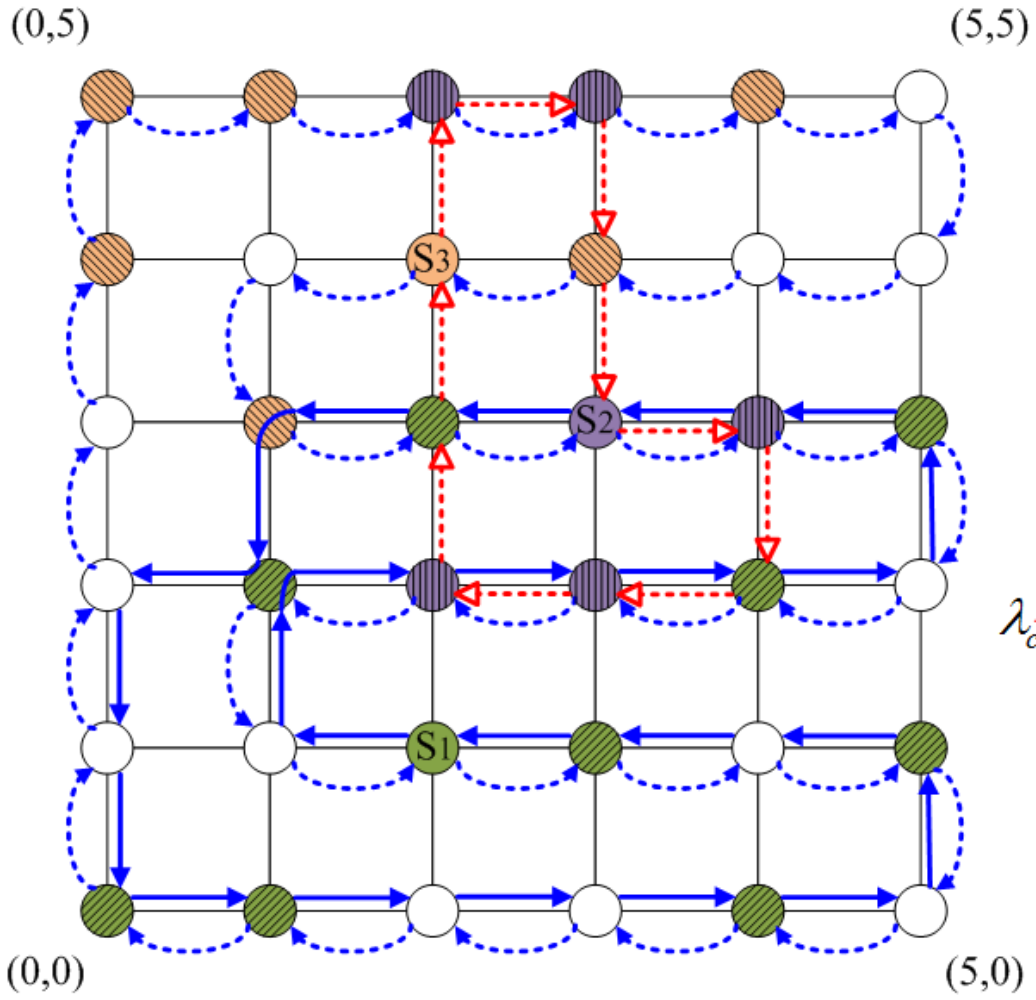
Wavelength:

Wavelength Table:

	λ_1^+	$\omega_{ij1}=0, e_{ij}\in H^+$
λ_c	λ_1^-	$\omega_{ij1}=0, e_{ij}\in P_1; \omega_{ij1}=1, e_{ij}\in H^- - P_1$
	λ_2^+	
	λ_2^-	
	⋮	⋮
	$\lambda_{W_{\max}}^+$	
	$\lambda_{W_{\max}}^-$	

Multicast Routing Example

- Routing for Multicast Group M2.



Multicast Group:

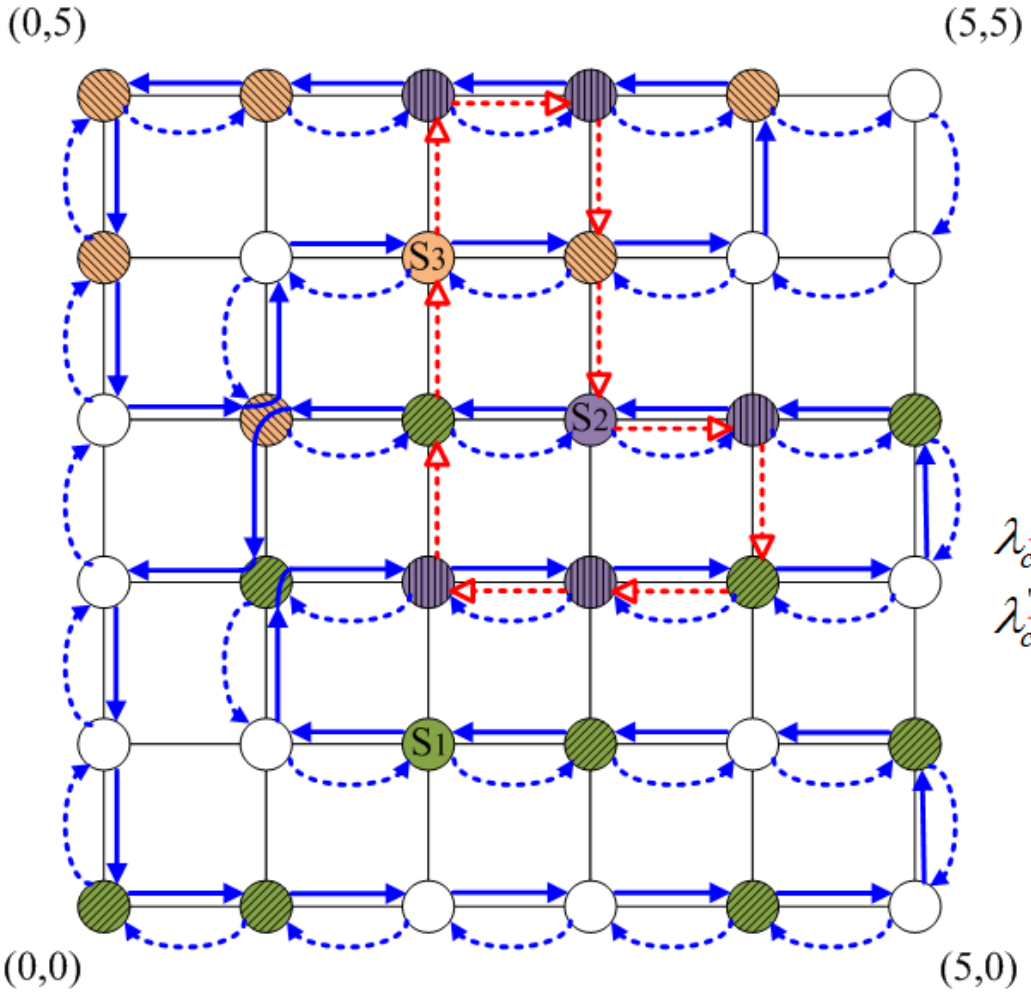
Wavelength:

Wavelength Table:

λ_1^+	$\omega_{ij1}=0, e_{ij}\in H^+$
λ_1^-	$\omega_{ij1}=0, e_{ij}\in P_1; \omega_{ij1}=1, e_{ij}\in H^- - P_1$
$\lambda_c \rightarrow \lambda_2^+$	$\omega_{ij2}=0, e_{ij}\in P_2; \omega_{ij2}=1, e_{ij}\in H^+$
λ_2^-	
⋮	⋮
$\lambda_{W_{\max}}^+$	
$\lambda_{W_{\max}}^-$	

Multicast Routing Example

- Routing for Multicast Group M3.



Multicast Group:

M_1 M_2 M_3

Wavelength:

λ_1^+ λ_1^- λ_2^+

Wavelength Table:

	λ_1^+	$\omega_{ij1}=0, e_{ij}\in H^+$
λ_c →	λ_1^-	$\omega_{ij1}=0, e_{ij}\in P_1\bigcap P_3; \omega_{ij1}=1, e_{ij}\in H^- - P_1 - P_3$
λ_c' →	λ_2^+	$\omega_{ij2}=0, e_{ij}\in P_2; \omega_{ij2}=1, e_{ij}\in H^+$
	λ_2^-	
	⋮	⋮
	$\lambda_{W_{\max}}^+$	
	$\lambda_{W_{\max}}^-$	

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Conclusions

- **Problem:**

  High-Performance and Efficient Multicast Routing for ONoCs

- **Solution:**

- Dynamically established optical multicast ring.
- Single-write-multi-read using a single wavelength.
- Reusing established multicast ring via optical token arbitration.
- Wavelength reuse among link-disjoint multicast rings.

Thank You !