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Impact of NoC technology on system performances in a context of optical/CMOS co-design

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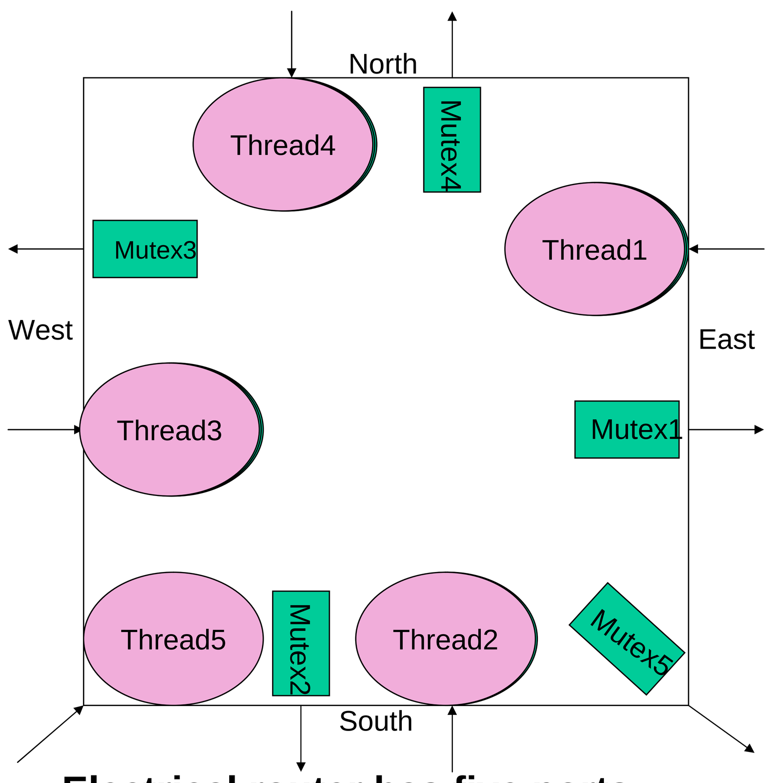
I. Introduction

With the increasing complexity of multiprocessor systems-on-chip (MPSoC), global communication on chip has become a major challenge for system performance improvement within restricted power and area budgets. Network-on-chip (NoC) is emerging as an alternative to existing dedicated interconnection and shared bus. This poster will firstly present our studies based on electrical and optical routing model. Considering the difficulty of run-time management of the communication among the multiprocessors, especially flow control from the local resources in NoC, which may contain hundreds and thousands of IPs, we use the controllable and observable method by constructing a state space model to overcome this problem. Then we propose some routing topologies with the three dimension, which mix CMOS layer & optical layer. The heterogeneous system is discussed at last.

II. Routing model

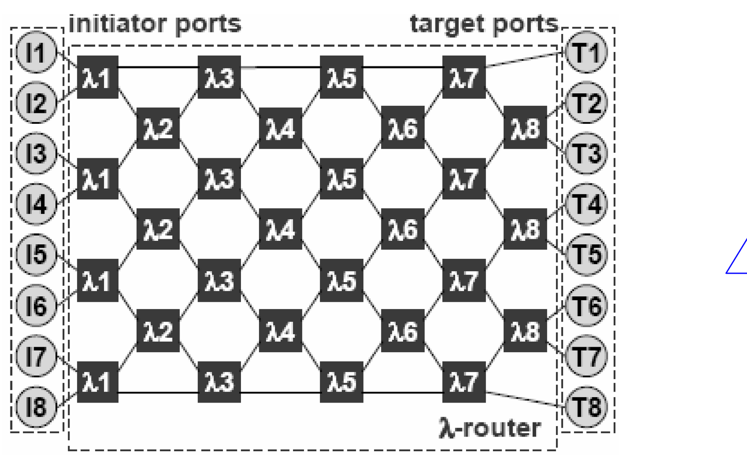
- **To study the performance of the network on chip, we construct the nodes of the network: the router. Two types of routing model, electrical routing model and optical routing model have been considered.**

A. Electrical routing model

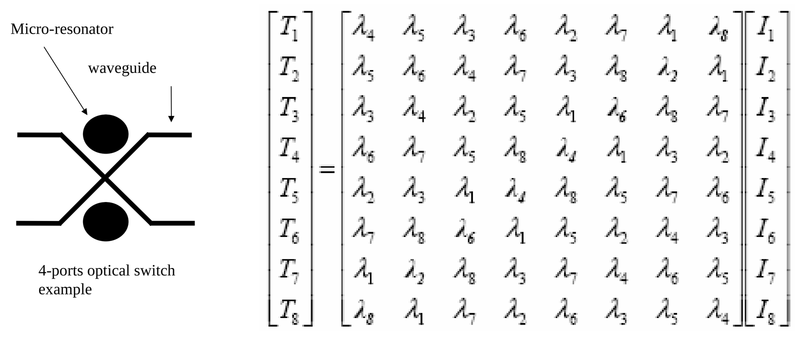


Electrical router has five ports (North, East, South, East and local)

B. Optical routing model (λ router)

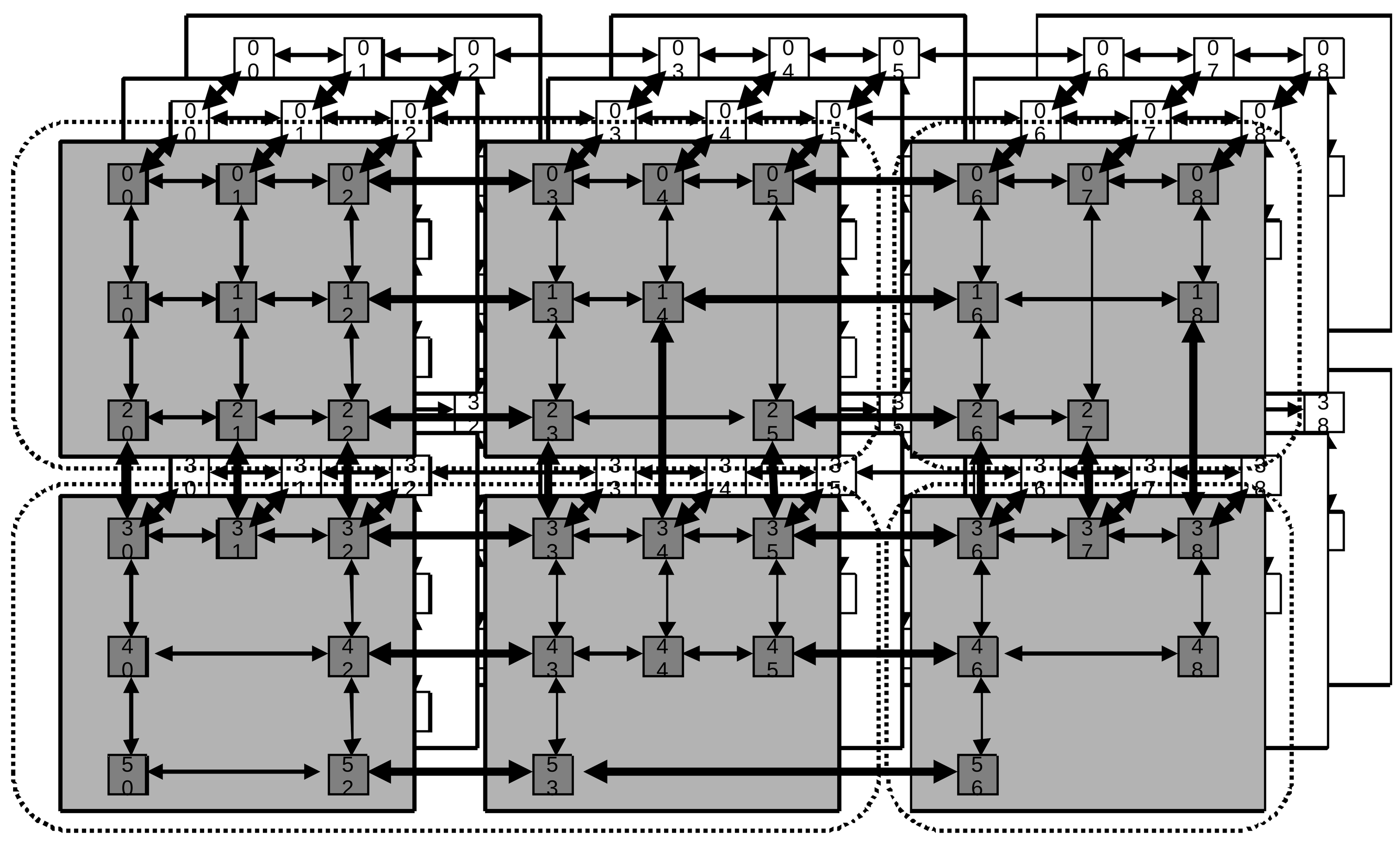


Optical router is a *passive* optical network composed of several 4-port optical switches (based on add-drop filters)



III. 3D topology of NoC

A clustered hierarchical NoC topology is composed of several irregular meshes.



Routing algorithm of the irregular 3D ENoC:

The wormhole routing algorithm used here is hardwired and deterministic;

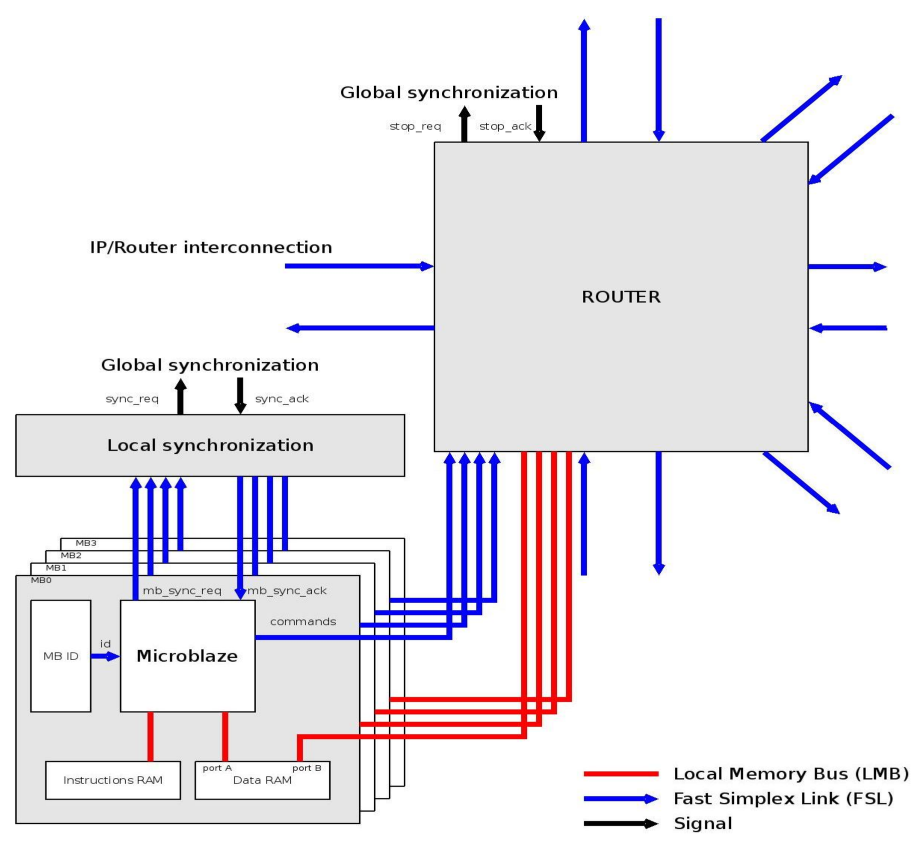
The first row and the first column are called the main axis;

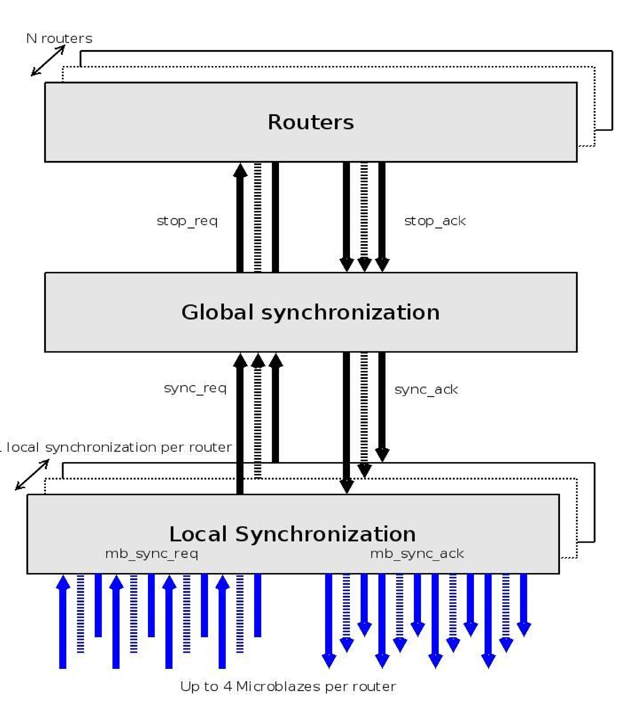
The routing can be XY or XYX or XYZX or YX or YXY or YXZY according to the places of the source and the destination.

Several restrictions must be followed:

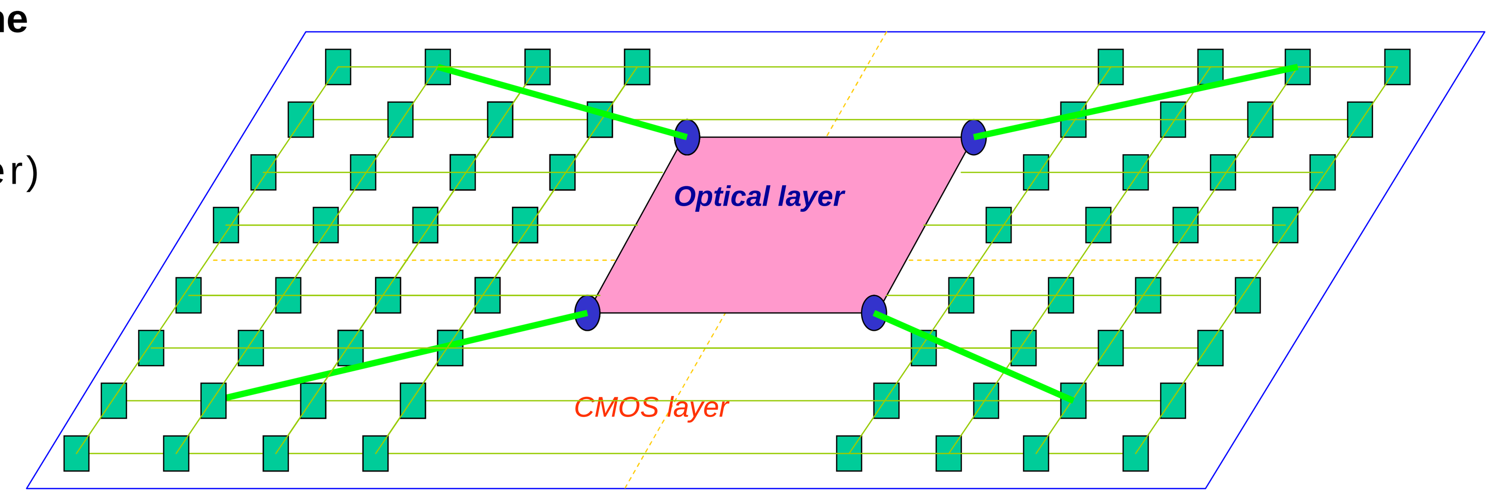
1. There is always a router on the main axis.

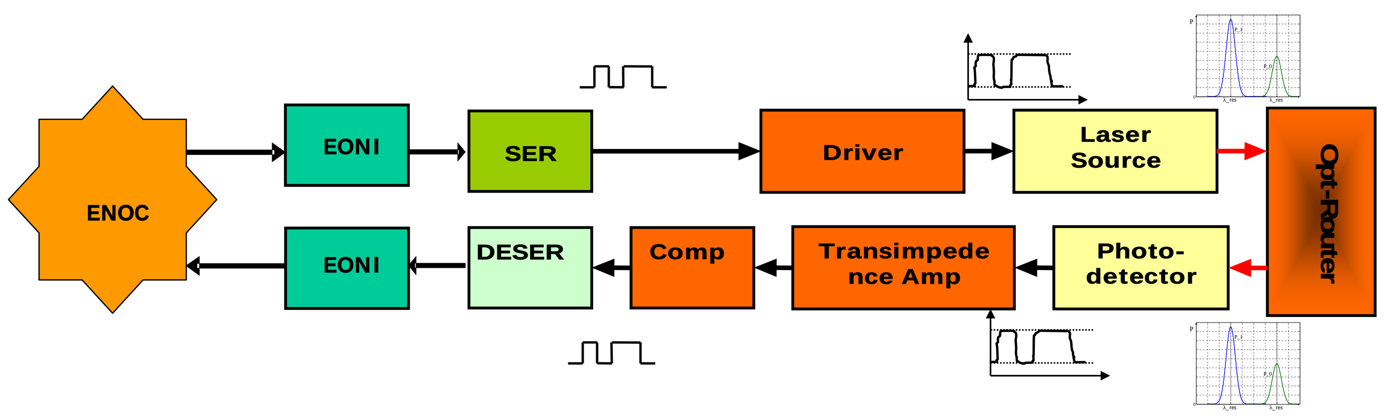
2. A router is fully connected if there are other routers in the same axis.

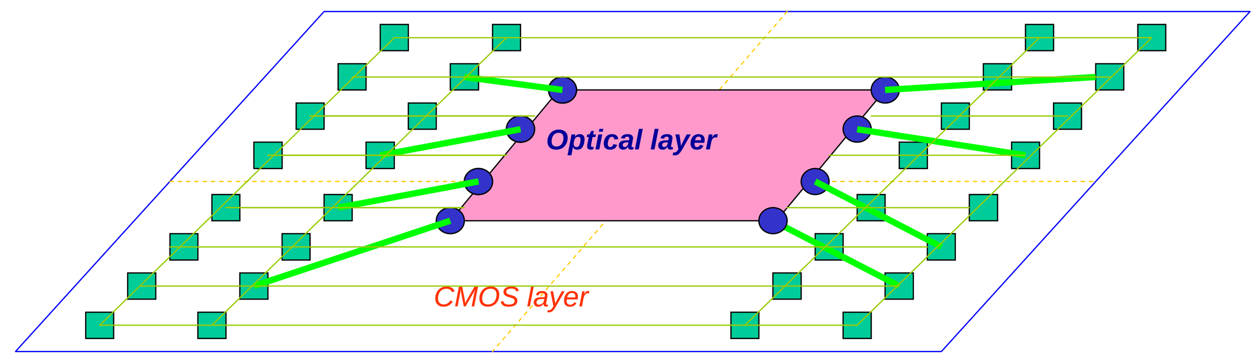




IV. Integrating electrical and optical routing design







Nodes	ENoC	ONoC
32	16	2
32	8	4
Nodes	ENoC	ONoC
64	32	2
64	16	4
Nodes	ENoC	ONoC
128	64	2
128	32	4
128	16	8
Nodes	ENoC	ONoC
256	128	2
256	64	4
256	32	8

- **The objective is to shorten the unnecessary distance caused by ENOC and to enhance the performance of the co-design of optical and CMOS NoC.**
- **Our initial research is based on the regulation of the product of ENoC node number and ONoC node number to compare the system influence of the optical layer on the CMOS layer.**
- **The topics about TSV (Through Silicon Via) and 3D architecture will be studied.**

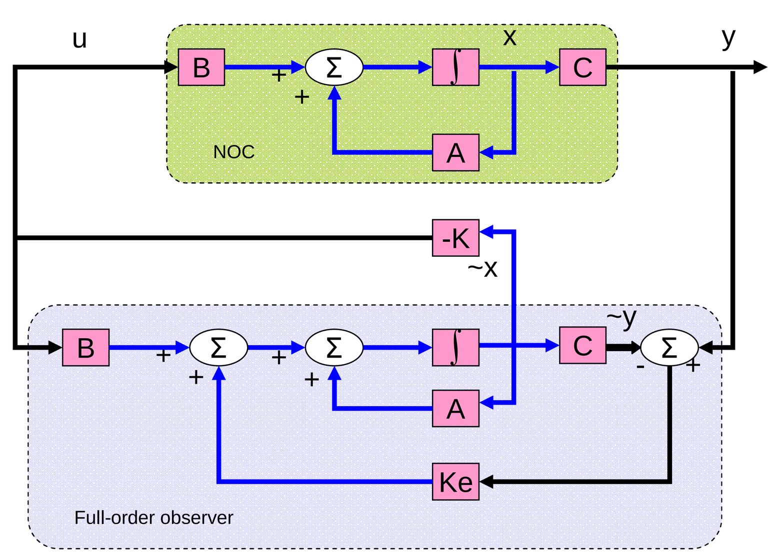
V. Using state space method to feedback NoC

State Equation: $$\frac{dx}{dt} = Ax + Bu$$

Output Equation: $$y = Cx + Du$$

Full order state observer model:

$$\frac{d\tilde{x}}{dt} = A\tilde{x} + Bu + Ke(y - C\tilde{x}) = (A - KeC)\tilde{x} + Bu + Key$$



- **If a NoC contains large number of IPs, controlling the input and output flow rates alone is not sufficient to stabilize the network.**
- **We try to construct a state space model with state observer controller in its feedback path to monitor the intermediate flow rates and to stabilize the NoC.**
- **There are two kinds of the observer: full order observer and minimum order observer.**

VI. Discussion of the heterogeneous system

- **This poster is dedicated to discuss a heterogeneous system composed of ENoC, ONoC and 3D architecture. In addition, considering the large number IPs NoC, we take the state space method to stabilize the system.**
- **As the difficulties of 3D, TSV, optical architecture and the implementation of both hardware and software on one chip, the heterogeneous system is still a challenge. The cost performance of the heterogeneous system could be evaluated by our system model.**
- **Different tools (like SystemC, VHDL, MatLab, MPI) could be used in a heterogeneous system's simulation, but it might result the incompatibility and unavailability of the software that the whole simulation will lost its precise, sometimes will be incorrect. To solve this problem, a simulator of the whole heterogeneous system is under development.**