Design of Bandwidth Aware and Congestion Avoiding Efficient Routing Algorithms for NoCs Platforms

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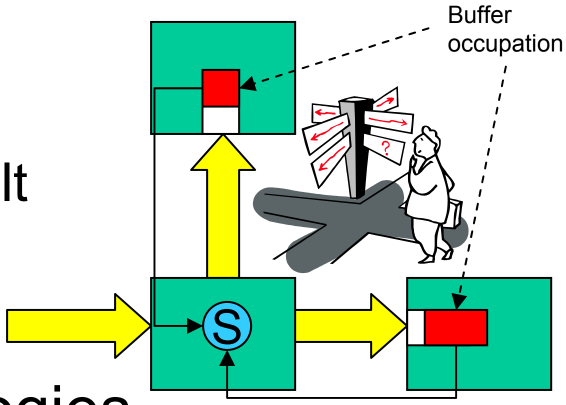
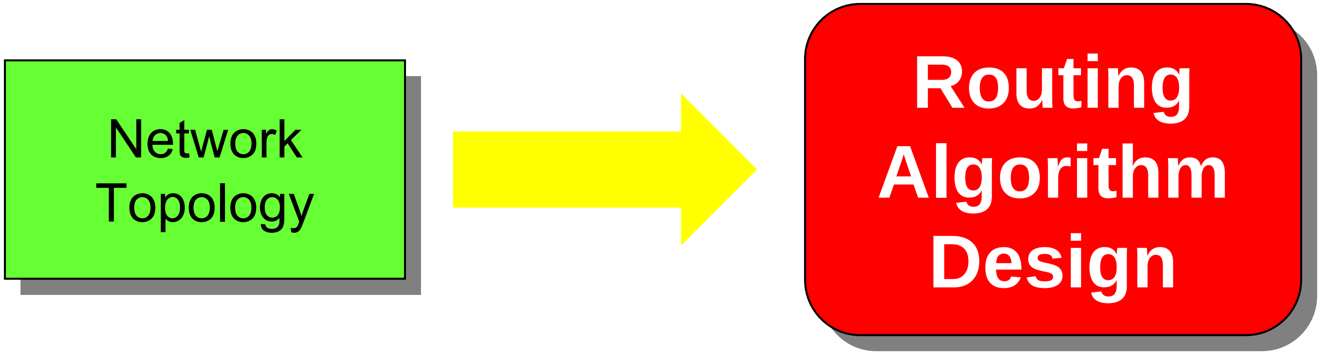
Outline

- Motivation
- Application specific scenario
- Bandwidth aware routing algorithm
- Experiments and Results
- Architectural implications
- Conclusions

Limitations of Current Routing Algorithms

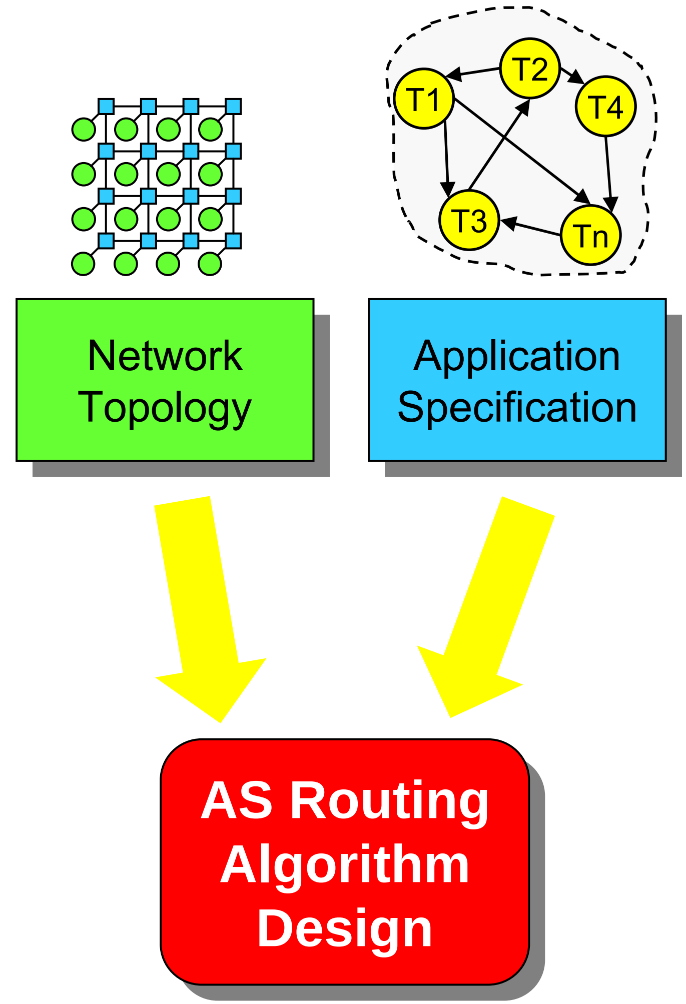
- Efforts biased toward performance
- Side effects like congestion ignored
  - ➔ Estimation and control of congestion is difficult in general
  - ➔ Partially tackled by the selection function
- Designed only for specific network topologies





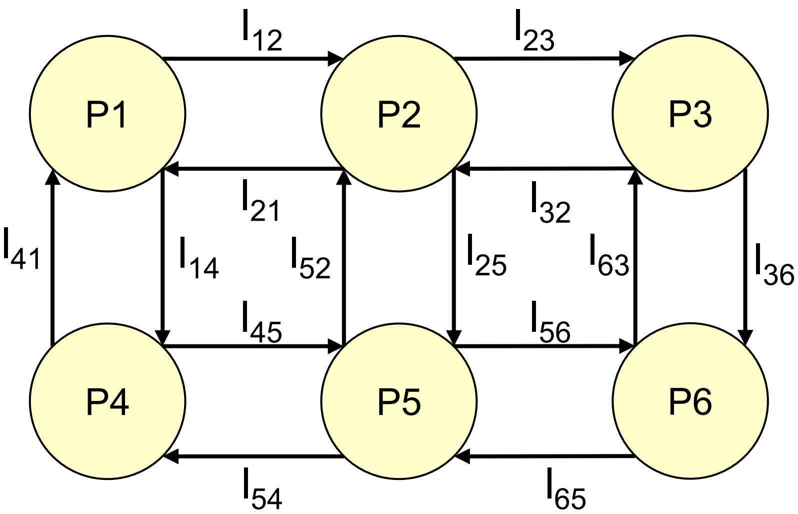
Application Specific Scenario

- Information available about
  - Tasks which communicate and tasks which do never communicate
    - After task mapping ➔ Information about network nodes which communicate
  - Concurrent/non concurrent communications
  - Communication bandwidth requirement for different pais
- Many opportunities
  - Improving performance (e.g., maximize routing adaptivity)
  - Simplify the estimation/control of congestion
  - Design more effective selection policies

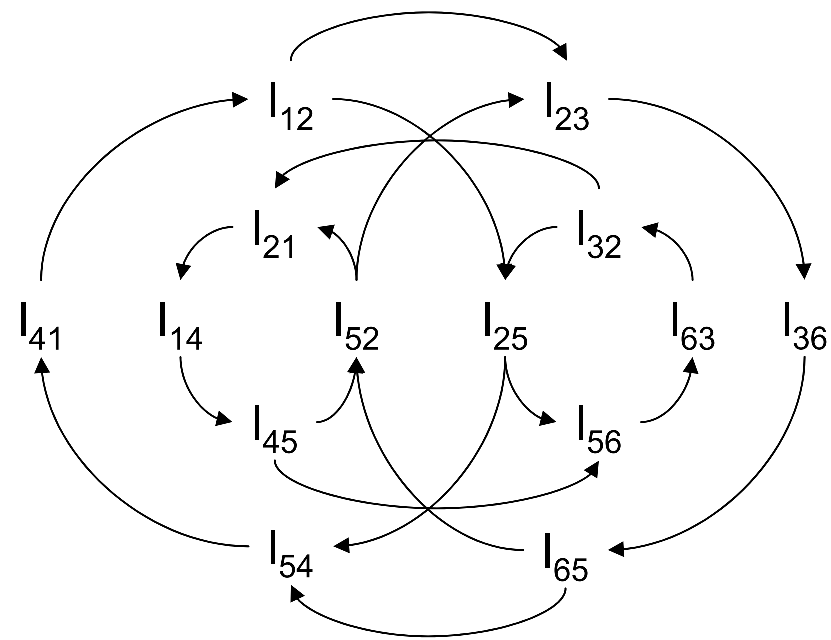


Channel Dependency Graph

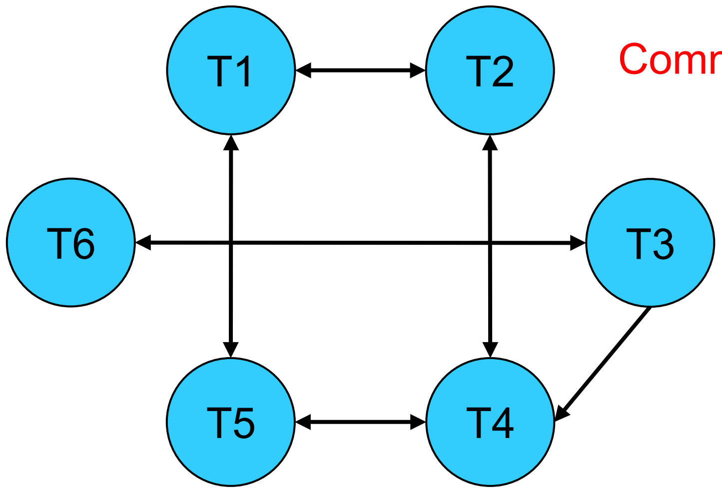
Topology Graph



Channel Dependency Graph

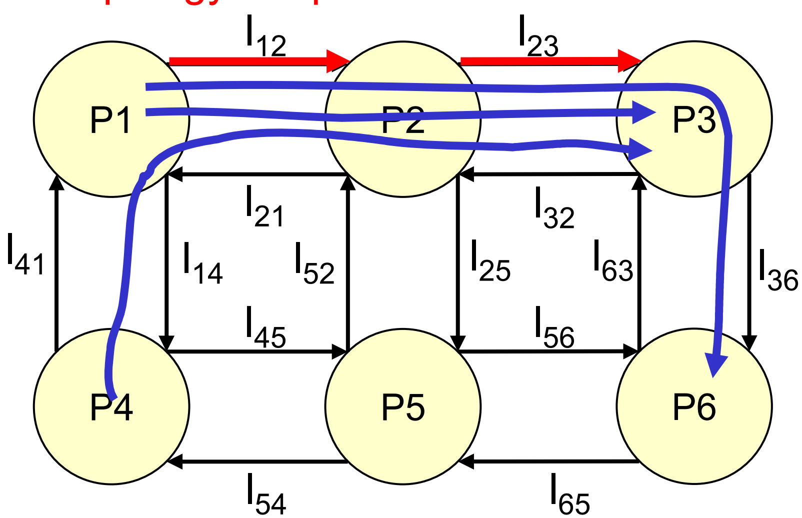


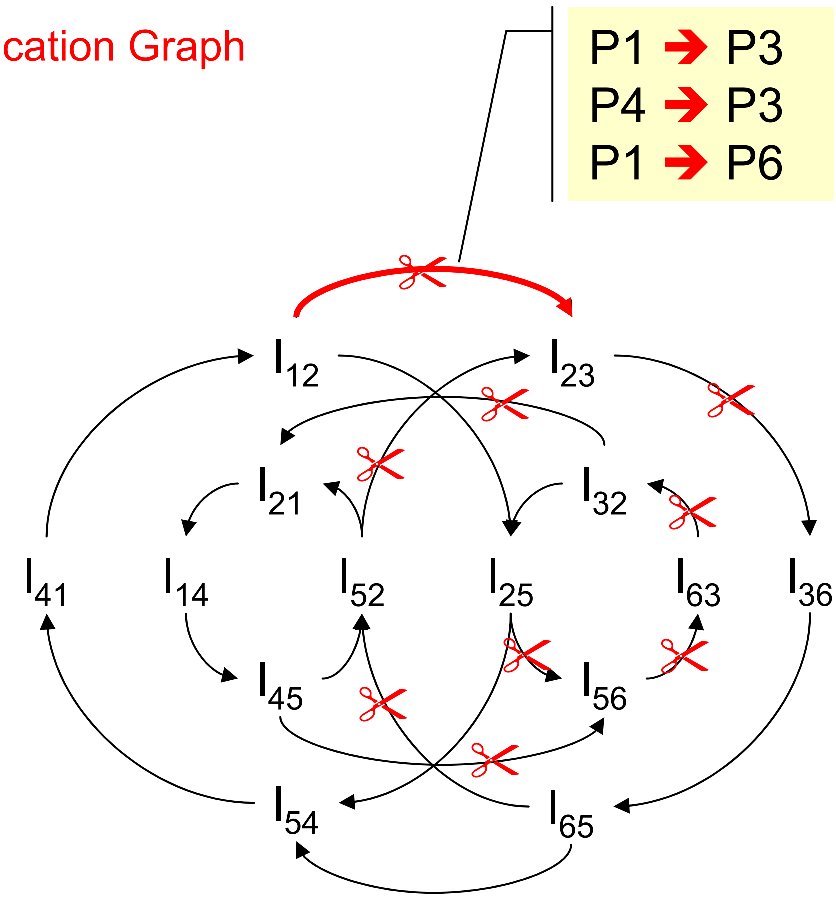
Application Specific CDG



Communication Graph

Topology Graph





Channel Dependency Graph

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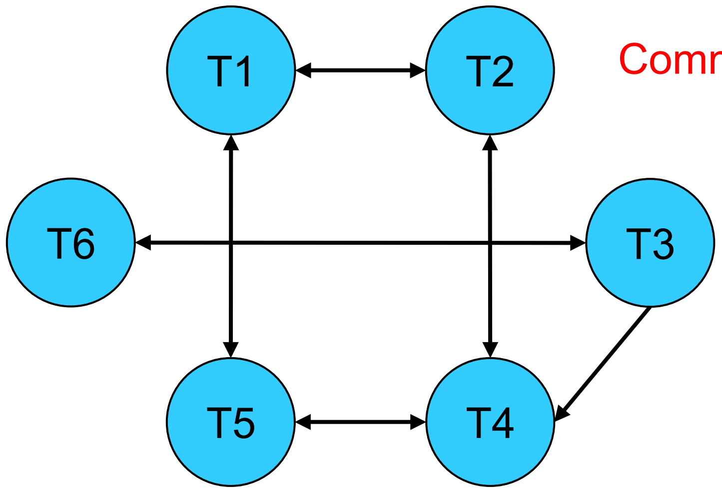
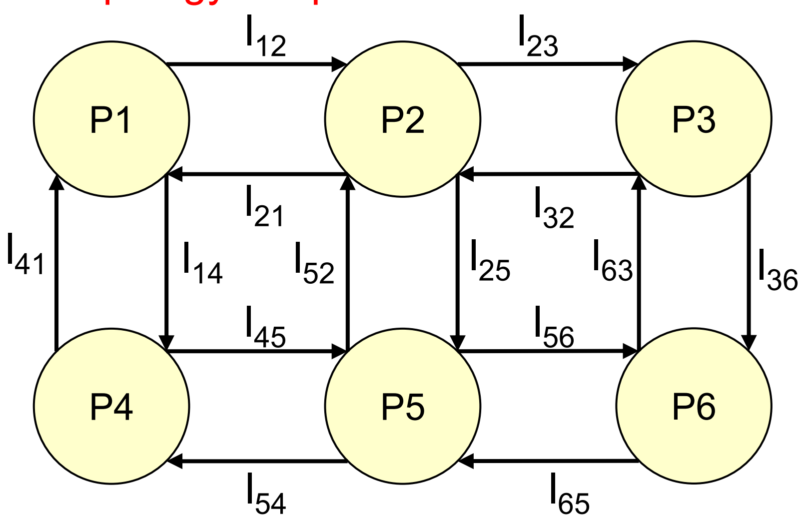
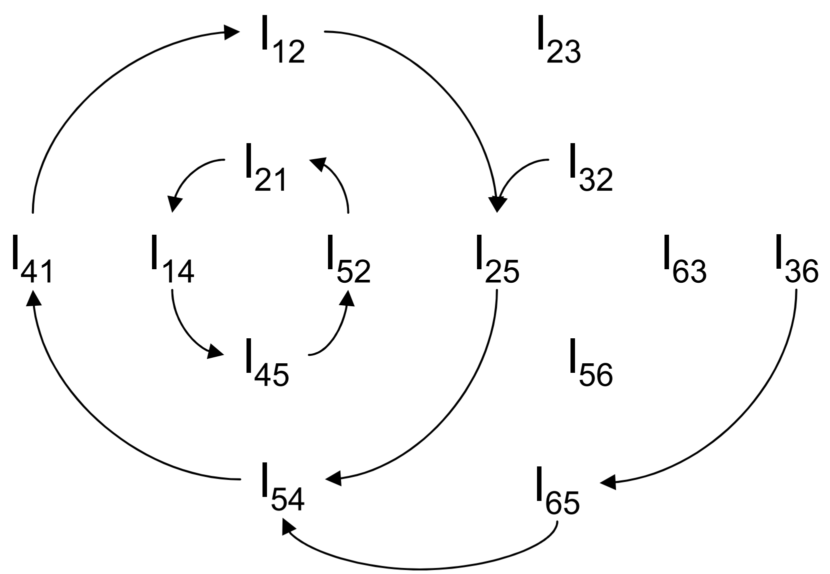


Communication Graph

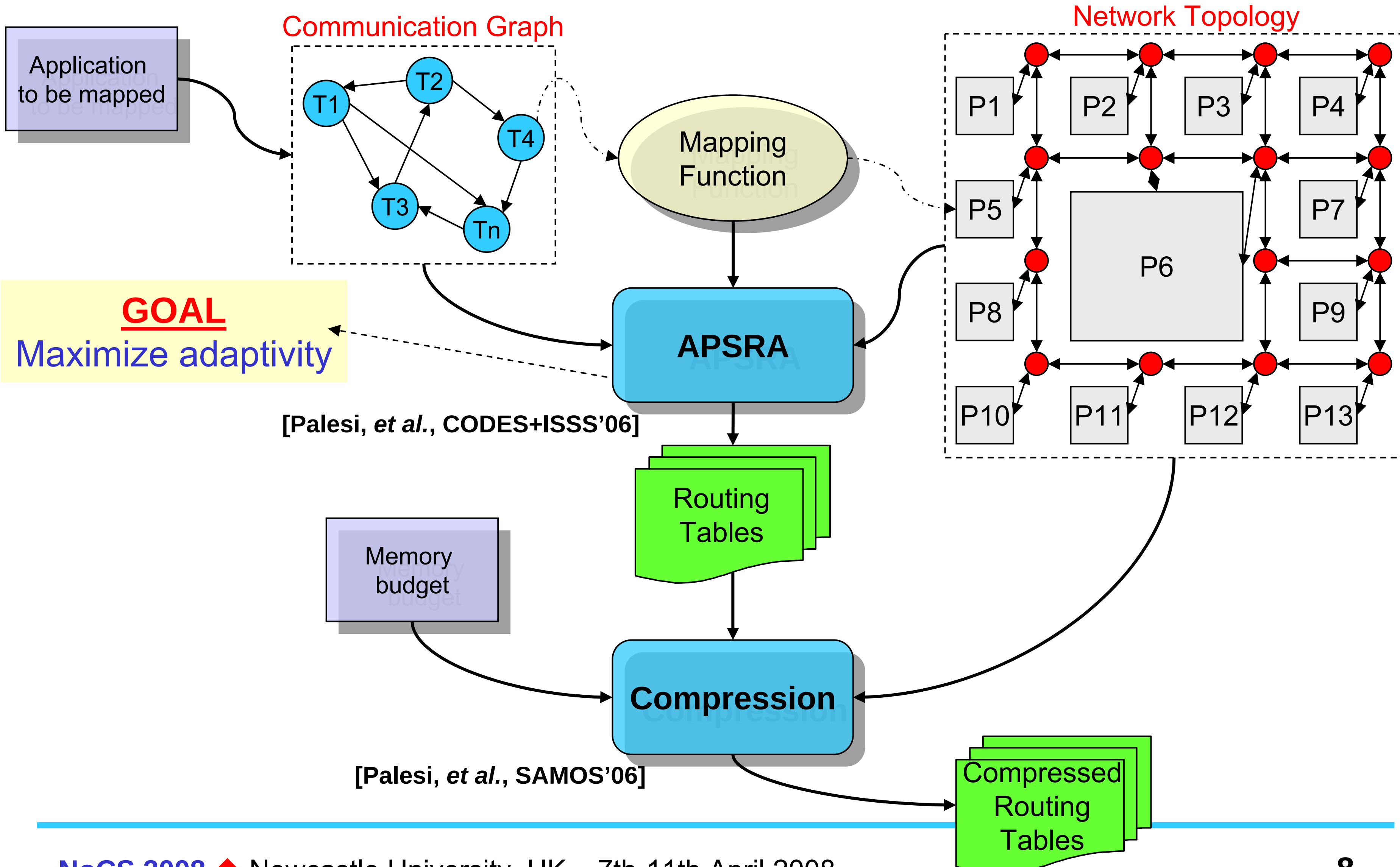
Topology Graph



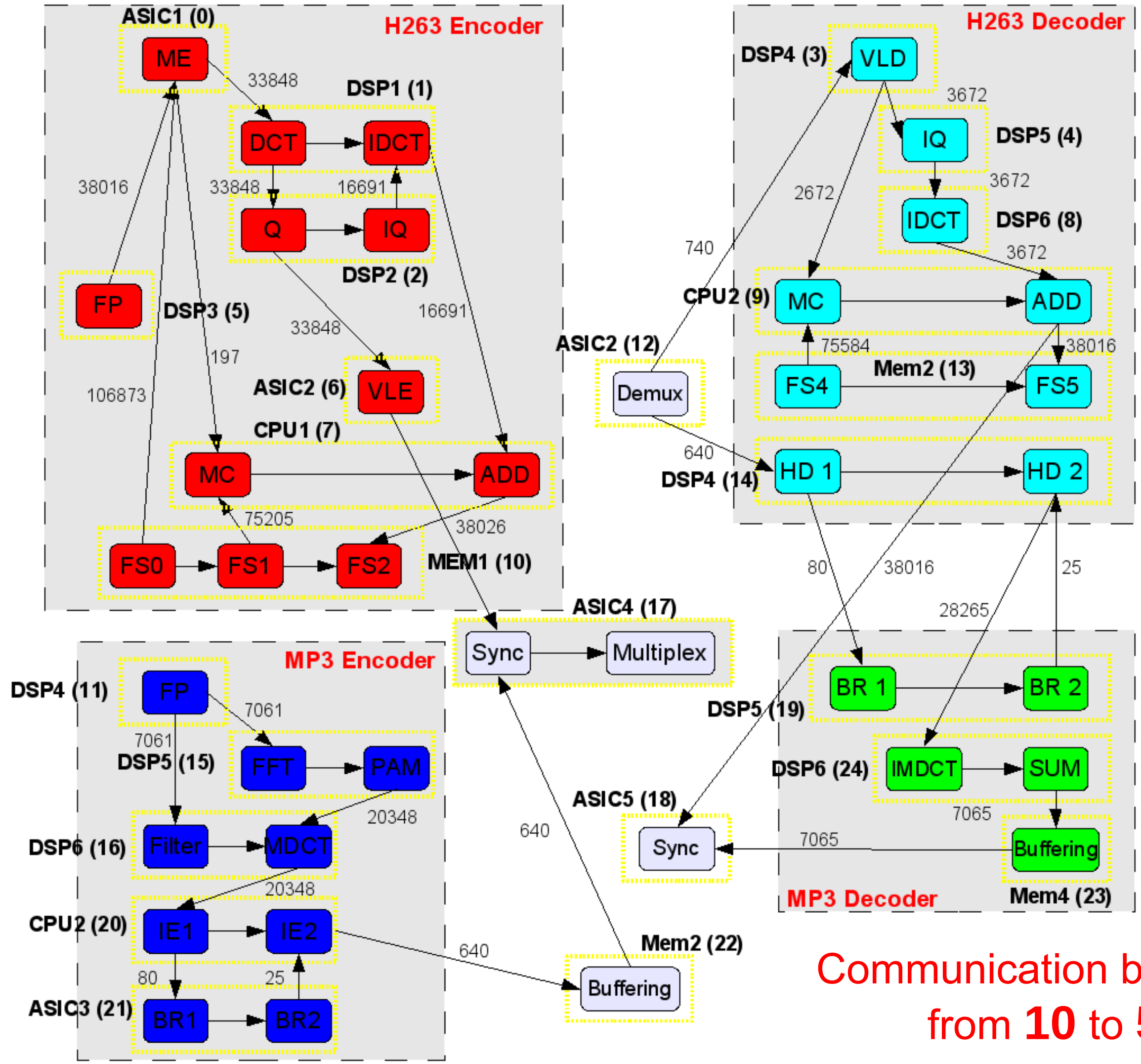


Application Specific
Channel Dependency Graph

APSRA Design Methodology



Bandwidth Variation: Multimedia Example



Source: Hu and Marculescu, TCAD 24(4), 2005

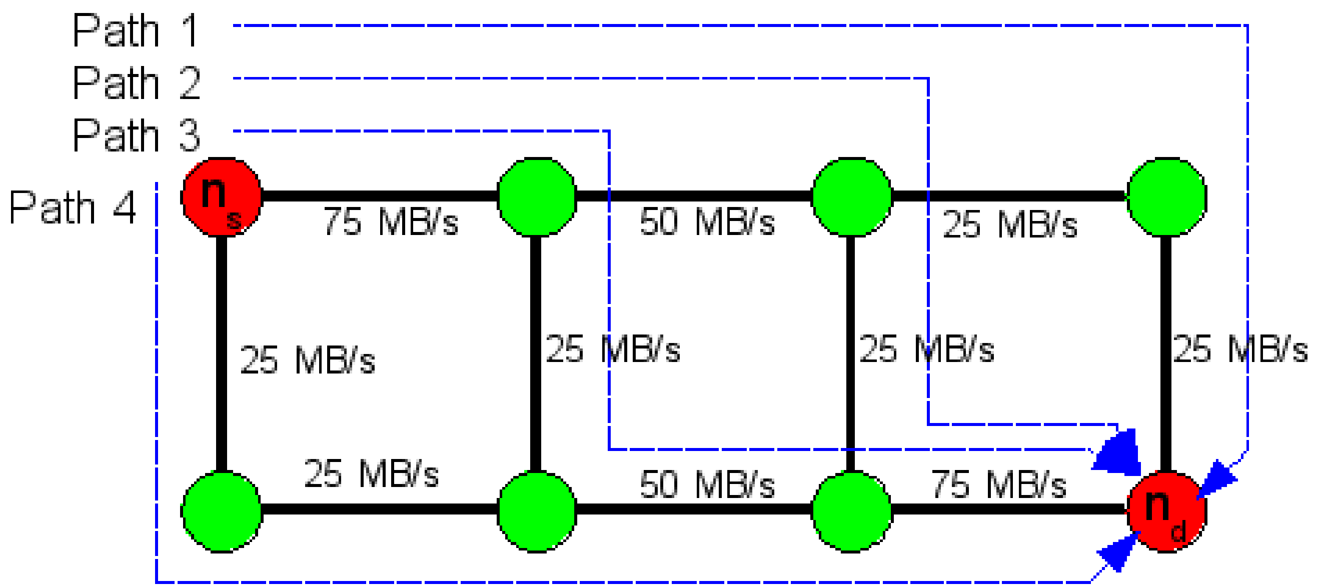
Communication bandwidth ranges from **10** to **500 MB/s**

Contributions

- Design APSRAs which
  - ➔ are highly adaptive
    - ✓ Translates into high performance, in general
  - ➔ uniformly distribute traffic over the network
  - ➔ allow maintenance of load of links under a given bandwidth threshold

1st Phase

- Removing a dependency ***d***
  - ➔ Removing all the paths which use ***d***
- As soon as a path is removed
  - ➔ The fraction of bandwidth it transports must be redistributed between the remaining paths



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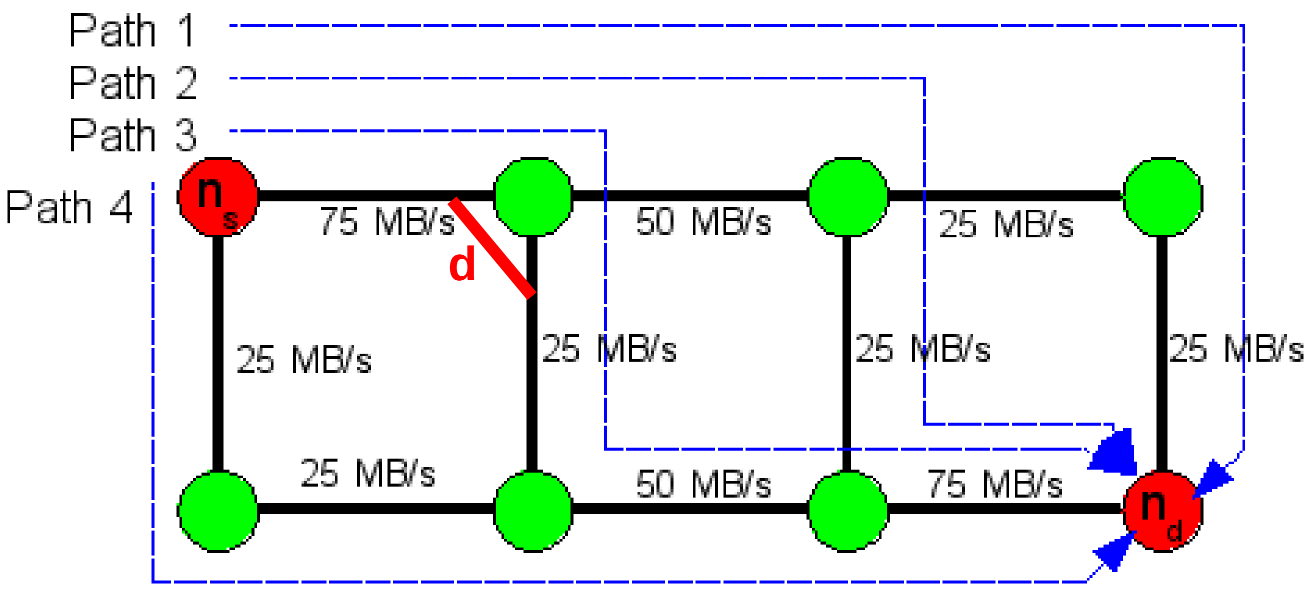

d due to *Path 3*

1st Phase

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  - ➔ Removing all the paths which use ***d***
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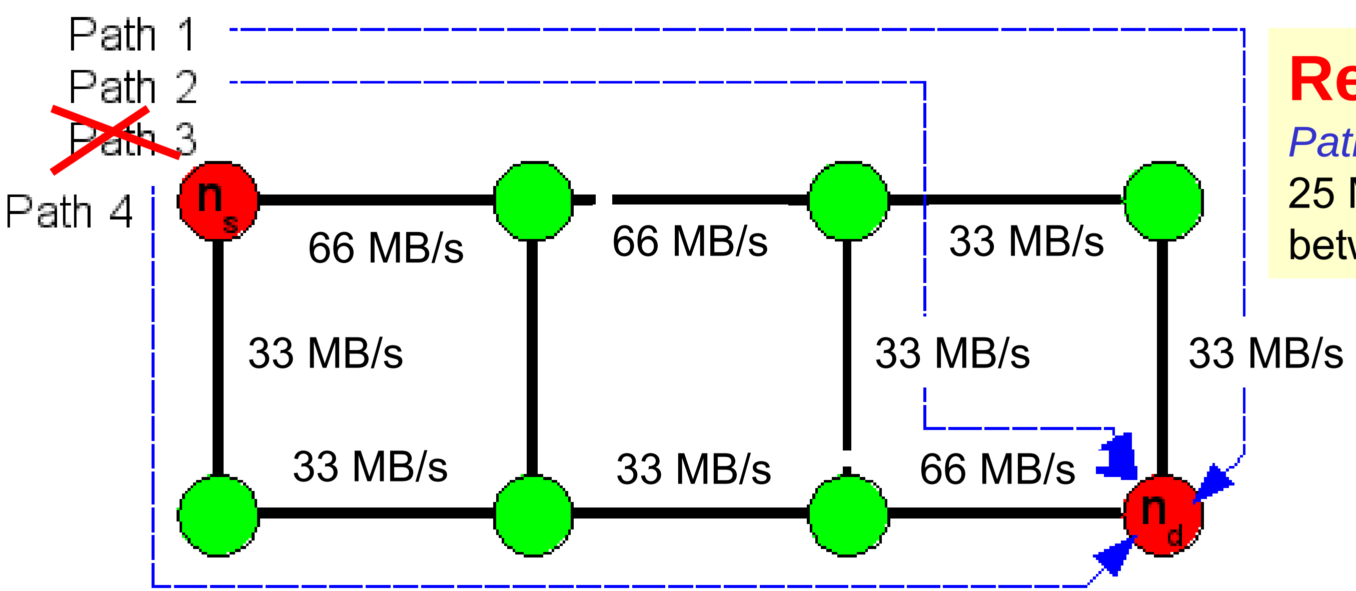

Remove d

Path 3 must be removed
25 MB/s must be redistributed between the remaining paths

1st Phase

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- As soon as a path is removed
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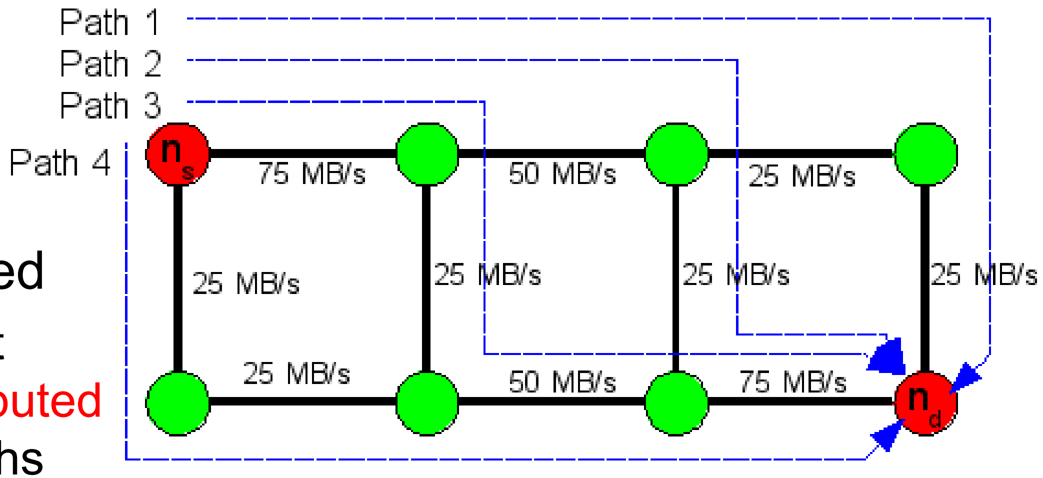


- Strategy
  - ➔ Removing the dependency ***d*** which minimizes the overhead of bandwidth that should be allocated to the remaining paths that do not use ***d***

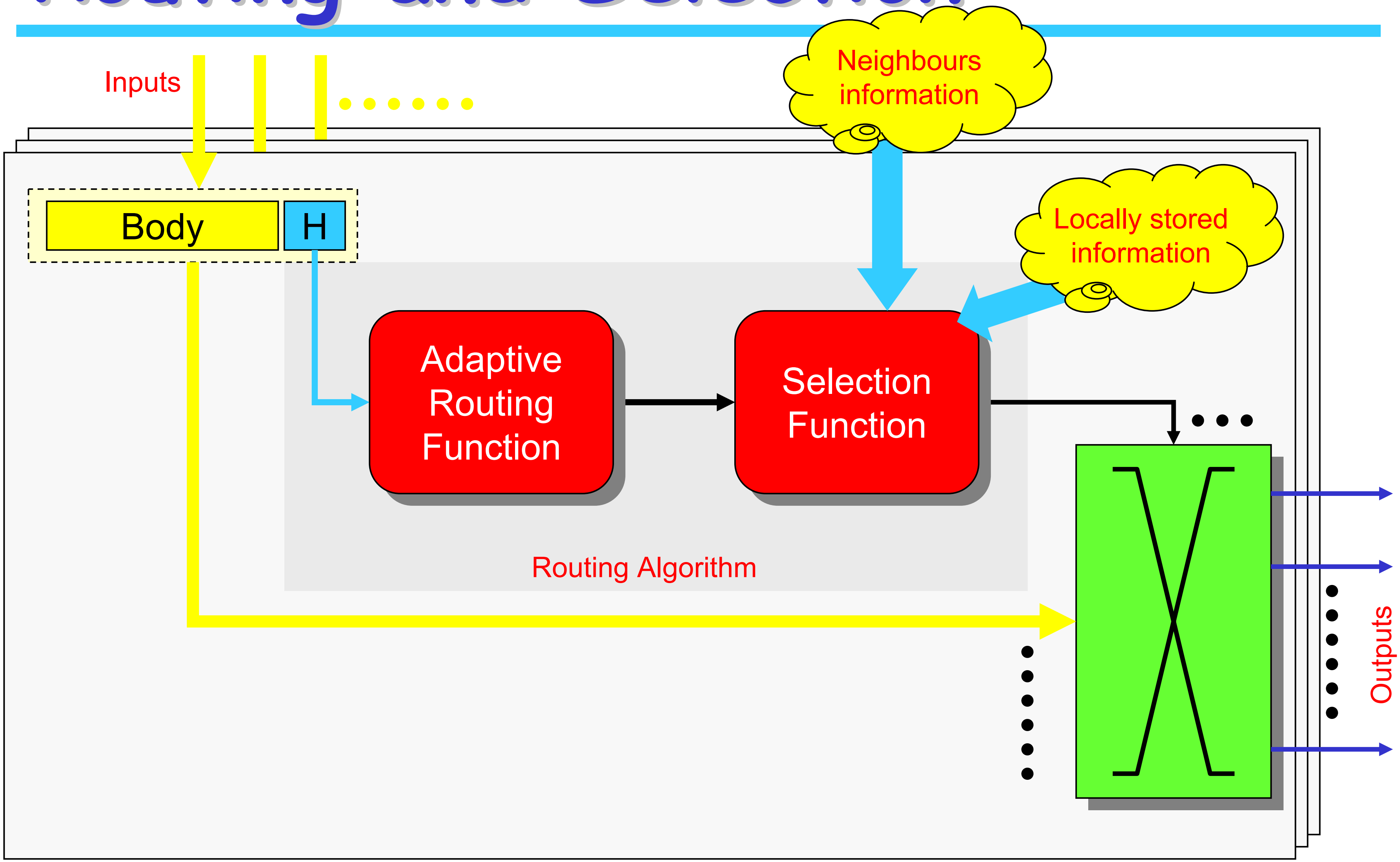
$$\mathrm{cost}(d) = \sum_{c \in C} \frac{B(c) \times \left|PT^2(c,d)\right|}{\left|P(c)\right| \times \left(\left|P(c)\right| - \left|PT^2(c,d)\right|\right)}$$

2nd Phase

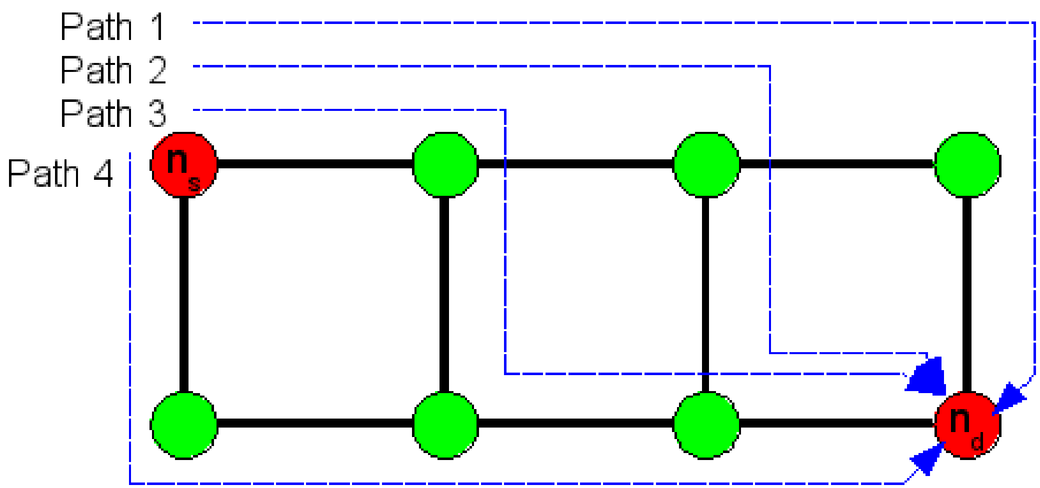
- After *Phase 1* we have a routing function which is
  - ➔ Deadlock free
  - ➔ Provides more adaptivity to communications characterized by higher communication bandwidth
- But…
  - ➔ It is possible that the agregate bandwidth (***AB***) on some links exceeds the capacity of that link
- **"Some"** routing paths passing on that link, must be removed to reduce the ***AB*** on that link down to the link capacity

$$\forall \text{ link } l \rightarrow AB(l) \leq Cap(l)$$

Routing and Selection



Load Balancing Selection Function



Dst	Admissible Out		Selection Prob	
…	…	…	…	…
…	…	…	…	…
n_d	E	S	0,75	0,25
…	…	…	…	…
…	…	…	…	…

Overhead

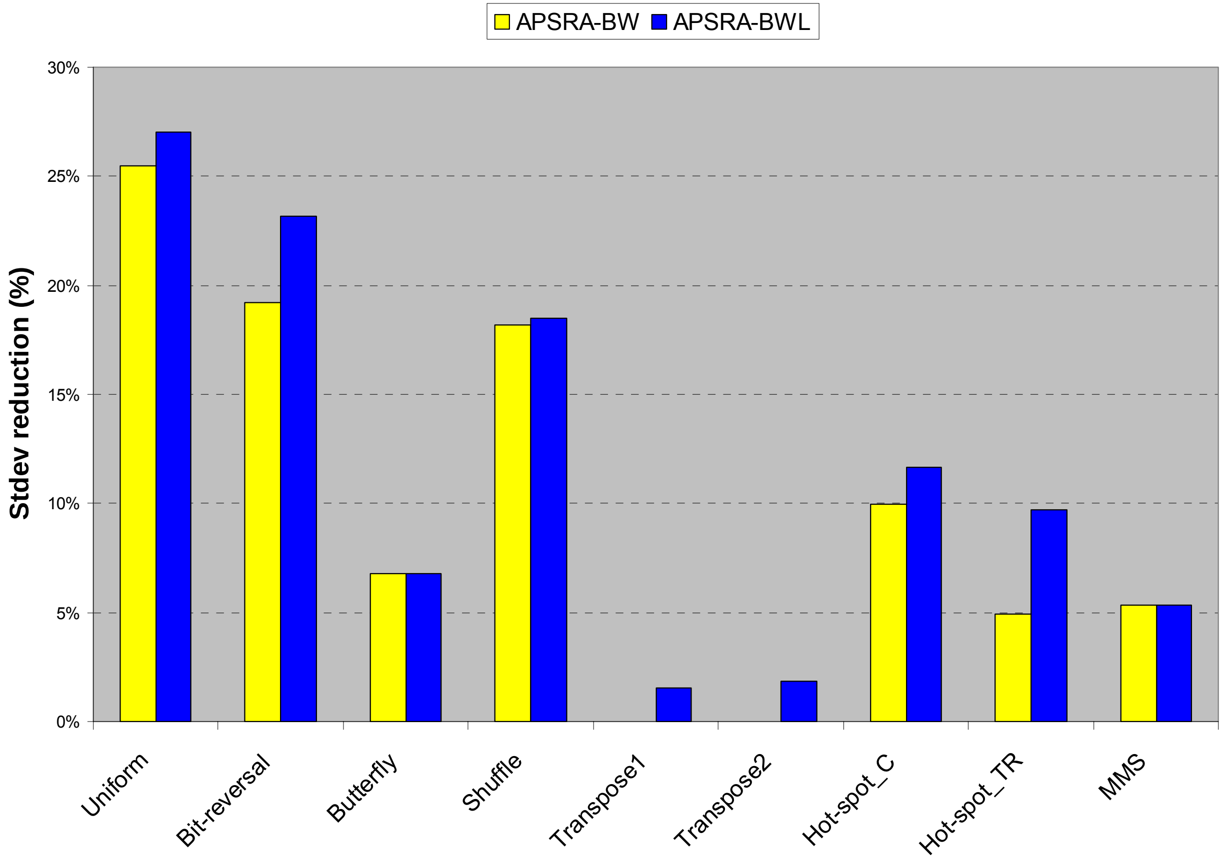
- The probability to select output channel ***l*** is proportional to the number of admissible paths starting from ***l*** and that can be used to reach the destination

Experimental Setup

- 8x8 mesh based NoC
- Buffer size 4-flits
- Simulation time 100,000 cycles
- Warmup time 20,000 cycles
- Traffic injection distribution
  - Poisson (for synthetic traffic scenarios)
  - Self-similar (for MMS traffic)

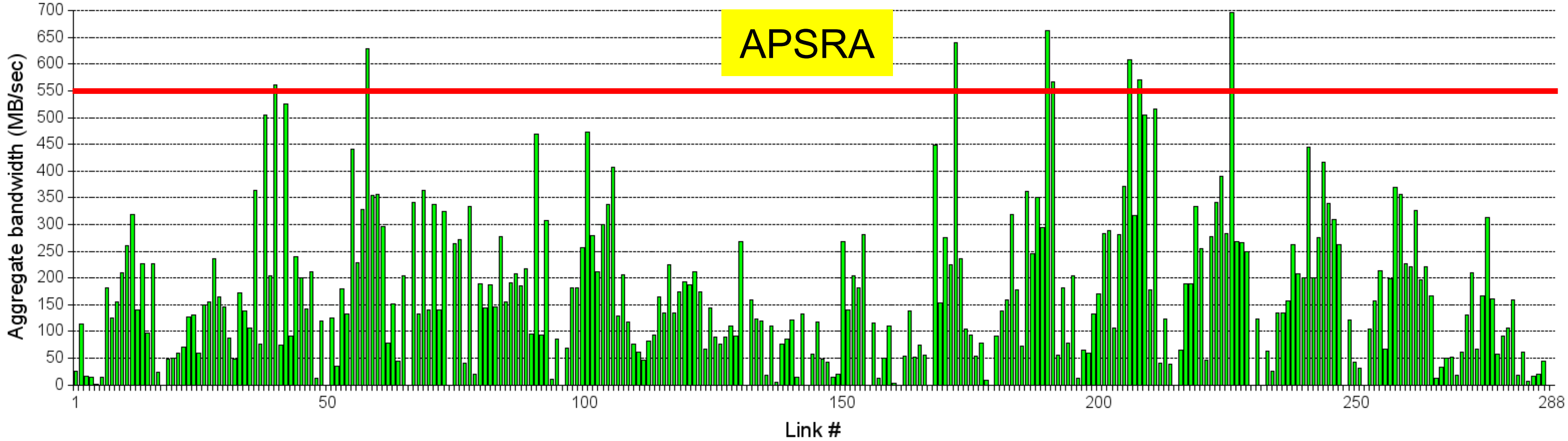
Stdev Reduction

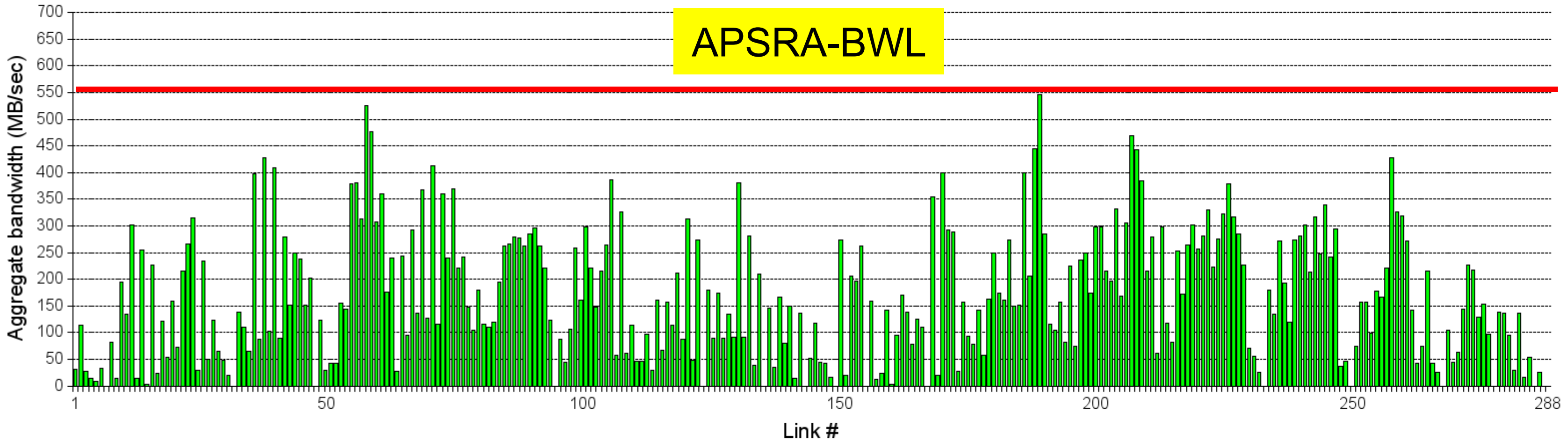
- Percentage reduction of standard deviation of the aggregated bandwidth in network links



Aggregate bandwidth

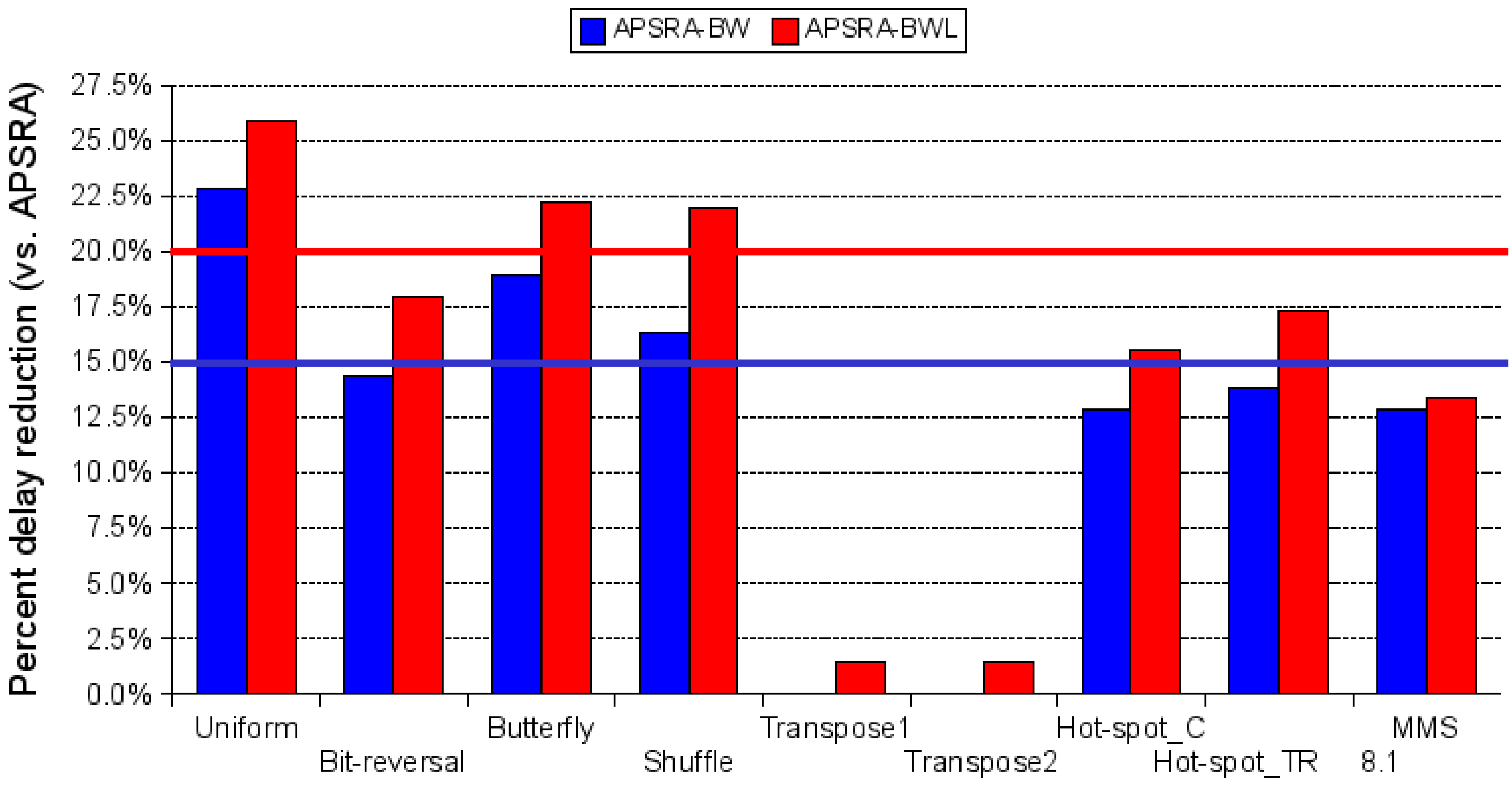
- Aggregate bandwidth per link for a 9x9 mesh-based NoC under *uniform* traffic





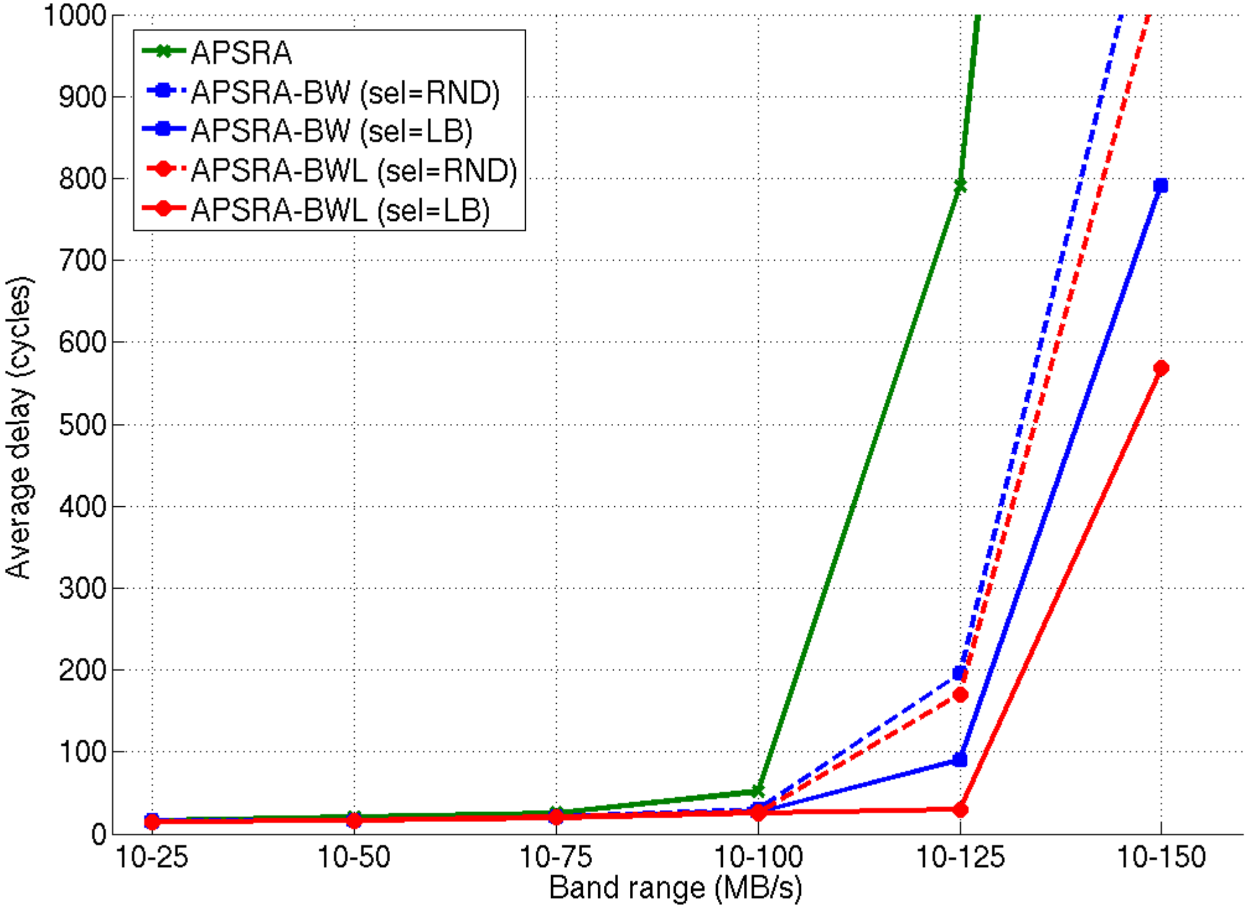
Delay Reduction

- Average delay reduction obtained when APSRA-BW and APSRA-BWL are used taking APSRA as a baseline



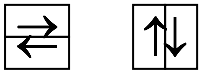
Average Delay Variation

- Average delay variation under uniform traffic for different ranges of communication bandwidth

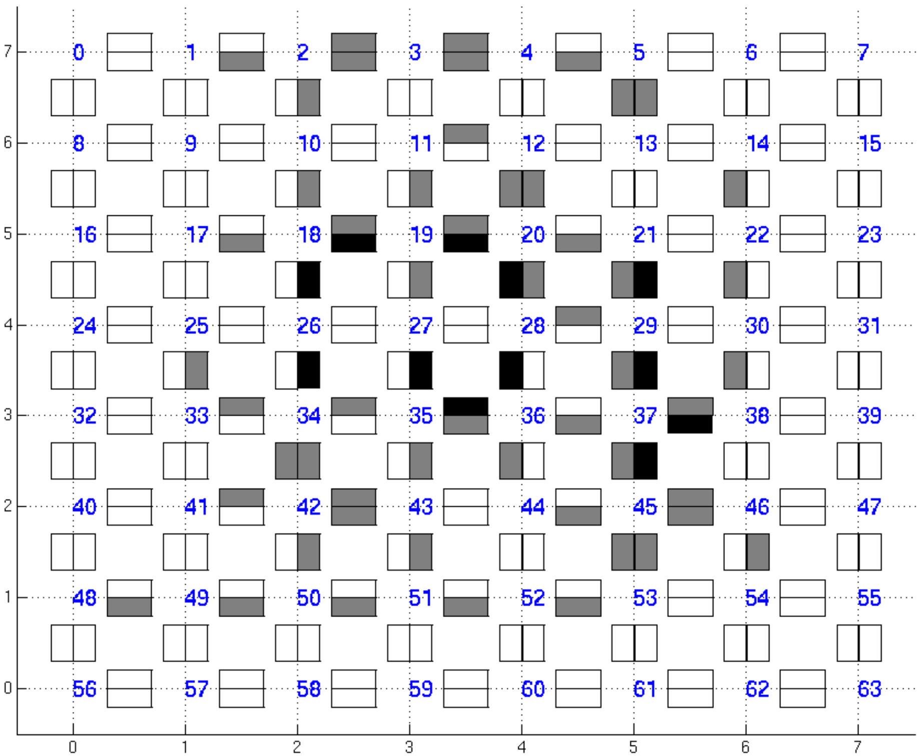


Links Utilization

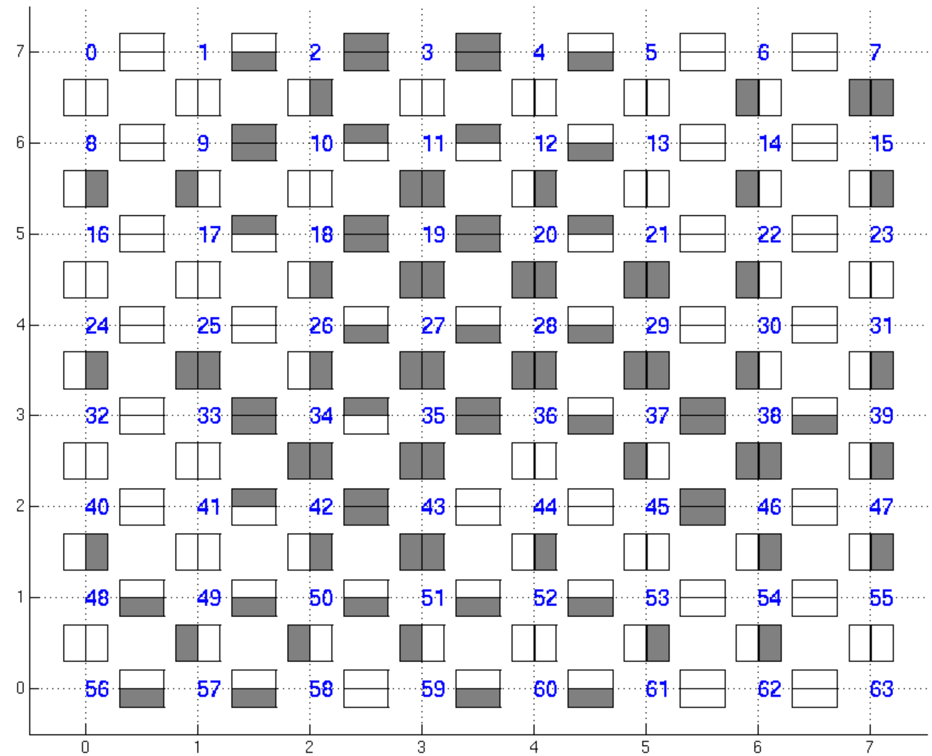
- Links utilization under *uniform* traffic for APSRA and APSRA-BWL



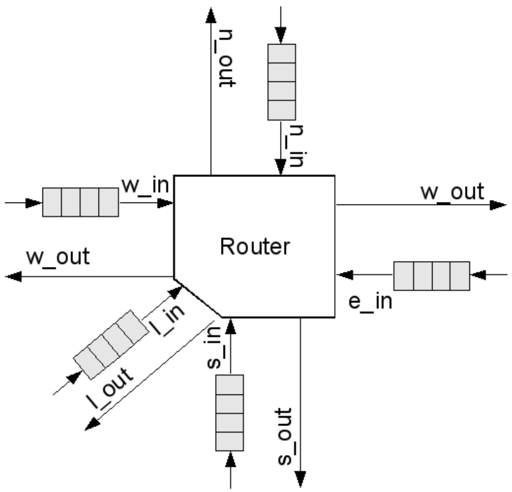
APSRA

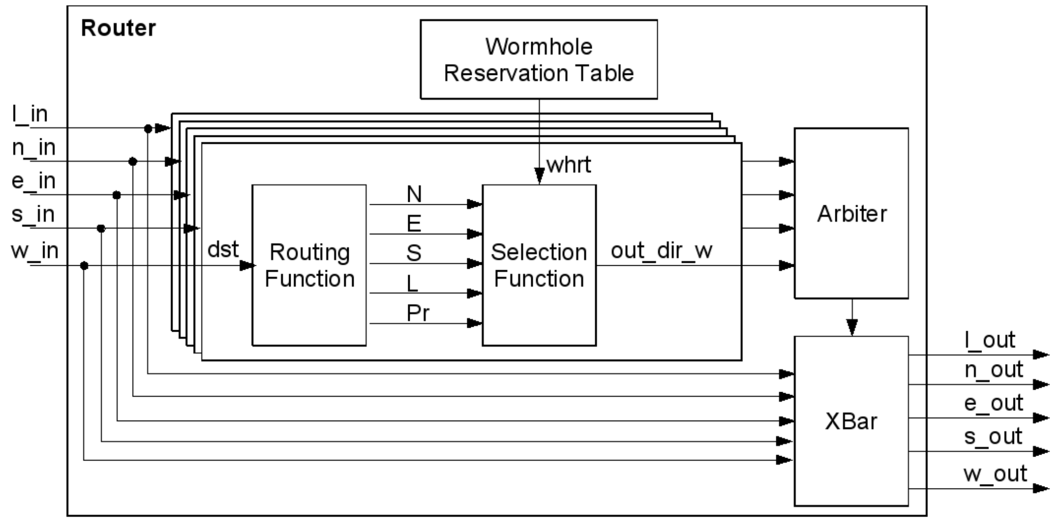


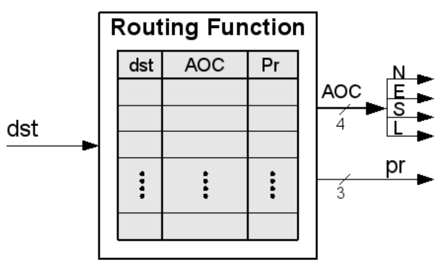
APSRA-BWL

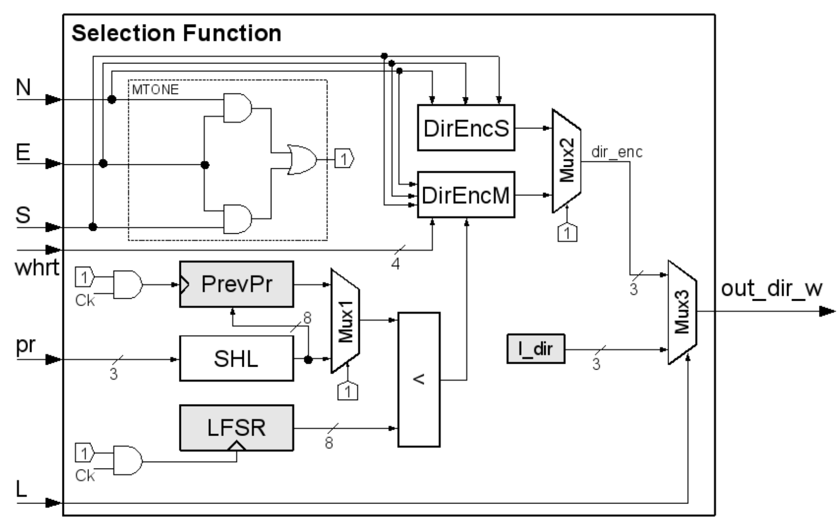


Router Architecture

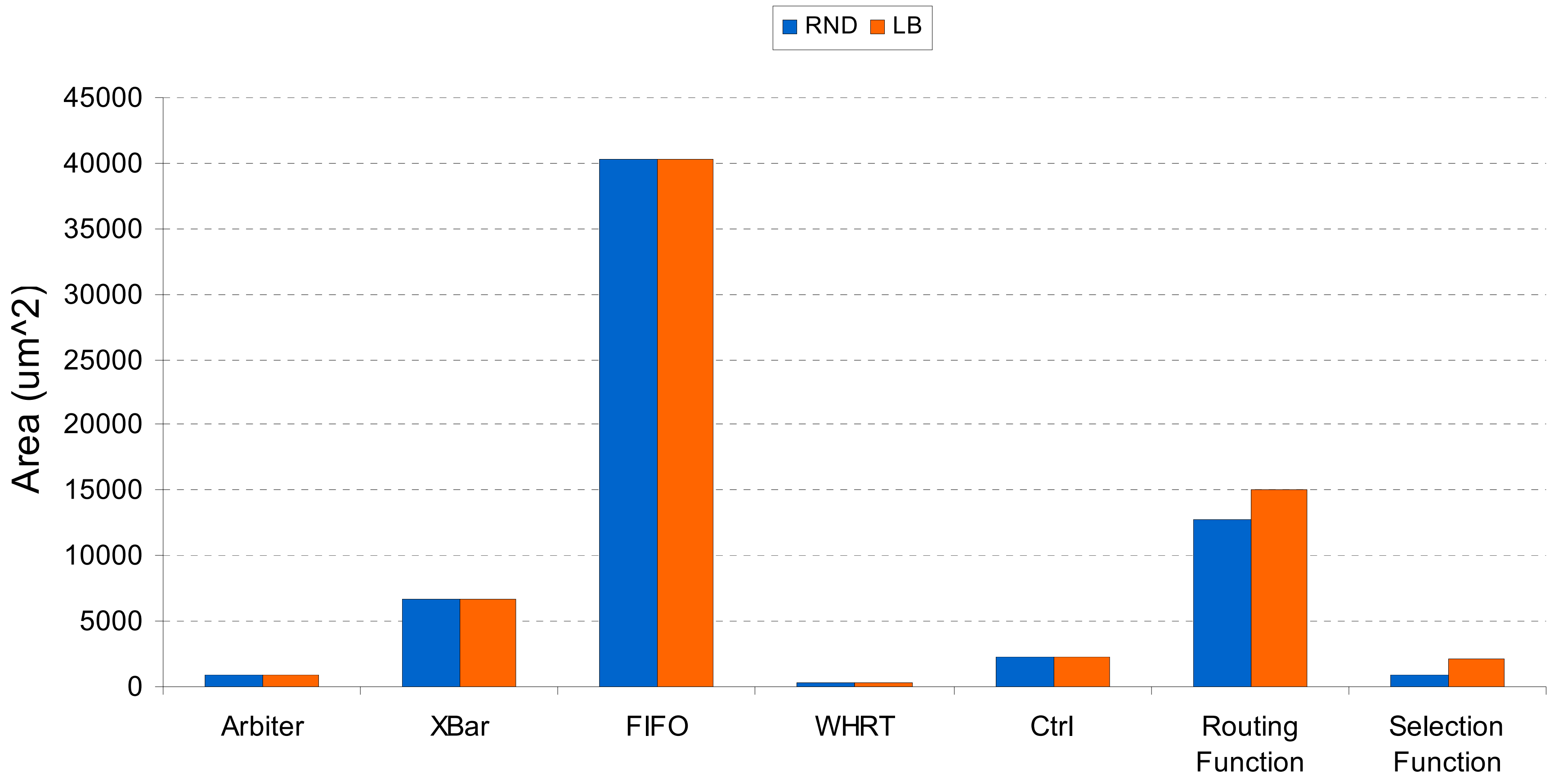








Area Overhead



+5% overall area overhead

Conclusions

- Bandwidth aware routing algorithm
  - ➔ Highly adaptive
  - ➔ Reduces the variation of load in the network links
  - ➔ Ensures that the link bandwidth is not violated
- Evaluate the idea for irregular mesh topology