Lecture 15: NoC Innovations

- Today: power and performance innovations for NoCs

Network Power

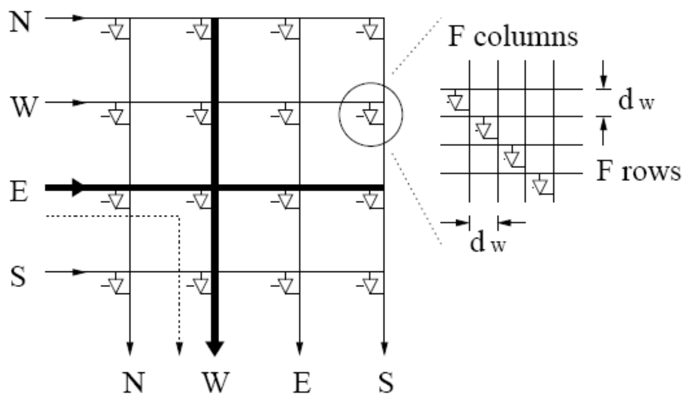
- Power-Driven Design of Router Microarchitectures in On-Chip Networks, MICRO'03, Princeton

- Energy for a flit = $E_R \, . \, H + E_{wire} \, . \, D$
  $= (E_{buf} + E_{xbar} + E_{arb}) \, . \, H + E_{wire} \, . \, D$

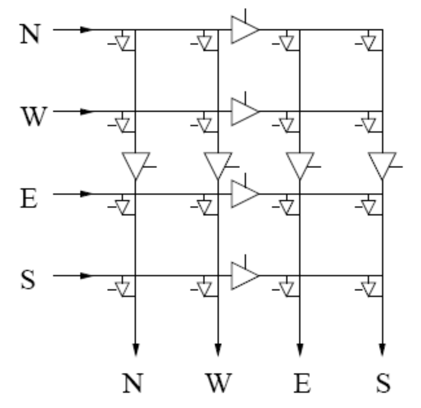
E_R = router energy
E_{wire} = wire transmission energy
E_{buf} = router buffer energy
E_{arb} = router arbiter energy
H = number of hops
D = physical Manhattan distance
E_{xbar} = router crossbar energy

- This paper assumes that $E_{wire} \, . \, D$ is ideal network energy (assuming no change to the application and how it is mapped to physical nodes)

Segmented Crossbar



(a) A 4×4 matrix crossbar.

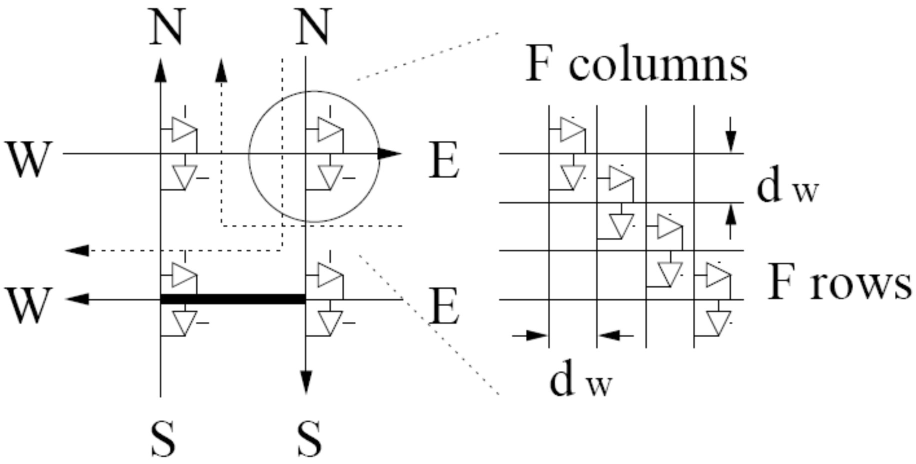


(b) A 4×4 segmented cross-bar with 2 segments per line.

- By segmenting the row and column lines, parts of these lines need not switch → less switching capacitance (especially if your output and input ports are close to the bottom-left in the figure above)
- Need a few additional control signals to activate the tri-state buffers
- Overall crossbar power savings: ~15-30%

Cut-Through Crossbar

- Attempts to optimize the common case: in dimension-order routing, flits make up to one turn and usually travel straight
- 2/3rd the number of tristate buffers and 1/2 the number of data wires
- “Straight” traffic does not go thru tristate buffers

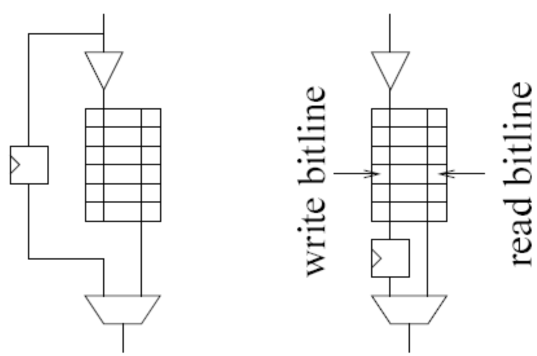


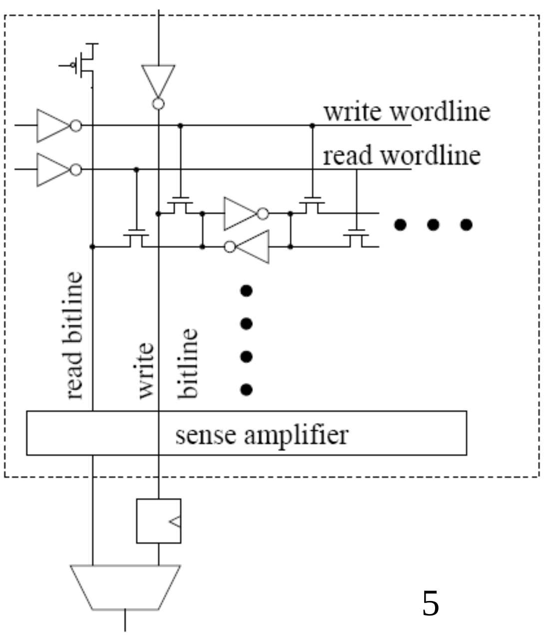
(a) A 4×4 cut-through crossbar.

- Some combinations of turns are not allowed: such as E → N and N → W (note that such a combination cannot happen with dimension-order routing)
- Crossbar energy savings of 39-52%

Write-Through Input Buffer

- Input flits must be buffered in case there is a conflict in a later pipeline stage
- If the queue is empty, the input flit can move straight to the next stage: helps avoid the buffer read
- To reduce the datapaths, the write bitlines can serve as the bypass path
- Power savings are a function of rd/wr energy ratios and probability of finding an empty queue



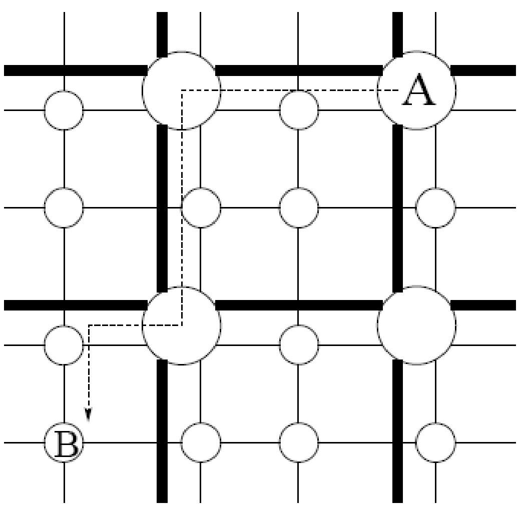


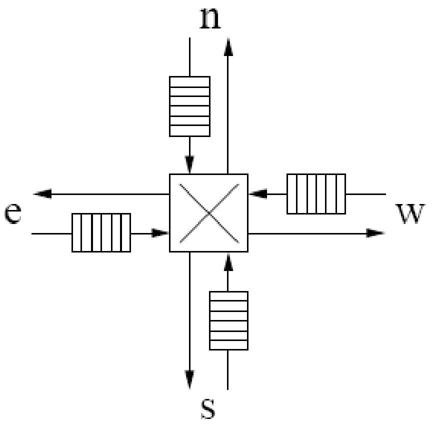
Express Channels

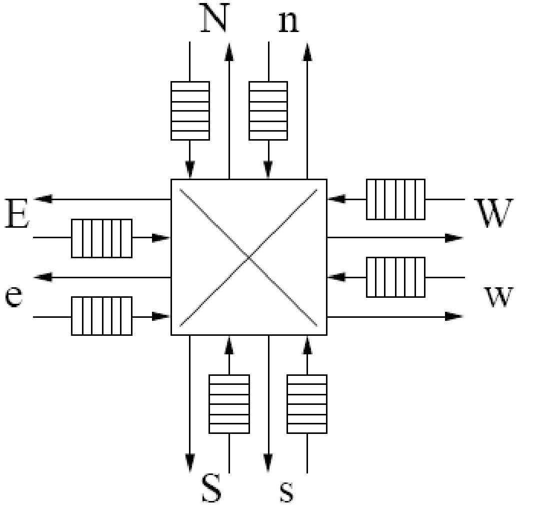
- Express channels connect non-adjacent nodes – flits traveling a long distance can use express channels for most of the way and navigate on local channels near the source/destination (like taking the freeway)

- Helps reduce the number of hops

- The router in each express node is much bigger now



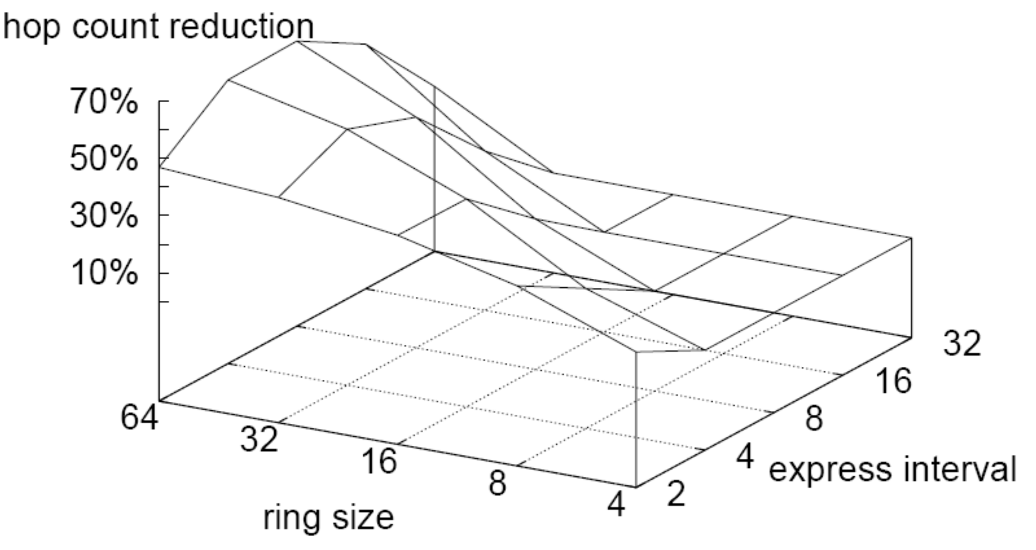




Express Channels

- Routing: in a ring, there are 5 possible routes and the best is chosen; in a torus, there are 17 possible routes

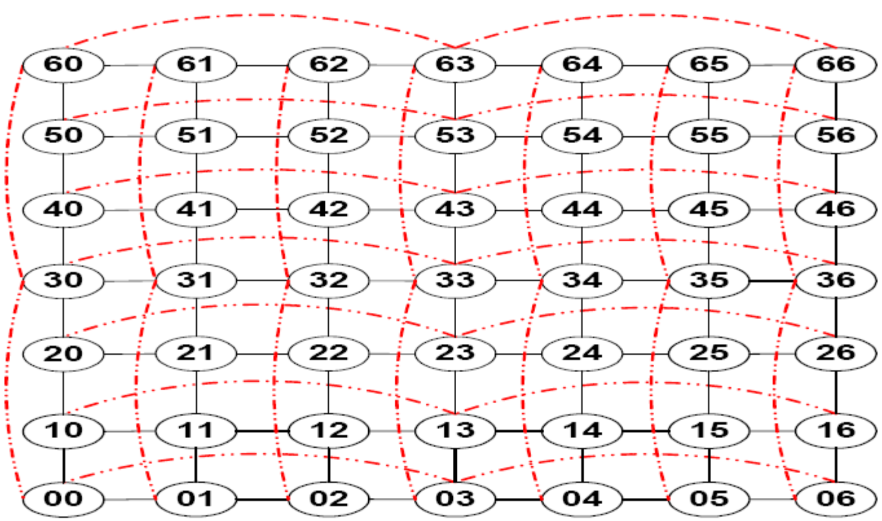
- A large express interval results in fewer savings because fewer messages exercise the express channels

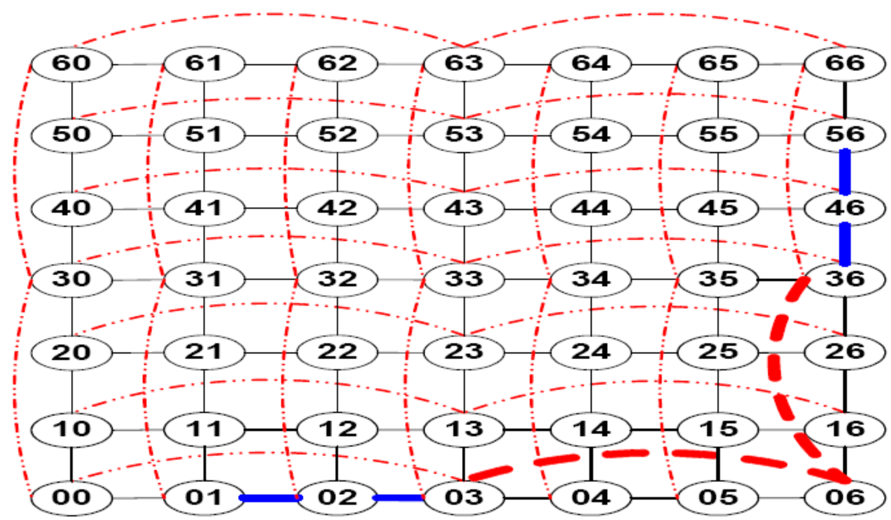


Express Virtual Channels

- To a large extent, maintain the same physical structure as a conventional network (changes to be explained shortly)

- Some virtual channels are treated differently: they go through a different router pipeline and can effectively avoid most router overheads





(b) VCs acquired from nodes 01 to 56

Router Pipelines

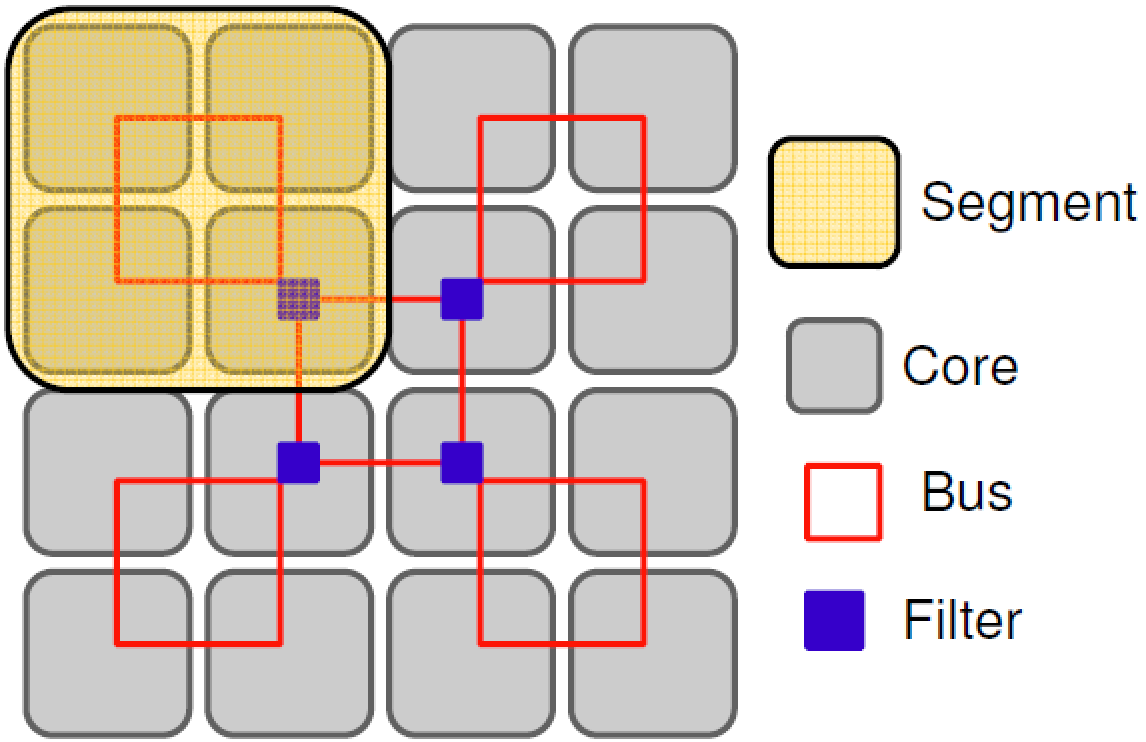
- If Normal VC (NVC):
  - at every router, must compete for the next VC and for the switch
  - will get buffered in case there is a conflict for VA/SA

- If EVC (at intermediate bypass router):
  - need not compete for VC (an EVC is a VC reserved across multiple routers)
  - similarly, the EVC is also guaranteed the switch (only 1 EVC can compete for an output physical channel)
  - since VA/SA are guaranteed to succeed, no need for buffering
  - simple router pipeline: incoming flit directly moves to ST stage

- If EVC (at EVC source/sink router):
  - must compete for VC/SA as in a conventional pipeline
  - before moving on, must confirm free buffer at next EVC router

Hierarchical Buses

Udipi et al., HPCA'10

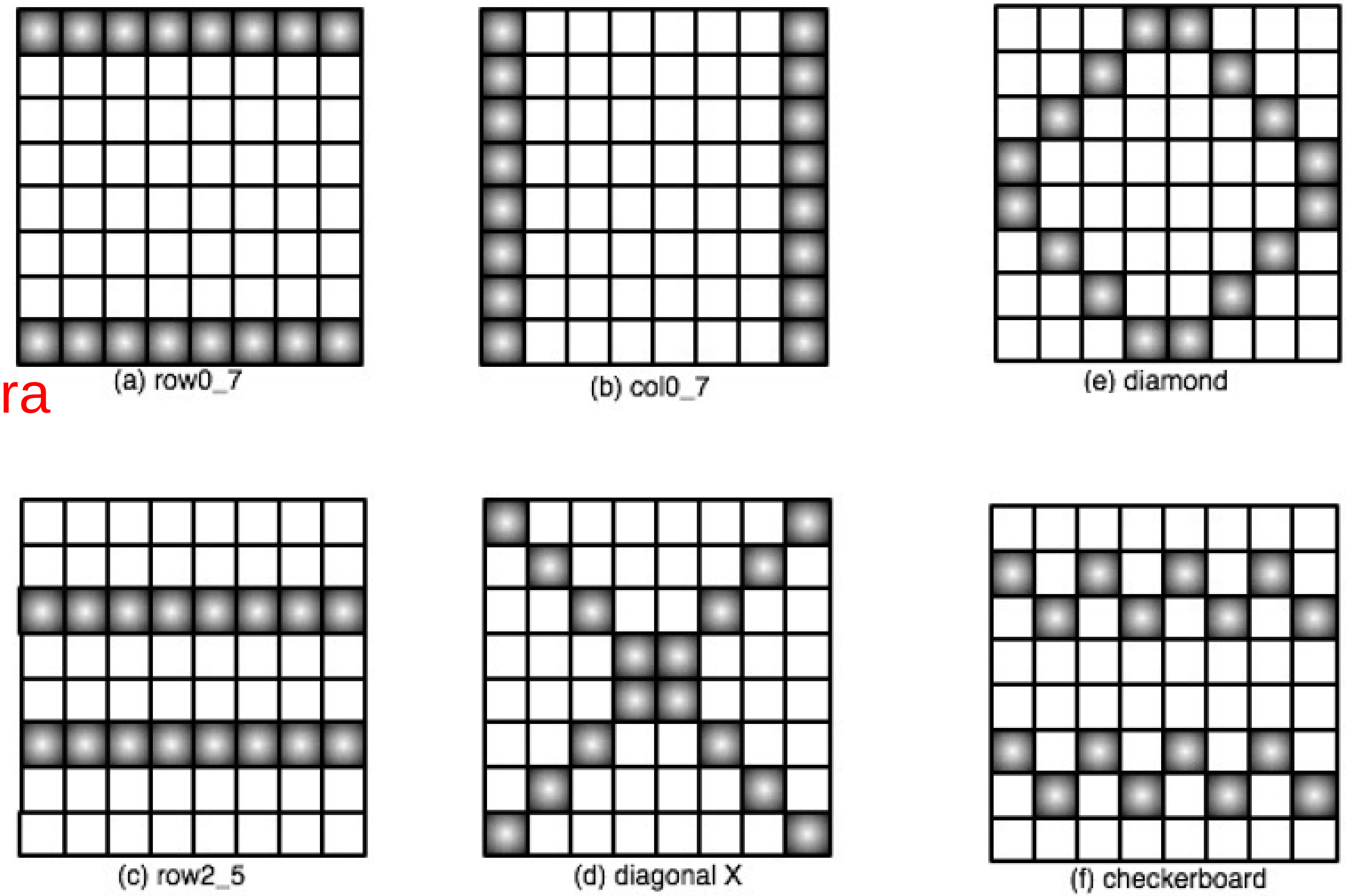


- Use buses to reduce routers
- Use bloom filters to stifle broadcasts
- Use page coloring to minimize travel beyond a bus

MC Placement

Abts et al., ISCA 2009

Tilera



MC Placement

- Diamond placement has the least link contention as it distributes traffic
- XY routing for requests and YX routing for replies is also effective in distributing traffic

NoX Router

Hayenga and Lipasti, MICRO 2011

- In speculative routers, two packets may be sent out at the same time on the link; receiver gets garbage
- Instead, send the XOR of the colliding packets
- In the next cycles, send the XOR of colliding packets, minus one of the colliding packets
- Receiver decodes all of the packets with XORs
- Saves one wasted cycle on every collision or mis-speculation

Title

- Bullet