Adaptive Stochastic Routing in Fault-tolerant On-chip Networks

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Research Background
"A Future FPGA proposal"

- ***NoC*** the new on-chip communication paradigm
- ***FPGA*** the fast prototype platform
- ***Fault-tolerance***
  – Cope with the errors of the nanoscale transistors
- ***NoRC*** = FPGA + NoC + Fault-tolerance
  – Tens to hundreds of programmable tiles connected by hardwired on-chip networks
  – Broadband communication fabric
  – Support multiple multimedia applications
  – Online reconfigurable hardware accelerators
  – Fault-tolerance

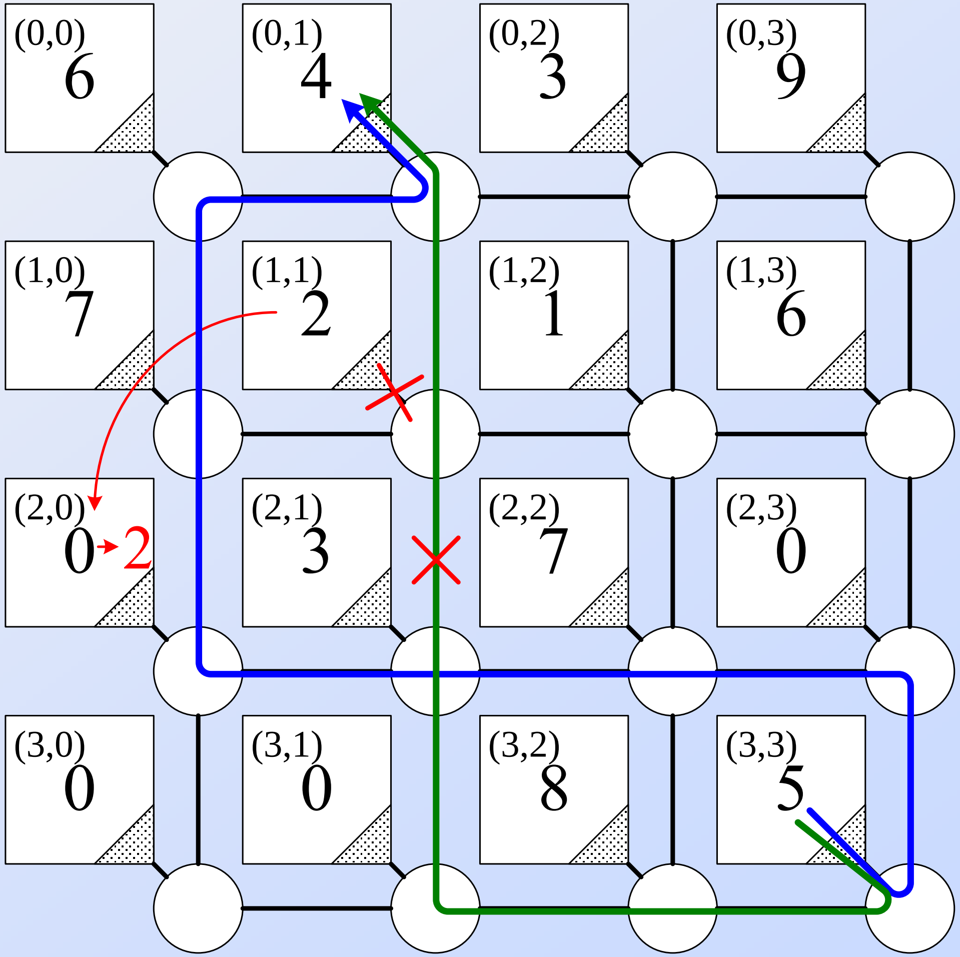
The NoRC Platform

- **Online reconfigurable processor node**
- **Connection oriented flow control**
  - Build a path before the data transmission
  - Delay guaranteed
- **Communicate by the Function Identifier (FID)**
  - Directly request a function instead of using the address
- **Stochastic routing algorithm (COSR)**
  - Directly search for the function on an unknown node
- **Fault-tolerance**
  - Random paths selected by the stochastic routing algorithm
  - Reconfigure the network when some nodes fail

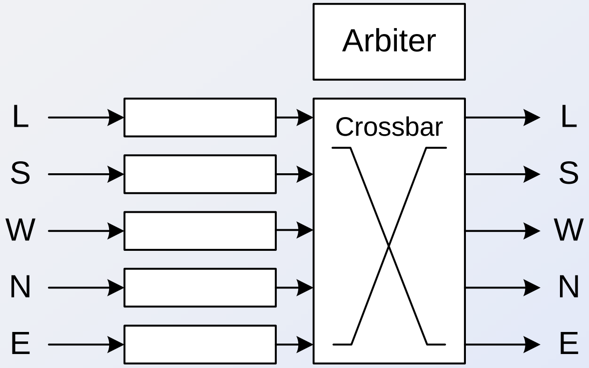
A NoRC Example

- The Connection Oriented Stochastic Routing (COSR) Algorithm

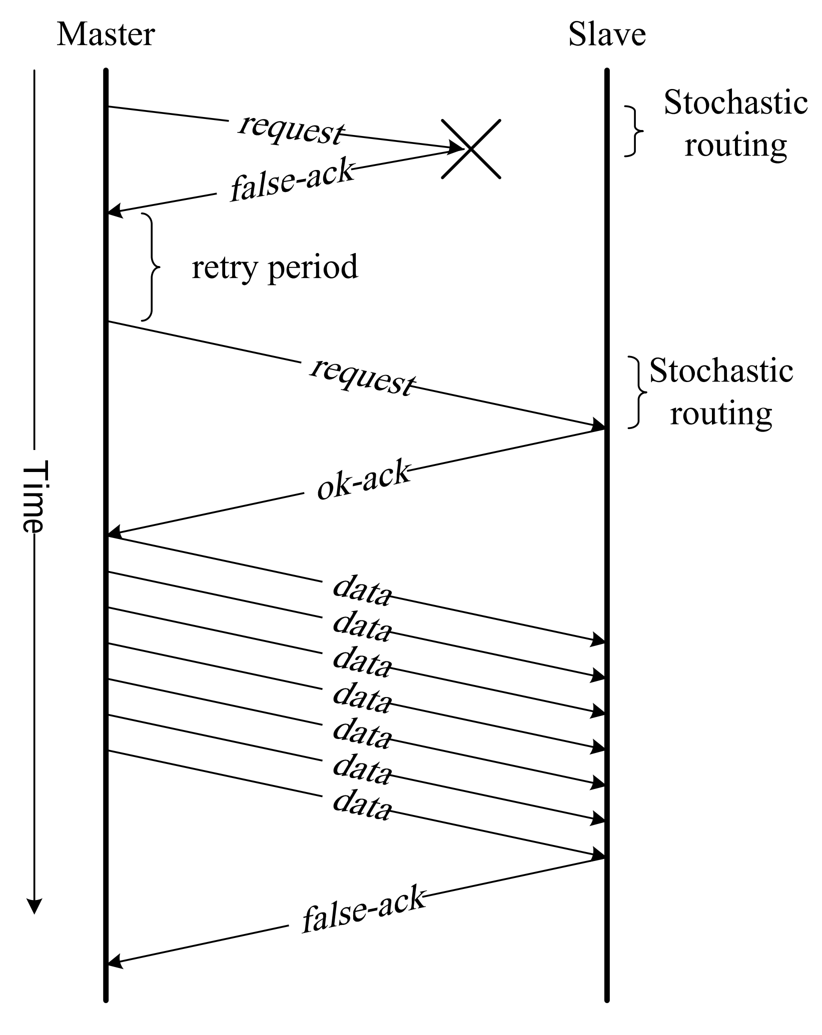
- The node reconfiguration



Router and Flit Types



- Simple router
- 4 types of flits
  - *request*
  - *false-ack*
  - *ok-ack*
  - *data*



Analyze the COSR

P, ports point to shorst paths

$\overline{\mathrm{P}}$, ports point to non-shortest paths

L, the length of a path

$\hat{p}$, the first selected port

$P = P\{L \le 16\}$

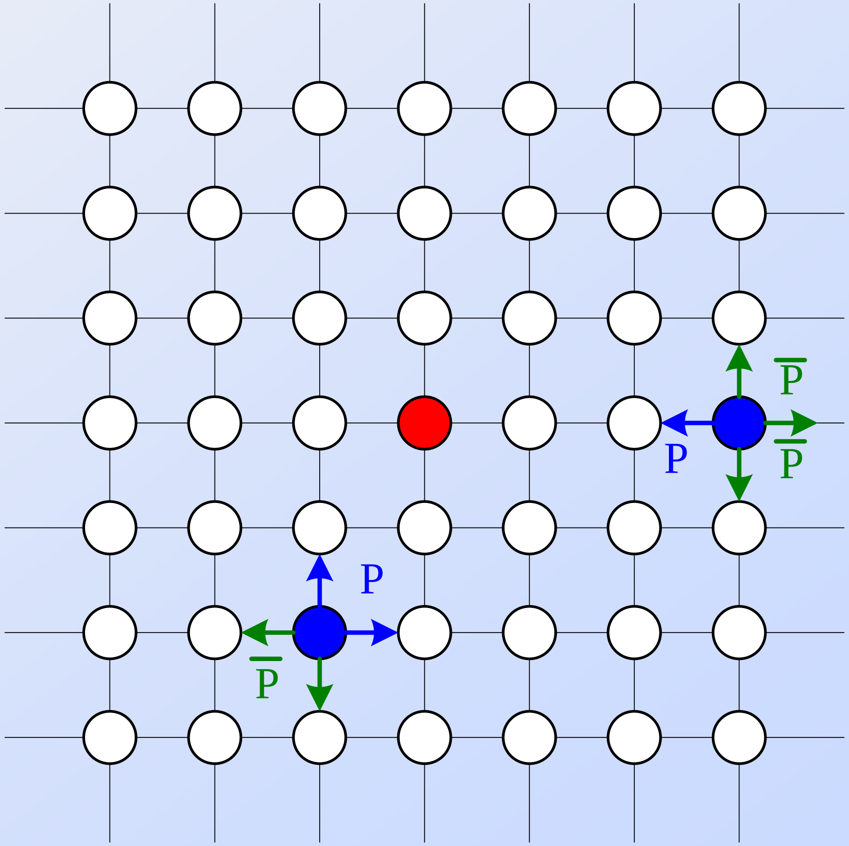
The probability to find the target in 16 hops

$P_{\mathrm{P}} = P\{L \le 16 \mid \hat{p} \in \mathrm{P}\}$

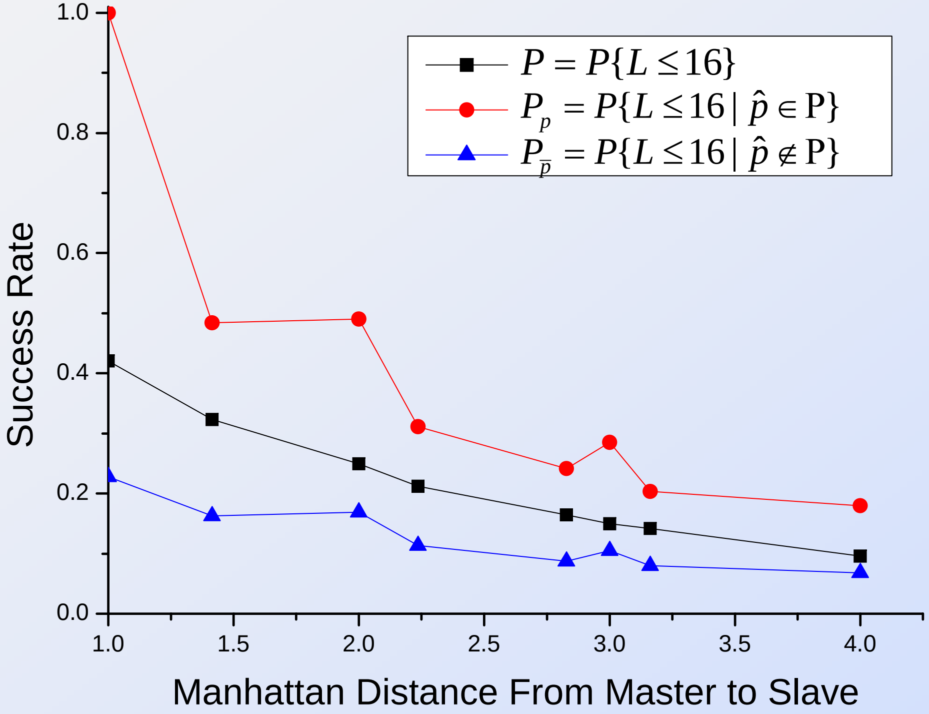
The probability when using set P

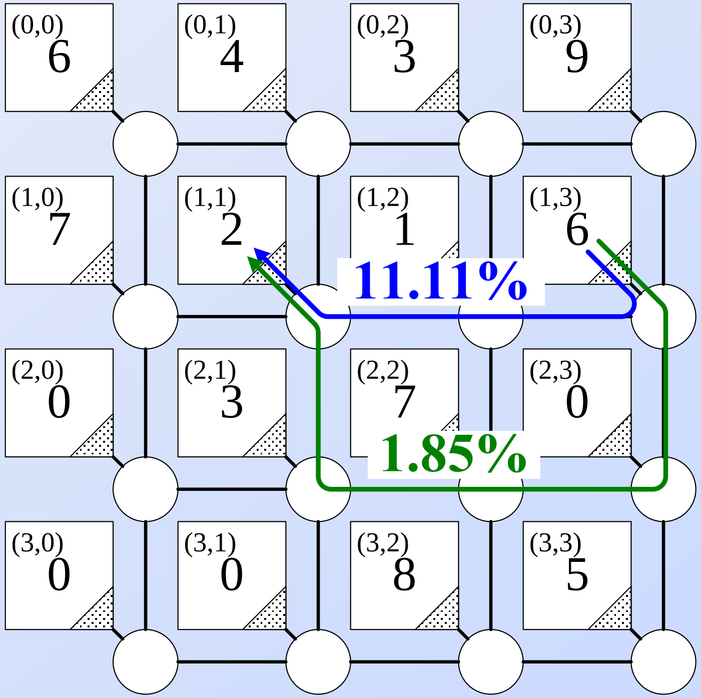
$P_{\overline{\mathrm{P}}} = P\{L \le 16 \mid \hat{p} \in \overline{\mathrm{P}}\}$

The probability when using set $\overline{\mathrm{P}}$



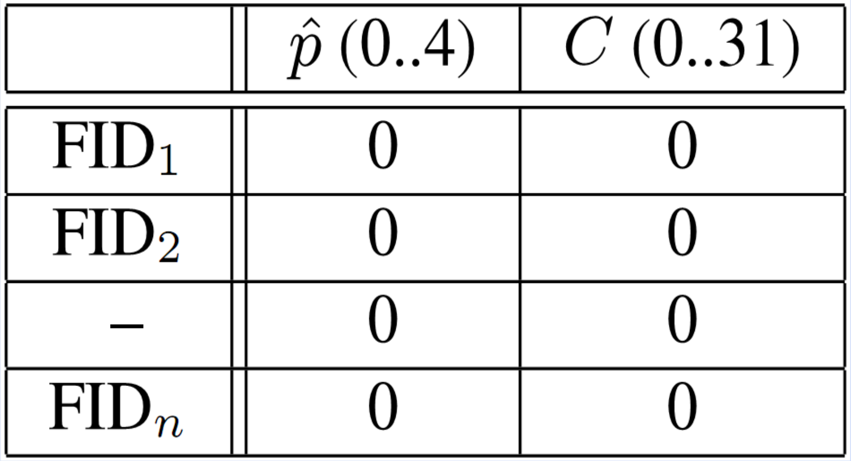
The Success Rate of COSR





Adaptive Stochastic Routing (ASR) Algorithm

Try to remember the last successful output port.



	$\hat{p}$ (0..4)	C (0..31)
FID_1	0	0
FID_2	0	0
–	0	0
FID_n	0	0

The update algorithm

- *request*

  Select a random number *v*

  Choose $\hat{p}$ in RT if *v*<*C*

  Choose a random port if $v \geq C$

- *false-ack*

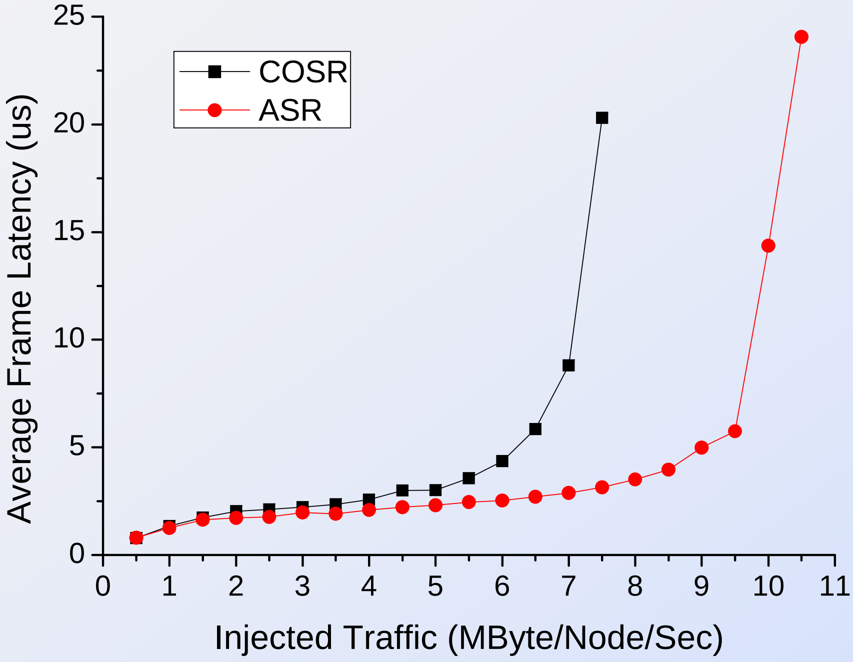
  C=C-1 if come from $\hat{p}$

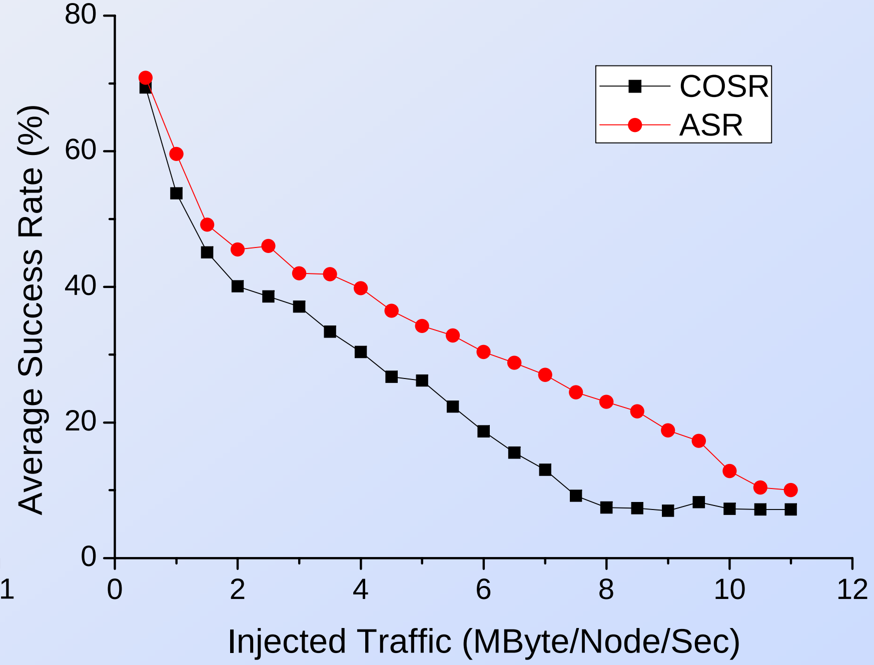
- *ok-ack*

  C=C+2 if come from $\hat{p}$

  Update $\hat{p}$ if C=0

Performance on an Error-free NoC

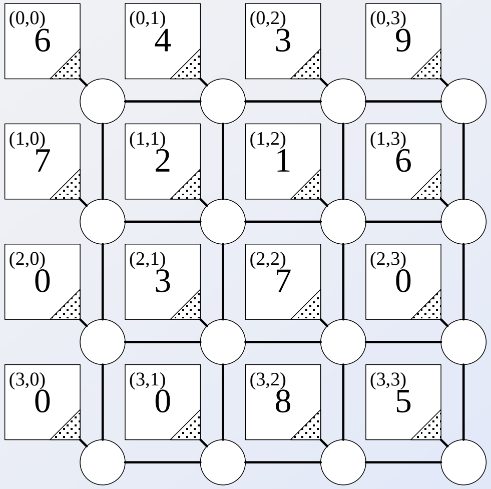




40% enlargement of the maximal accepted traffic.

15.59% higher success rate at the maximal 8MByte/Node/Sec injected traffic.

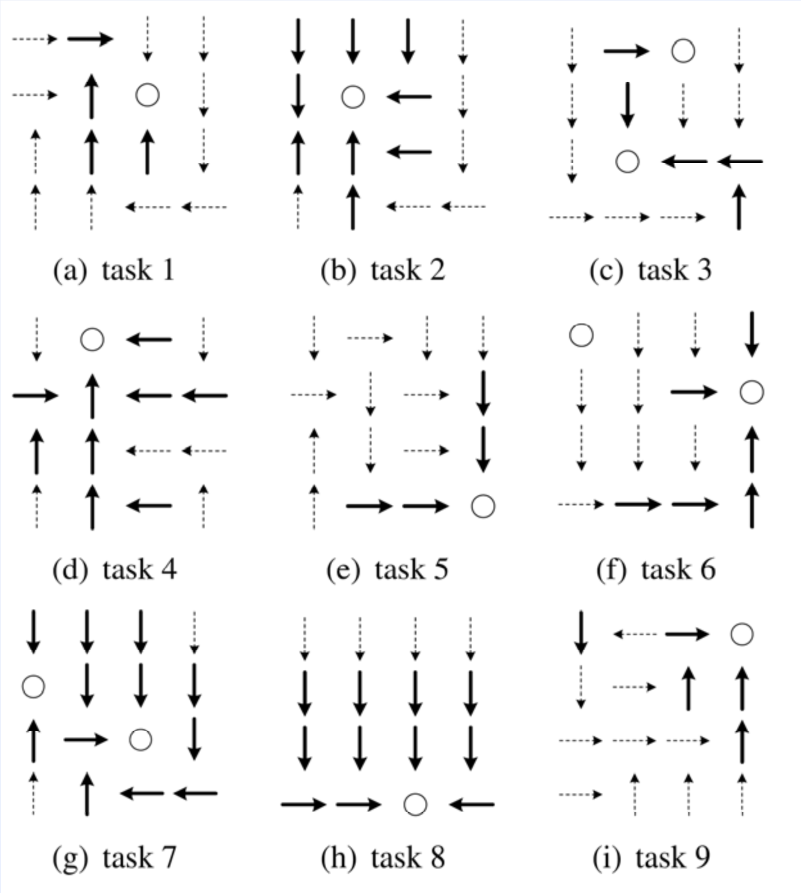
Result of the Learning Procedure



Injected traffic: 1MByte/Node/Sec

➞ Strong estimation, C >= 16

- -▸ Weak estimation, C < 16



(a) task 1 (b) task 2 (c) task 3

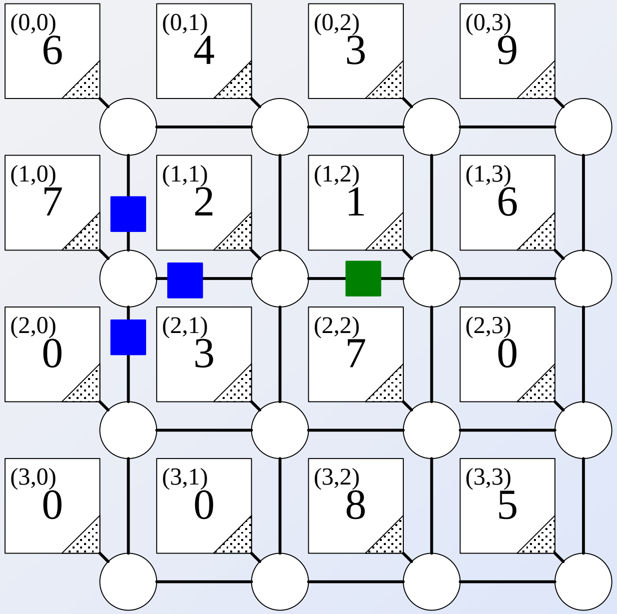
(d) task 4 (e) task 5 (f) task 6

(g) task 7 (h) task 8 (i) task 9

78.8% ports estimations are correct.

93.4% strong estimations are correct. (Strong estimations affect the routing procedure more significantly than weak ones.)

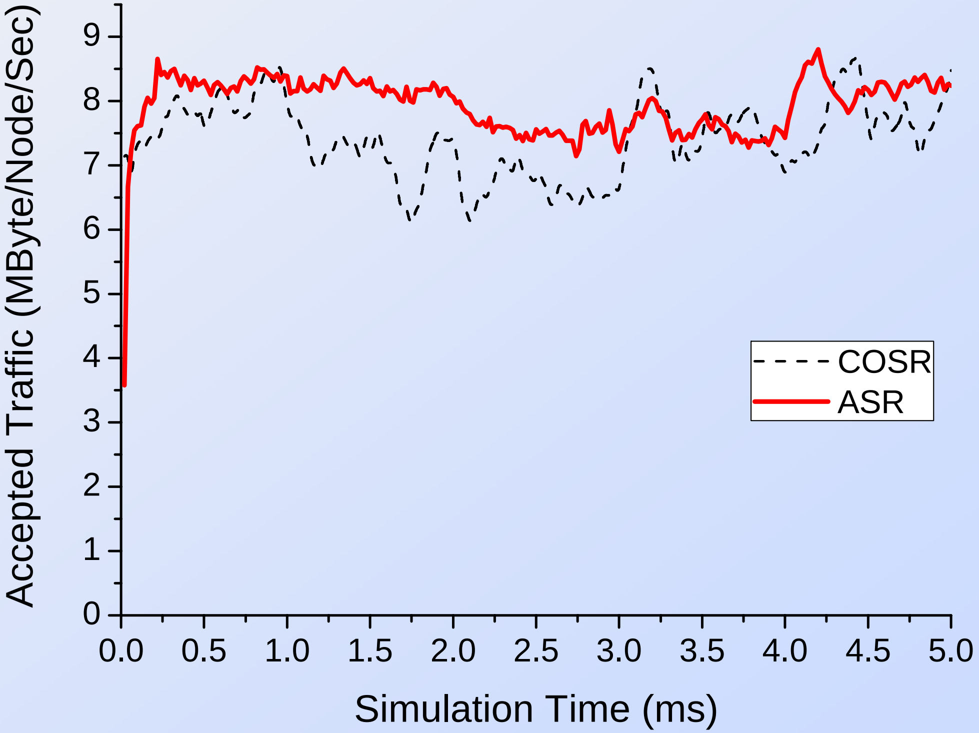
Performance on a Faulty NoC
Intermittent Errors



🟩 From 1ms to 3ms

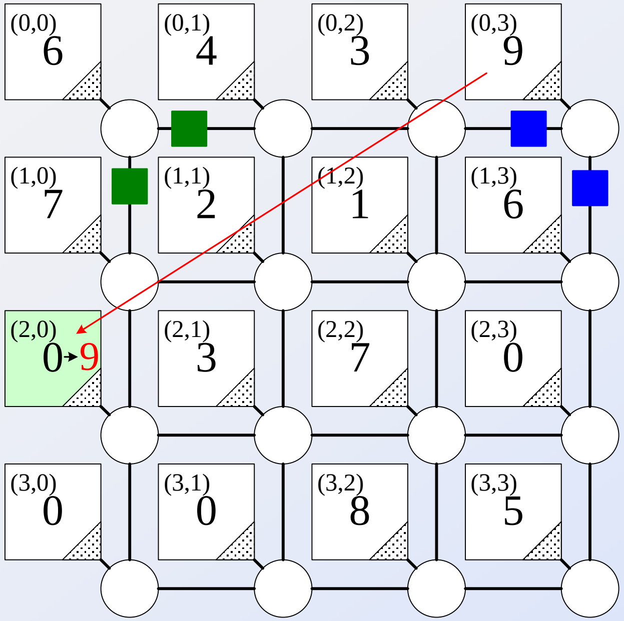
🟦 From 2ms to 4ms

Injected traffic: 8MByte/Node/Sec



Intermittent errors does not affect the traffic significantly.

Performance on a Faulty NoC Permanent Errors

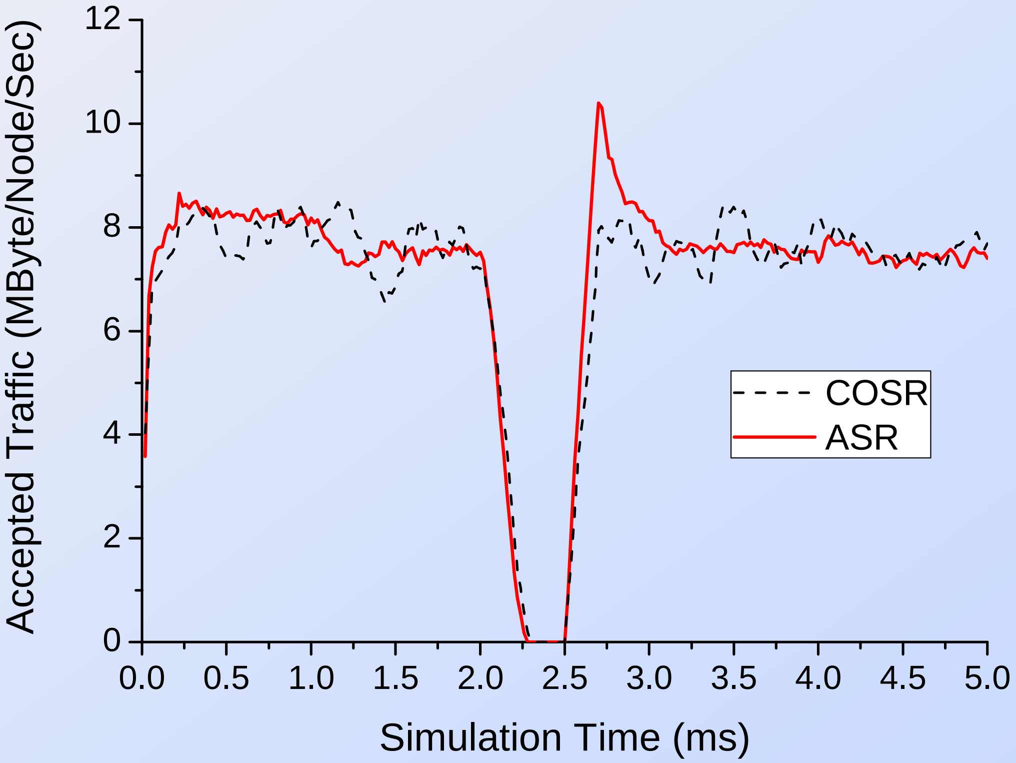


🟩 After 1ms

🟦 After 2ms

Node (2,0) is reconfigured to FID 9 after 2.5ms

Injected traffic: 8MByte/Node/Sec



If a node fails without an alternative node, the network can recover by reconfiguring it to another node.

Conclusions and Future Work

- Conclusions
  - NoRC is a fault-tolerant and dynamically reconfigurable NoC platform.
  - The COSR algorithm can search for any existing functions (slave candidates) but it is inefficient.
  - By learning from the results of COSR, ASR could improve the sub-optimized performance.
  - Both Algorithms are fault-tolerant to permanent/intermittent errors.

- Future Work
  - Implement them into an asynchronous router.
  - Design an error detection scheme in routers.
  - Combine the deterministic routing algorithms and the stochastic routing algorithms to further improve the network performance.

Thanks for your listening!
And thank Simon for his presentation!

Any further questions,

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