

High-Performance Computing Networks at BYU

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Physics generally limits us on the faster resources, so we spend more time on parallelism.

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 - For communicating with data storage

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- If the processes are on different hosts, we have to go out to some communication fabric (“*Inter-node*” communication)
 - There's a lot of research in speeding up *intra-node* communication, but that's more of a Computer Science or Electrical Engineering problem. We'll spend our time today on *inter-node* communication

Technologies for *inter*-node communication

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 - Remote Direct Memory Access (RDMA)

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| | <i>SDR</i> | <i>DDR</i> | <i>QDR</i> | <i>FDR</i> |
|------------|------------|------------|------------|------------|
| <i>1x</i> | 2.5 Gb/s | 5 Gb/s | 10 Gb/s | 14 Gb/s |
| <i>4x</i> | 10 Gb/s | 20 Gb/s | 40 Gb/s | 56 Gb/s |
| <i>12x</i> | 30 Gb/s | 60 Gb/s | 120 Gb/s | 168 Gb/s |

Encoding Overhead

Infiniband uses bit-line encodings to guarantee bit transitions for clock synchronization:

- SDR, DDR, QDR - 8b/10b encoding (8 data bytes encoded in 10 bytes total; 20% overhead)
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|------------|----------------------------|----------------------------|-----------------------------|--------------------------------|
| <i>1x</i> | 2.5 Gb/s raw 2 Gb/s net | 5 Gb/s raw 4 Gb/s net | 10 Gb/s raw 8 Gb/s net | 14 Gb/s raw 13.6 Gb/s net |
| <i>4x</i> | 10 Gb/s raw 8 Gb/s net | 20 Gb/s raw 16 Gb/s net | 40 Gb/s raw 32 Gb/s net | 56 Gb/s raw 54.3 Gb/s net |
| <i>12x</i> | 30 Gb/s raw 24 Gb/s net | 60 Gb/s raw 48 Gb/s net | 120 Gb/s raw 96 Gb/s net | 168 Gb/s raw 162.9 Gb/s net |

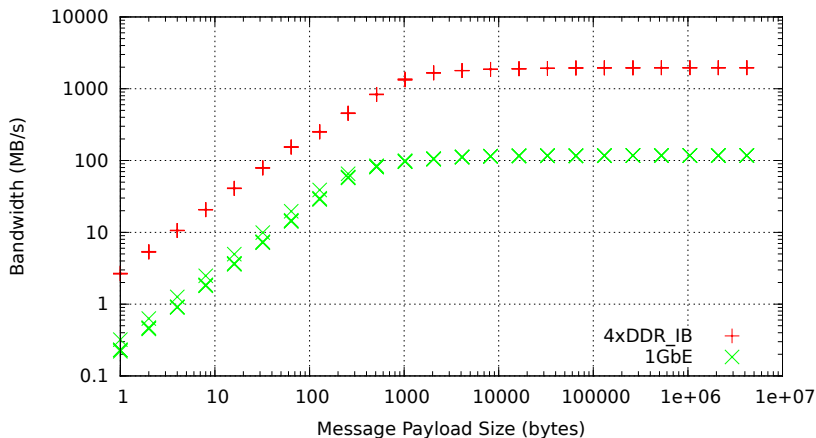
Performance at BYU's FSL

The graphs shown in the next couple of slides represent the bandwidth and latency performance of 4xDDR Infiniband vs 1Gb/s Ethernet at the Fulton Supercomputing Lab.

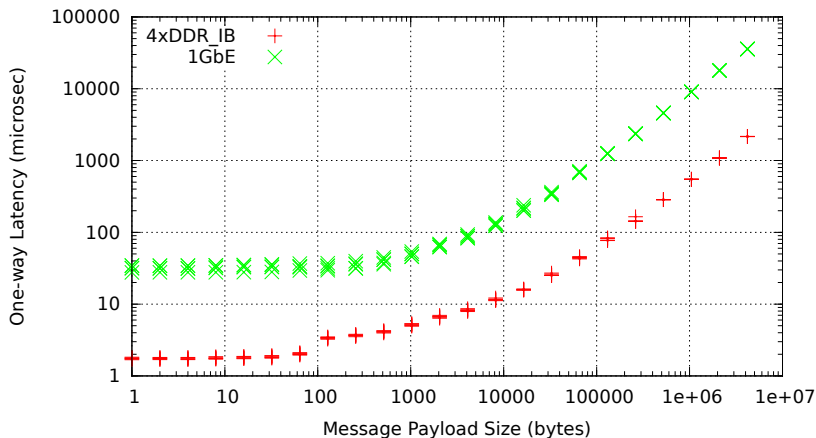
- All tests were performed host-to-host with one intervening switch (eg. host-switch-host)
- All tests utilize increasing message sizes, to demonstrate where one effect ends and the other starts
- Tests were performed using the “osu_bw” and “osu_latency” binaries from the OSU Micro-Benchmarks for MPI (a.k.a. “OMB”)¹

¹<http://mvapich.cse.ohio-state.edu/benchmarks/>

Bandwidth Comparison - 4xDDR IB vs 1Gb/s Ethernet



One-way Latency Comparison - 4xDDR IB vs 1Gb/s Ethernet



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- Build a cohesive model of the network topology
- Load the switch forwarding tables with the LID/Port mapping

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- The Subnet Manager loads all the forwarding tables into the switches
 - as long as you can build an appropriate graph parsing algorithm, and implement it in a subnet manager, you can use a topology
 - allows some much more interesting topologies than those commonly Ethernet and TCP/IP networks usually use.²

²Technically you can use any topology with Ethernet as well. It just takes a huge amount of very-messy work, for very little benefit. I don't recommend trying it.

Possible Topologies

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- Tree/Fat-Tree

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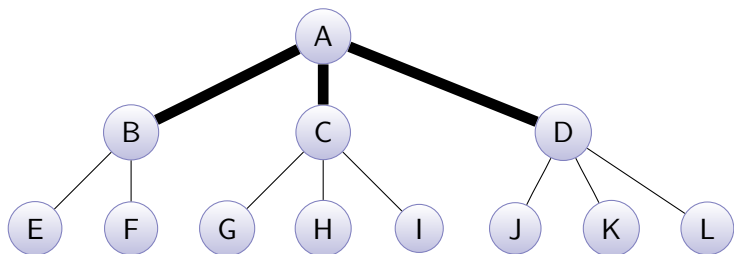
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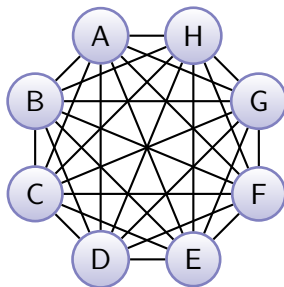
Fat Tree Example

A *Fat Tree* is basically a tree with increased bandwidth (faster links or more links) between upper tiers relative to lower tiers; Ethernet has no problems with this one, so it's not terribly exciting



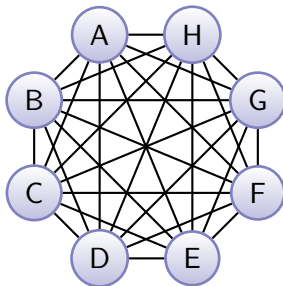
Fully-connected Mesh Example

- Pro: Shortest hop-count (1 hop) from any point to any other point



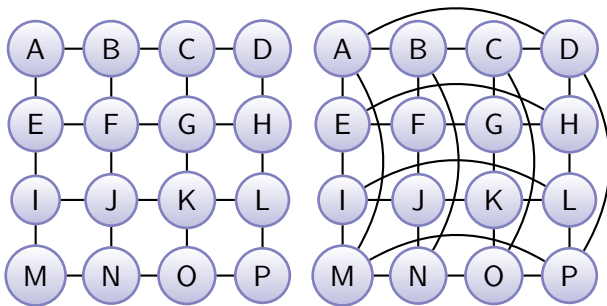
Fully-connected Mesh Example

- Pro: Shortest hop-count (1 hop) from any point to any other point
- Con: takes a huge amount of cables, and the cable count increases very, very quickly.



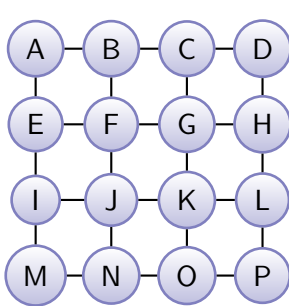
Rectangular Mesh / Torus Example

- Pro: Excellent for large topologies (no spine switches to buy)

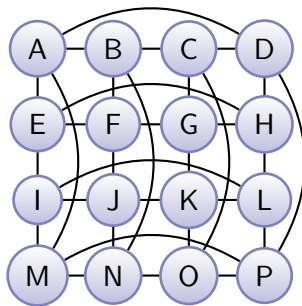


Rectangular Mesh / Torus Example

- Pro: Excellent for large topologies (no spine switches to buy)
- Con: Higher hop count than other options, depending on size and shape



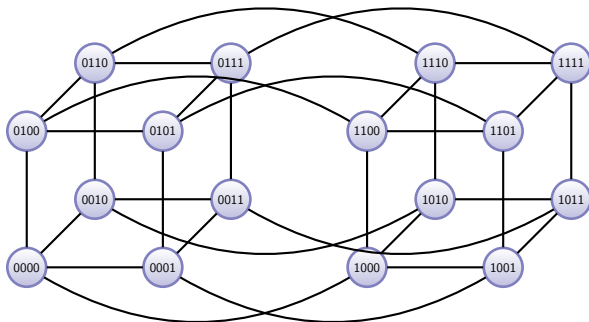
(c) Rectangular



(d) Torus

Hypercube³ example (4-dimensional)

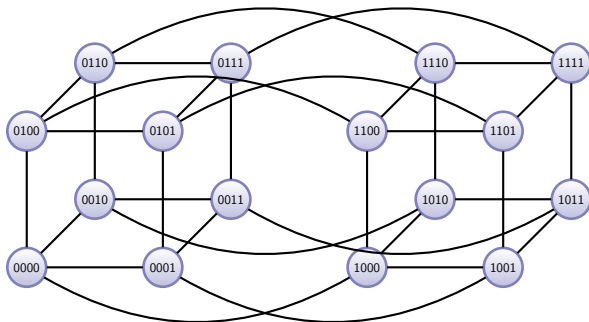
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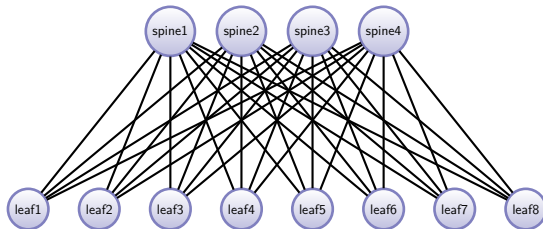
- Pro: for d dimensions, no more than d hops from any other point in the topology
- Con: cables/ports at each endpoint increase linearly with the dimension



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Folded Clos Network Example

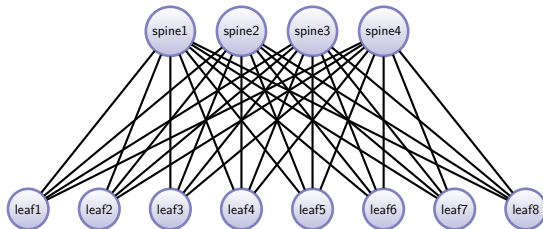
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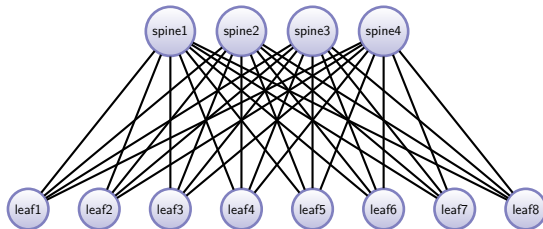
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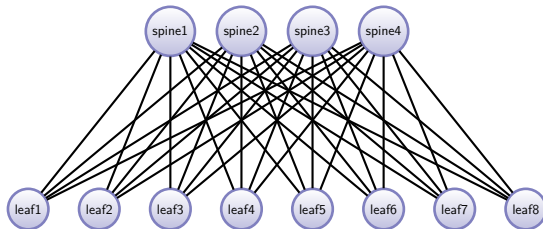
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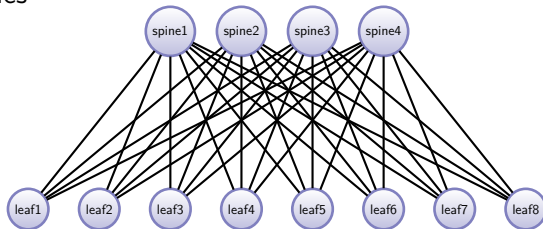
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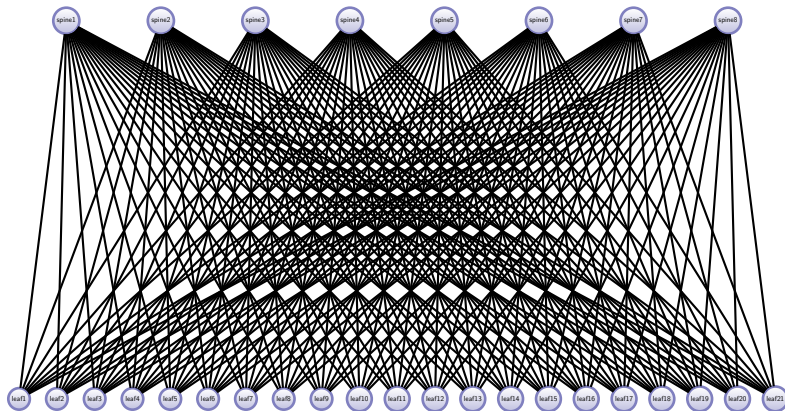


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- Con: Scalability limited by the port count of spine & leaf switches



BYU Supercomputing's Clos Network



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- MBB to Client BW Ratio

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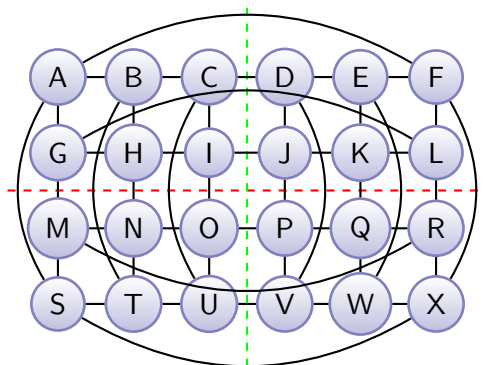
- If you were to draw a line across a topology, such that half the clients/switches/whatever are on each side of the line, the total bandwidth of all the links “cut” by that line is the *bisection bandwidth*

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- If you were to draw a line across a topology, such that half the clients/switches/whatever are on each side of the line, the total bandwidth of all the links “cut” by that line is the *bisection bandwidth*
- Of all the possible *bisection bandwidth* lines, the one with the minimum bandwidth is called the *minimum bisection bandwidth*

MBB Example - Torus

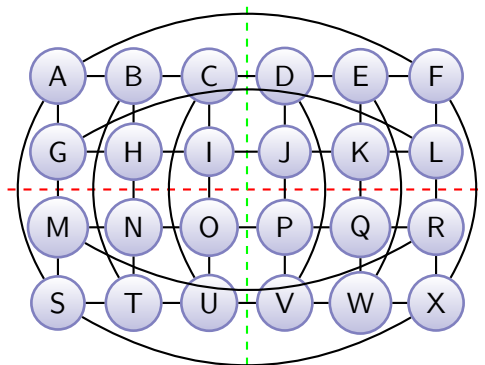
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- Green line cuts 8 links; red line cuts 12 links; Green is the *minimum*



Why is MBB important?

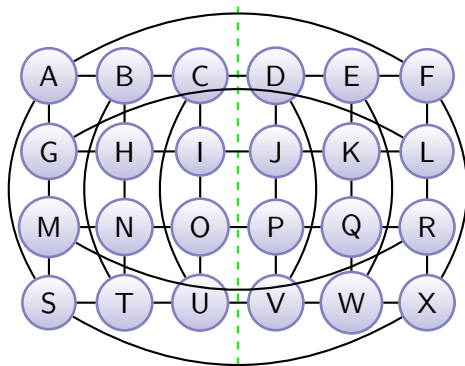
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- MBB represents the available bandwidth during a worst-case scenario:
 - All the clients on one side of the MBB line are trying to communicate with someone on the other side of the line, as fast as possible

MBB Example - Torus (cont)



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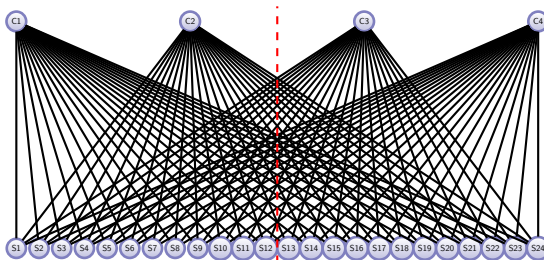
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 - Each half has 12 switches, or $12 \times 16 = 192$ hosts, and the green line bisects 8 links, for a ratio of 24:1

MBB vs Client BW - Clos

Anyone want to try this one?

- Assume that 16 hosts are attached to each of the 24 switches at the bottom, and none to the 4 on the top
- 4 links coming out of each of the 24 switches on the bottom (1 to each of 4 core sw)



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- Some approaches:
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 - TRILL - Transparent Interconnection of Lots of Links - Multi-path Ethernet⁴

⁴The best reference I'm aware of is *Introduction to Trill* by Radia Perlman and Donald Eastlake, available at <http://www.ipjforum.org/?p=582>

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- You absolutely *must* understand the communication patterns of your applicaiton, in order to select the correct technology and topology
- What you're used to doing now, may change in the future (eg. TRILL)

Questions?

Any questions?