Comparison of Deadlock Recovery and Avoidance Mechanisms to Approach Message Dependent Deadlocks in on-Chip Networks

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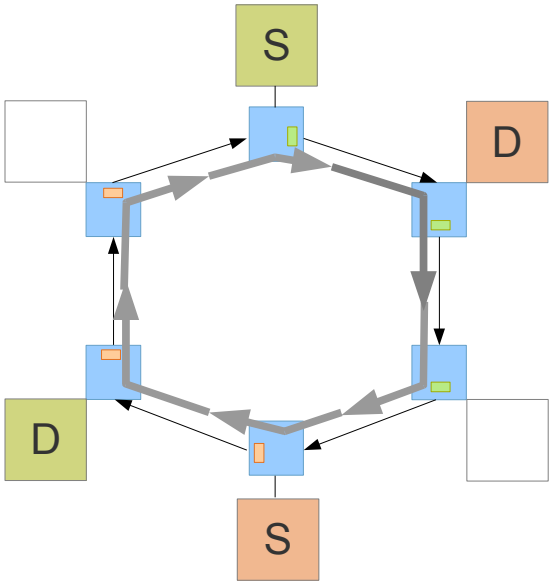
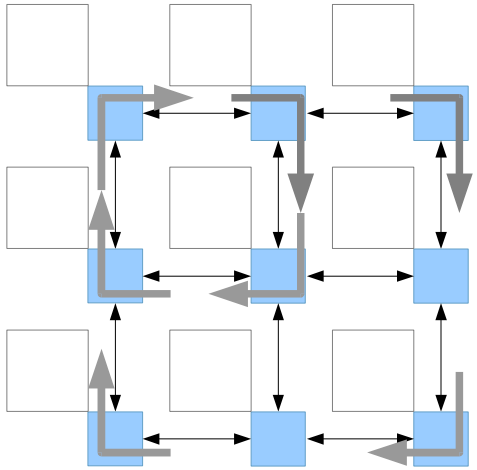
Networks-on-Chip & Deadlocks

- Packet-switched NoCs susceptible to deadlocks
  - Especially wormhole forwarding
- Routing cycles in channel dependency diagram

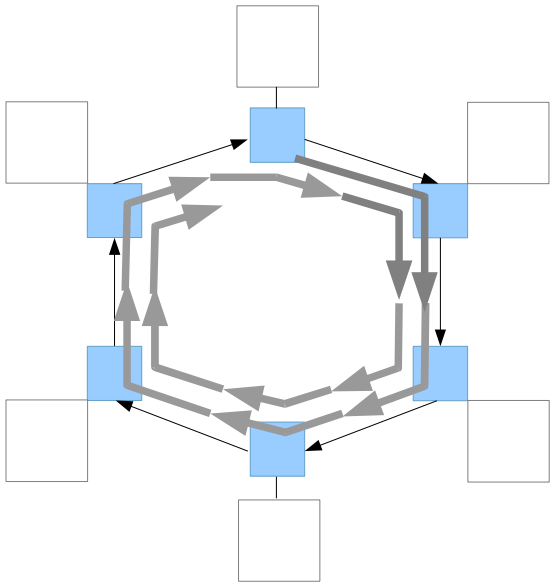




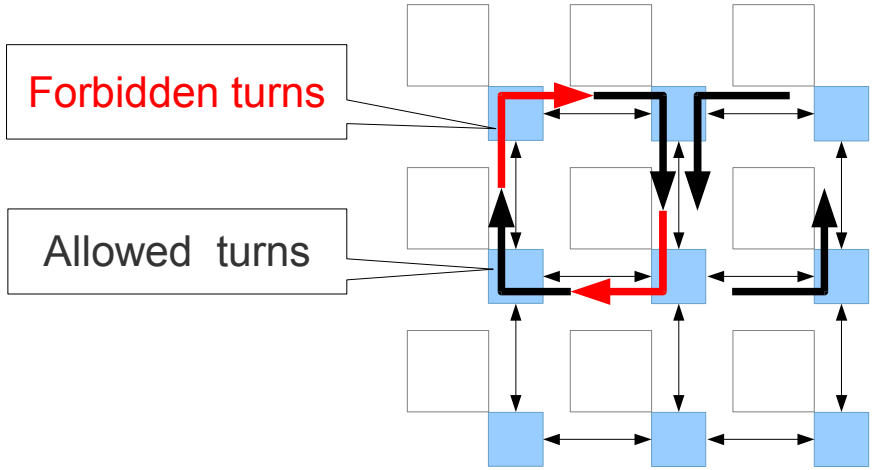
Deadlock Prevention

- Removal of Routing cycles

Implementation of virtual channels and adaption of routing function

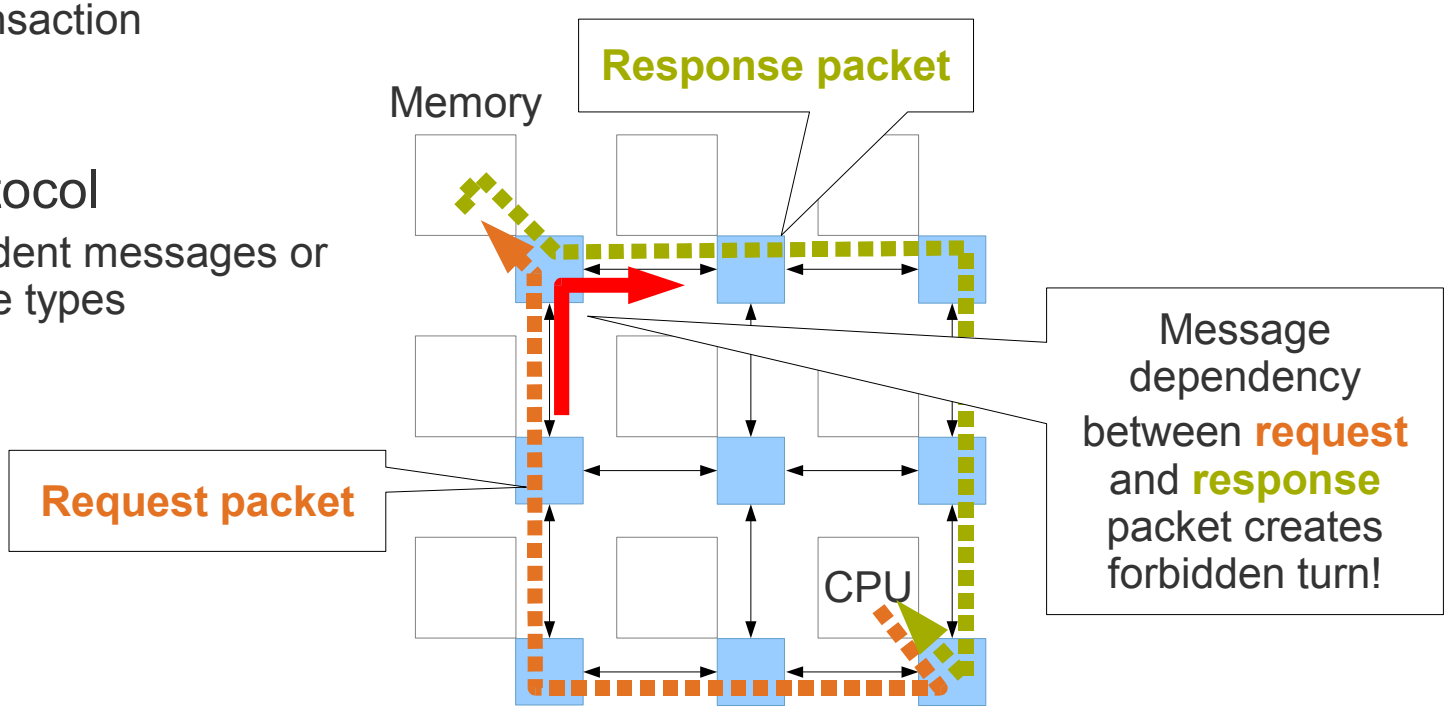


Restriction of routing function



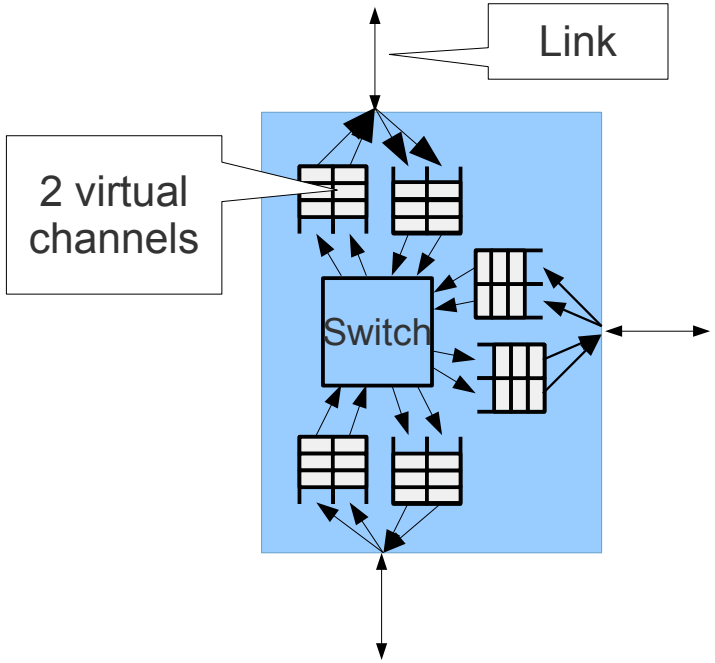
Message Dependent Deadlocks

- Network itself free of routing cycles
- Communication contains message dependencies
  - Memory access: read request -> read response
  - DMA transaction
  - ...
- N-way protocol
  - N dependent messages or message types



Message Dependent Deadlock Avoidance

- Buffer Sizing
  - Destination tile guarantees reception of all packets
    -> Huge input buffers
- End-to-end flow control
  - Limitation of sender quota
    E.g. credit based
- Strict ordering
  - Separation of message types in different networks
  - E.g. virtual channels: Buffer size rises with number of dependent messages



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- Comparison of Deadlock Recovery and Deadlock Avoidance
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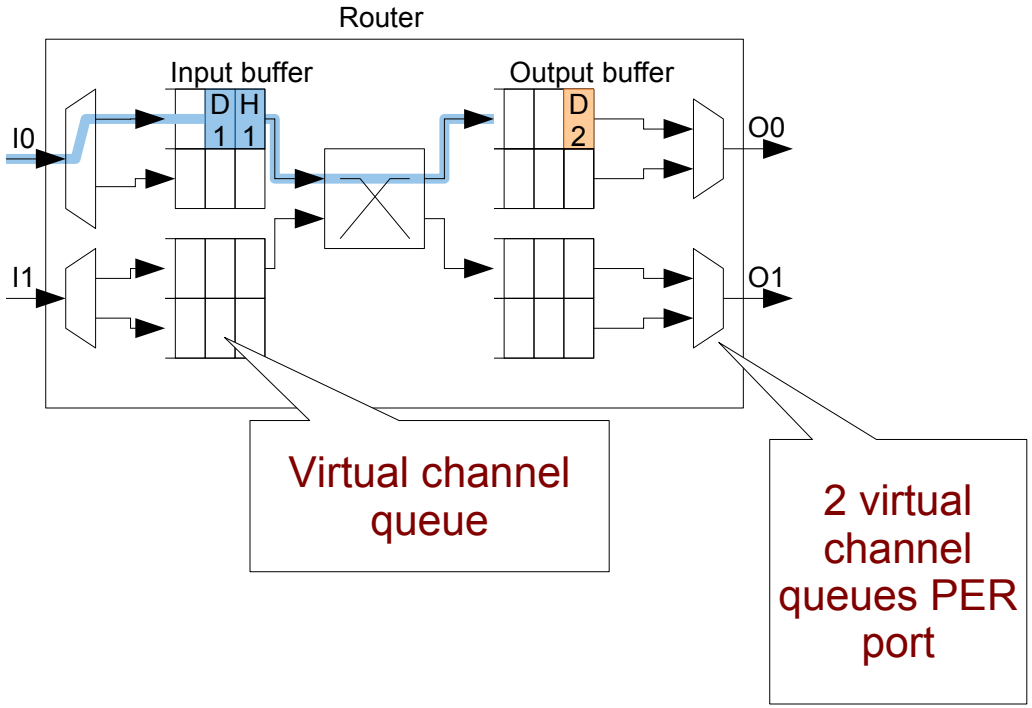
Deadlock Avoidance

Strict Ordering with virtual channels

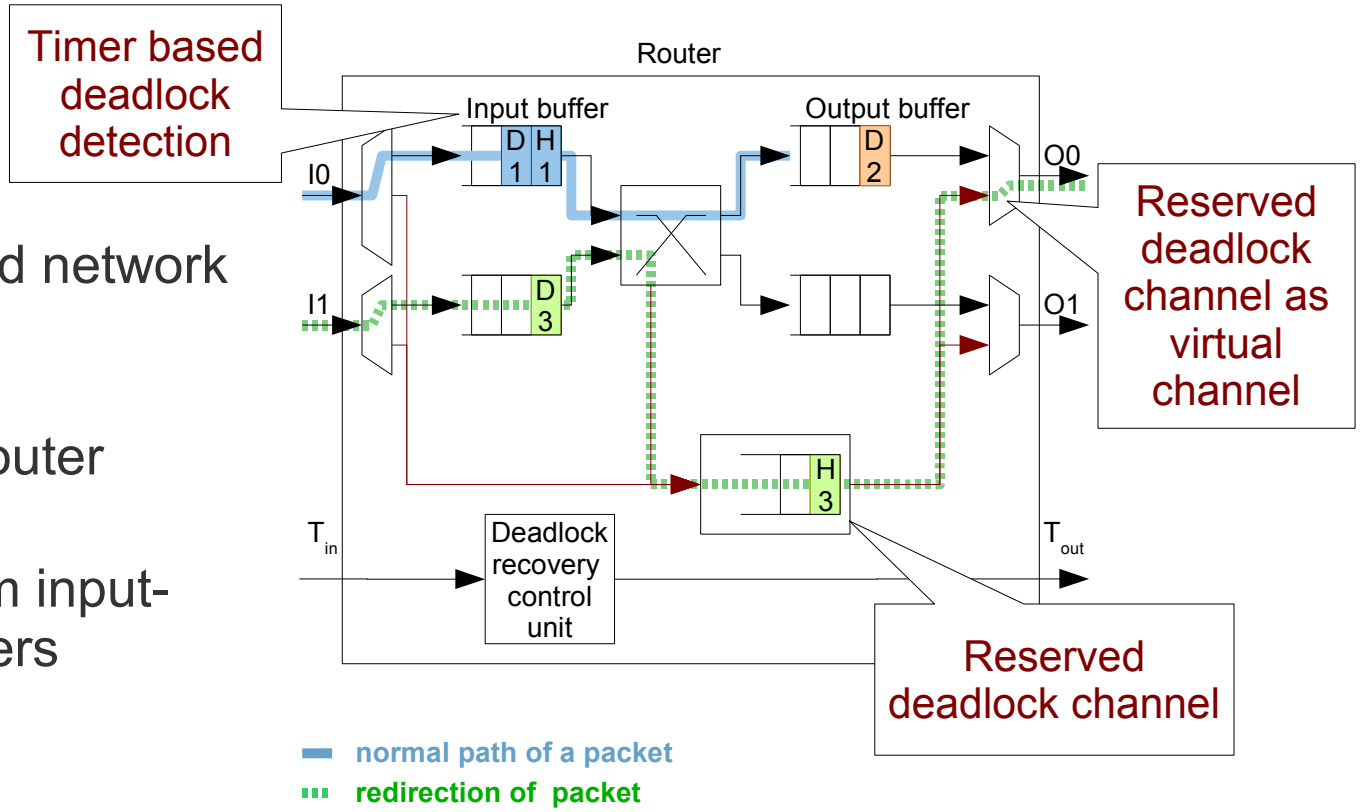
- Additional buffer queues **per port** (number of message types!)



Deadlock Recovery in HPC

Additional channel in the network reserved for deadlocked packets

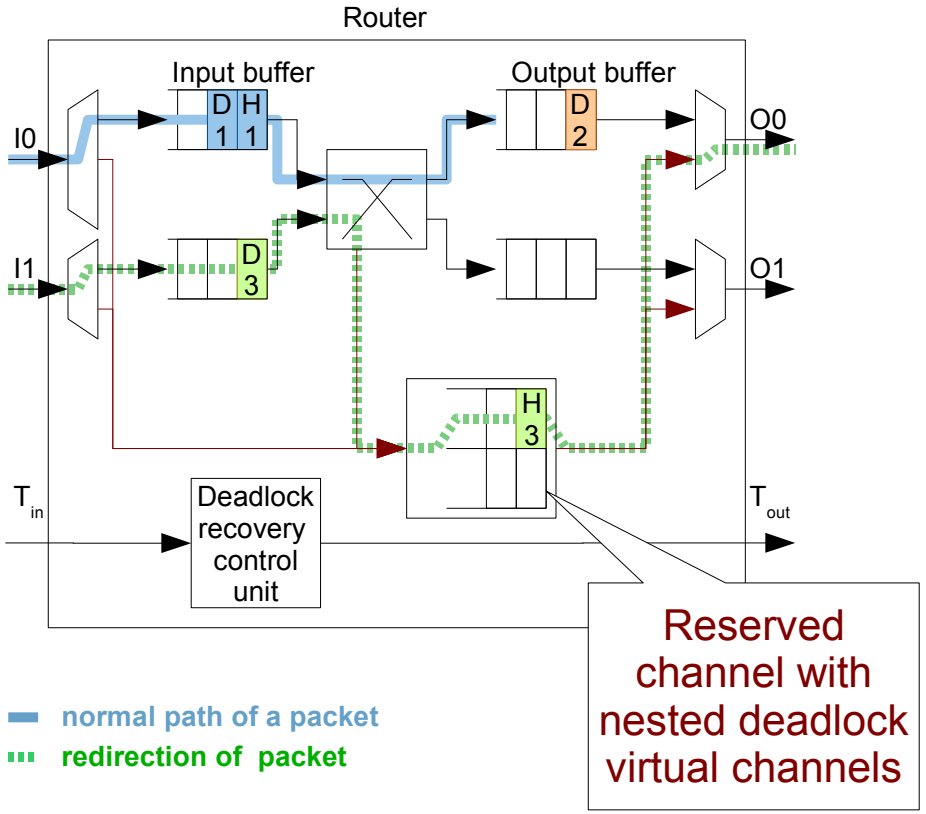
- In all routers and network interfaces
- Central to the router
- Redirection from input- and output buffers



Deadlock Recovery for NoCs

Avoid deadlocks in reserved deadlock channel

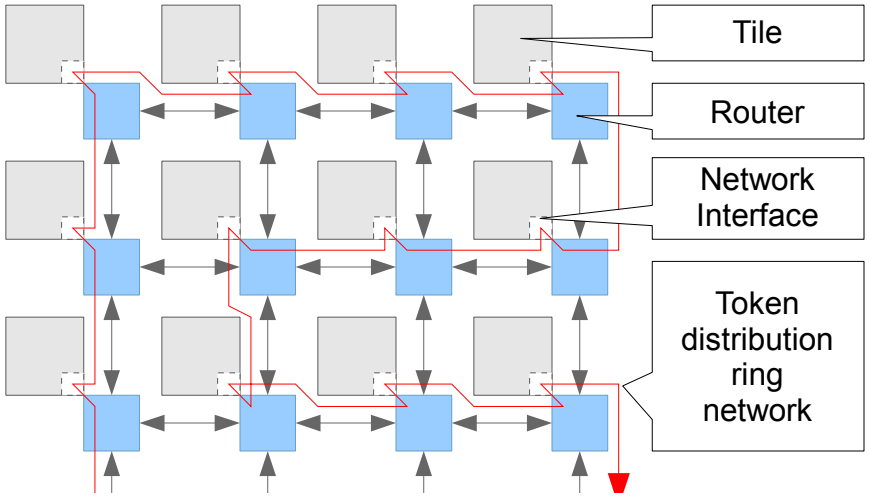
- Strict ordering in deadlock recovery channel
- Exclusive access to deadlock virtual channels



Access Regulation Scheme

Exclusive access to each deadlock virtual channel by token based access scheme

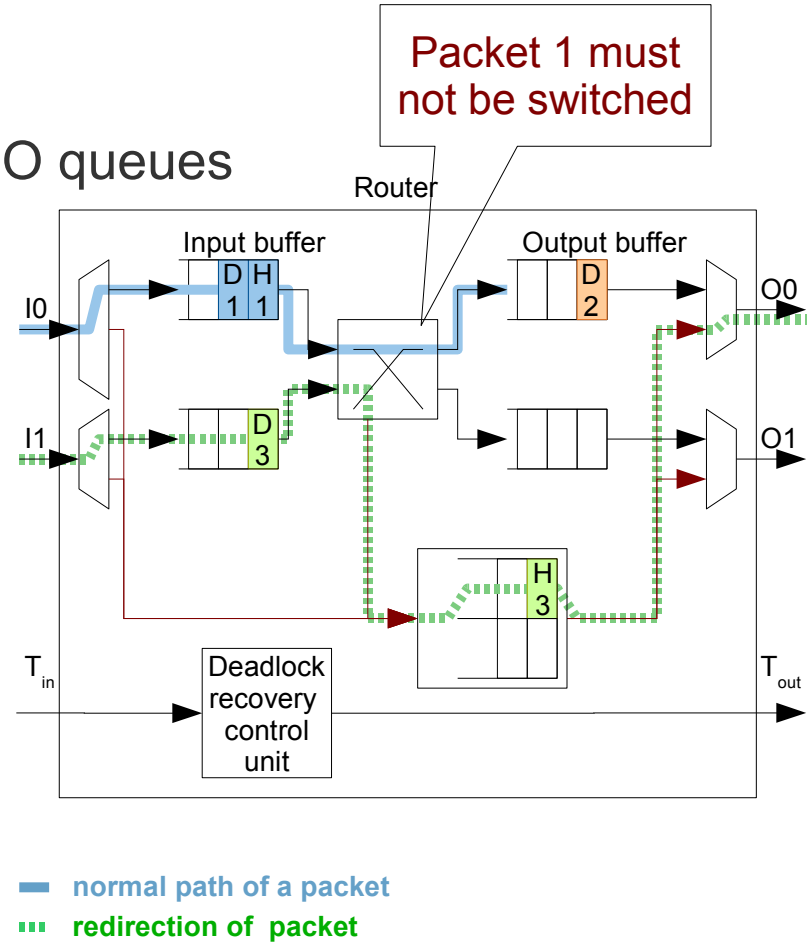
- Tokens circle through the token distribution ring network
- On redirection:
  - Token travels with redirected packets
  - Released on reception in the destination



Enable Redirection of Packets

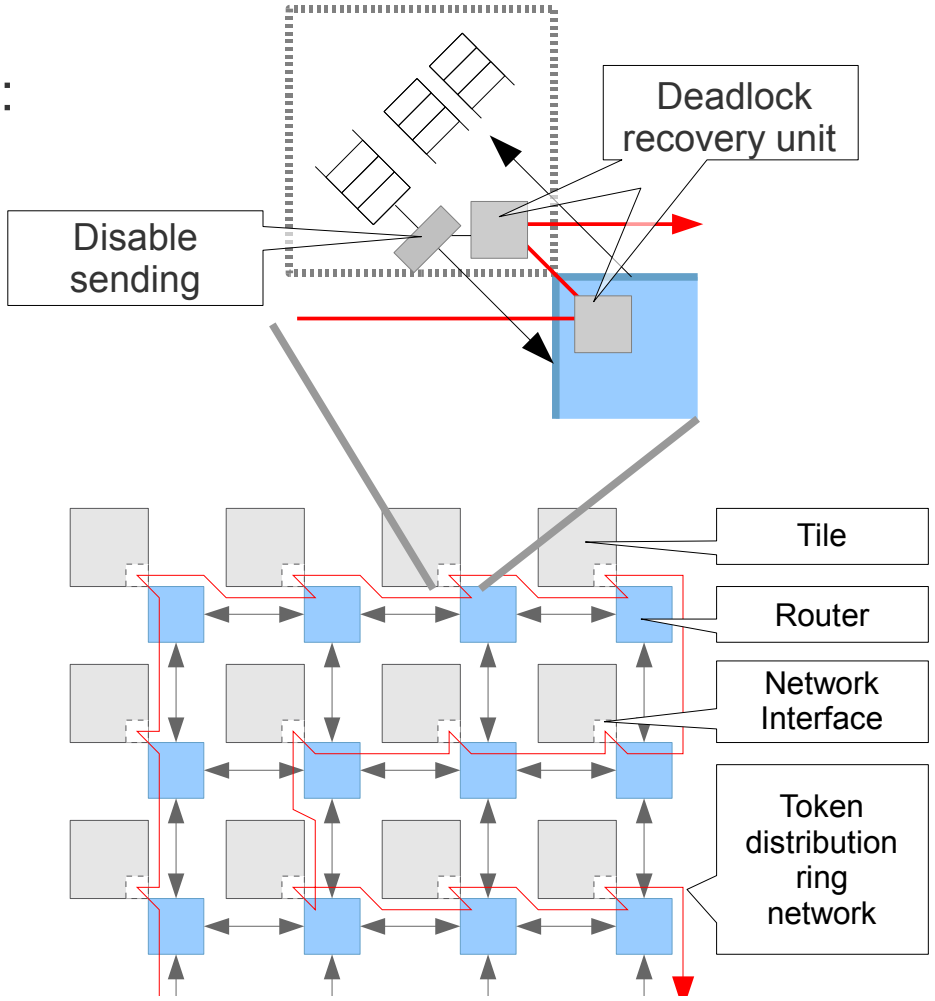
Problems:

- Buffers implemented as FIFO queues
- Wormhole forwarding
- Header flits always at first position in queues
  - Restrict switching function
  - Restrict flow control function
- Reduction of effective buffer size -> throughput



Back-off Mechanism

- Timer based deadlock detection: Congested network
- Back-off mechanism
  - Back-off token in token ring network
  - Forced sending stop for tiles



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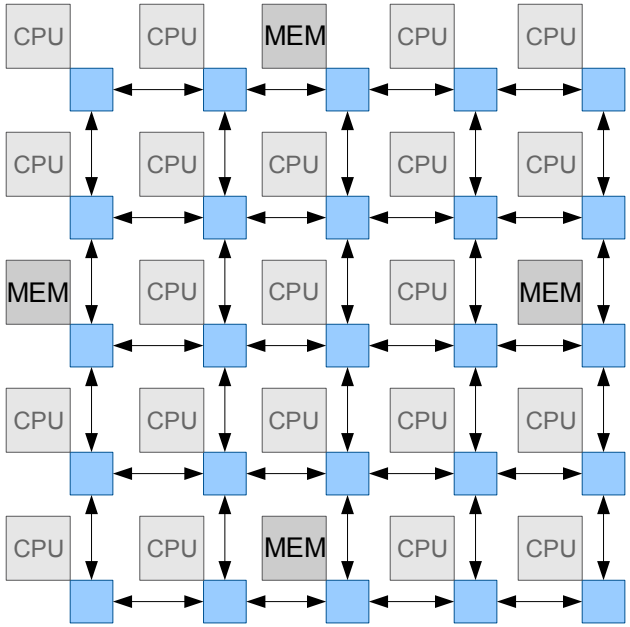
Comparison of Deadlock Avoidance & Recovery

- Common system architecture
  - 8x8 2D mesh architecture
  - XY routing, wormhole forwarding

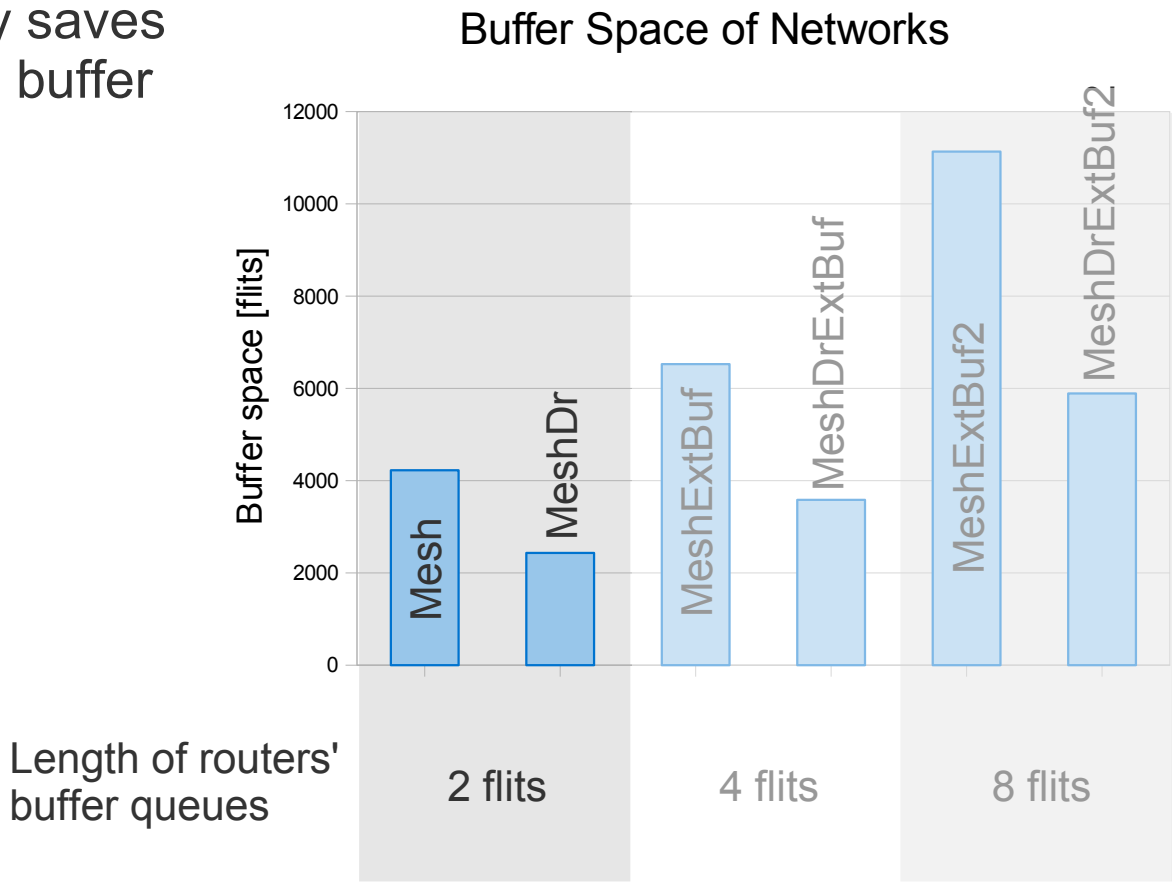
- Applied Traffic
  - Inter processor traffic (uniform distribution, rate constant)
  - Memory access traffic (uniform or varying localization, rate iterated)



- Deadlock Recovery (**MeshDr**)
- Deadlock Avoidance: strict ordering using virtual channels (**Mesh**)

Buffer Size Comparison

- Deadlock Recovery saves almost 50% of total buffer space
  - For 2 dependent messages

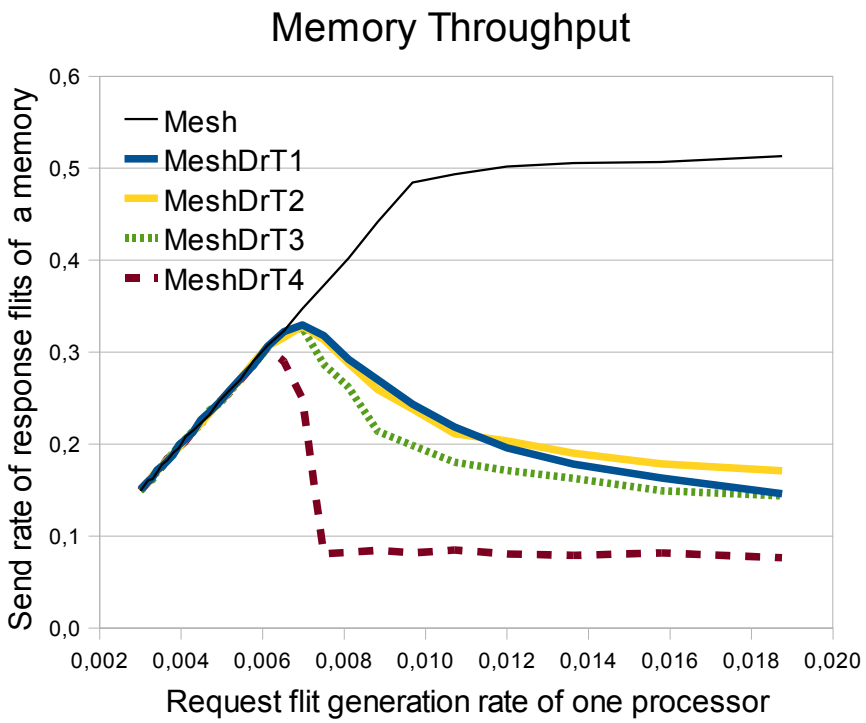


Memory Throughput

- Deadlock avoidance outperforms deadlock recovery

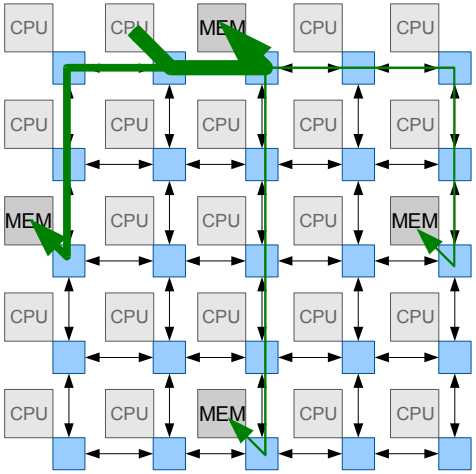
- Throughput of deadlock recovery depends on timings

Name of timings	Deadlock Detection Threshold [cycles]	Back-off Period [cycles]
T1	100	100
T2	100	150
T3	150	150
T4	50	50

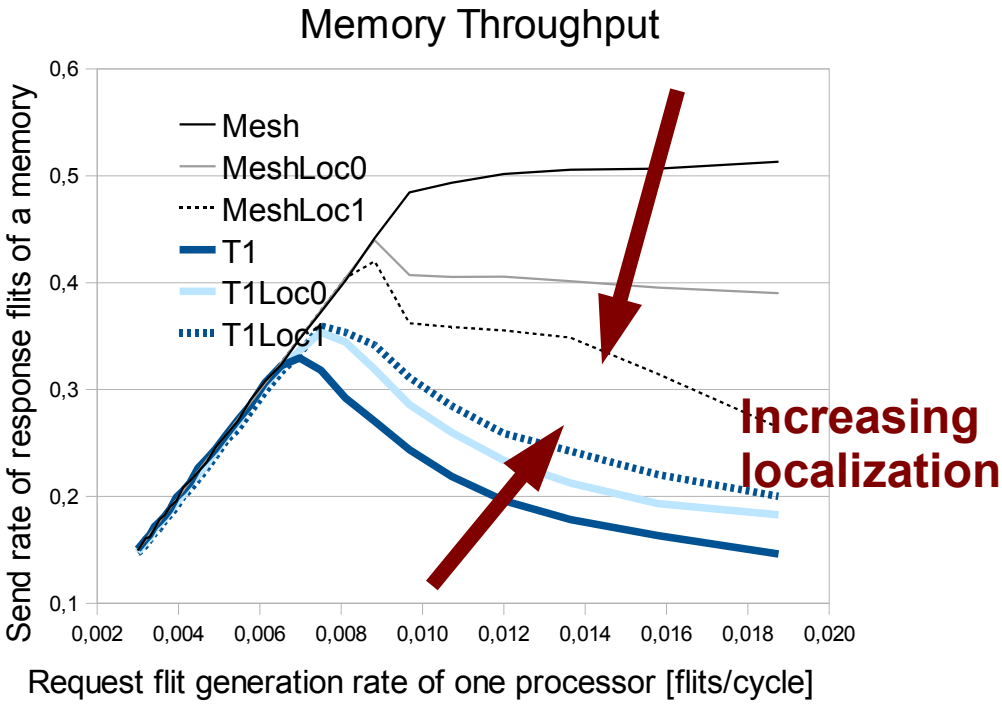


Localization of Memory Access Traffic

- Processors prefer nearer memories

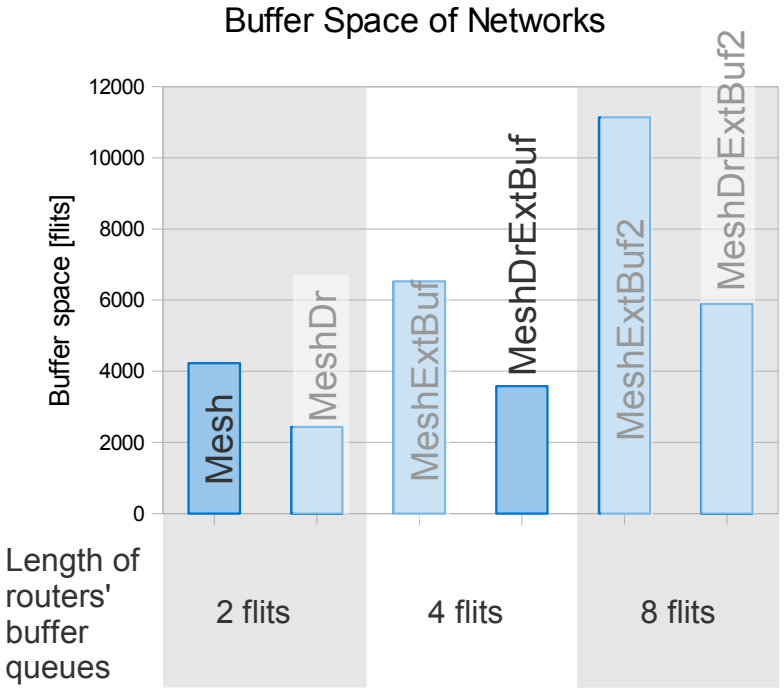


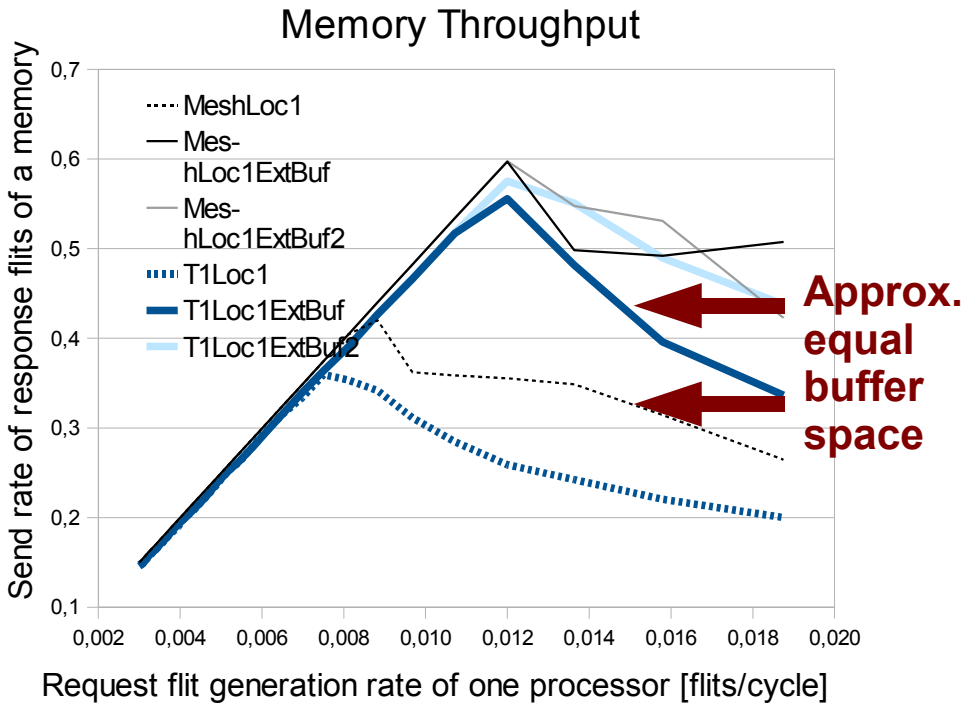
- Deadlock recovery profits from localization



Comparison of Networks with equal Buffer Space

- Higher throughput for recovery scheme with equal buffer space (for localized memory access traffic)





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Conclusion

- Significant savings in buffer space
  - For 2 dependent messages almost 50%
  - Savings increase with number of dependent messages
- Comparable buffer space leads to throughput advantage (for localized memory traffic)
- Future work
  - Deadlock detection
  - Random access to buffer queues
  - ...

Thank You!

Any Questions?

Effects of Restricted Switching & Flow Control

- Reduction of effective buffer size
- Reduction of throughput