High-Performance Computing Networks at BYU

Lloyd Brown

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

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  - For inter-process communication
  - For communicating with data storage

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- Communication between threads/processes on the same host ("*Intra*-node" communication) is extremely fast (usually via shared memory)
- 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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- Infiniband

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  - Remote Direct Memory Access (RDMA)

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	SDR	*DDR*	*QDR*	*FDR*
1x	2.5 Gb/s	5 Gb/s	10 Gb/s	14 Gb/s
4x	10 Gb/s	20 Gb/s	40 Gb/s	56 Gb/s
12x	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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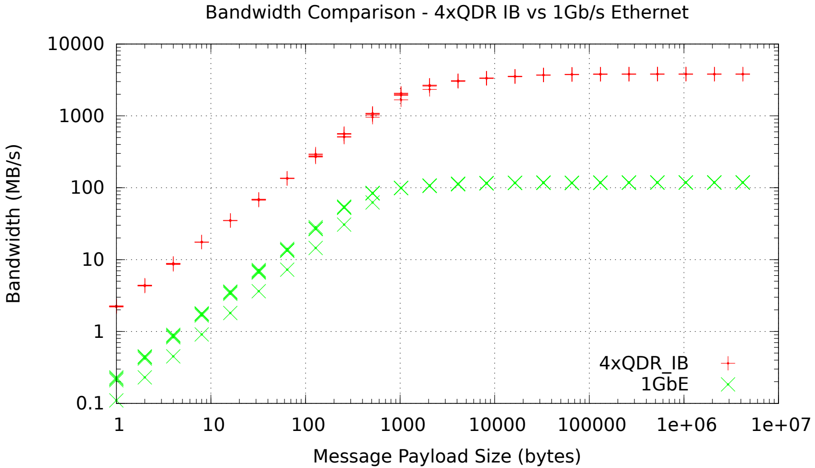
	SDR	*DDR*	*QDR*	*FDR*
1x	2.5 Gb/s raw 2 Gb/s net	5 Gb/s raw 4 Gb/s net	10 Gb/s raw 8 Gb/s net	14 Gb/s raw 13.6 Gb/s net
4x	10 Gb/s raw 8 Gb/s net	20 Gb/s raw 16 Gb/s net	40 Gb/s raw 32 Gb/s net	56 Gb/s raw 54.3 Gb/s net
12x	30 Gb/s raw 24 Gb/s net	60 Gb/s raw 48 Gb/s net	120 Gb/s raw 96 Gb/s net	168 Gb/s raw 162.9 Gb/s net

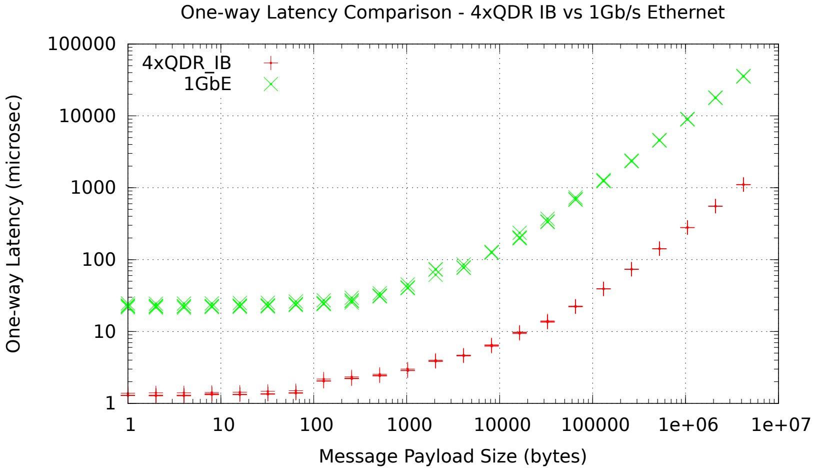
Performance at BYU's FSL

The graphs shown in the next couple of slides represent the bandwidth and latency performance of 4xQDR 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 - 4xQDR IB vs 1Gb/s Ethernet
Bandwidth (MB/s)
10000
1000
100
10
1
0.1
1
10
100
1000
10000
100000
1e+06
1e+07
Message Payload Size (bytes)
4xQDR_IB
1GbE


One-way Latency Comparison - 4xQDR IB vs 1Gb/s Ethernet
4xQDR_IB
1GbE
One-way Latency (microsec)
100000
10000
1000
100
10
1
1
10
100
1000
10000
100000
1e+06
1e+07
Message Payload Size (bytes)

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- Periodically sweep the network, looking for topology changes, checking for errors, etc.
- Build a cohesive model of the network topology
- Load the switch forwarding tables with the LID/Port mapping

Infiniband Topologies

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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]

[2] Technically 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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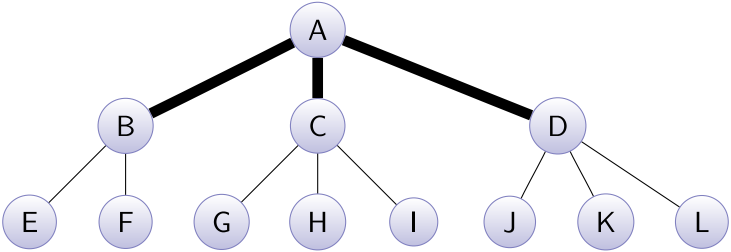
- Folded-Clos Network

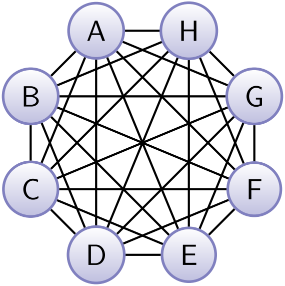
Fat Tree Example

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



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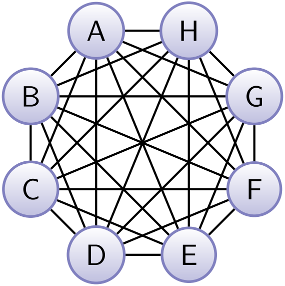
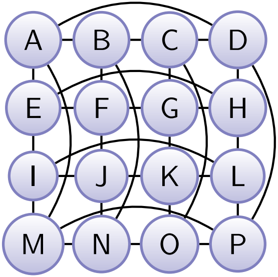


Torus example

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



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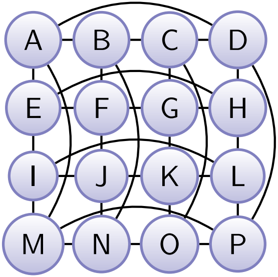

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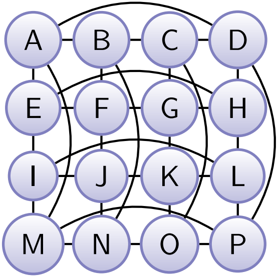
- Con: Less desirable bandwidth ratios (MBB to Client BW; discussed later)



Hypercube[3] example (4-dimensional)

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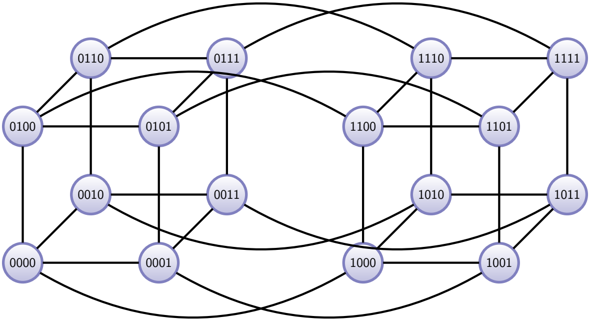

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Hypercube[3] example (4-dimensional)

- Pro: for *d* dimensions, no more than *d* hops from any other point in the topology
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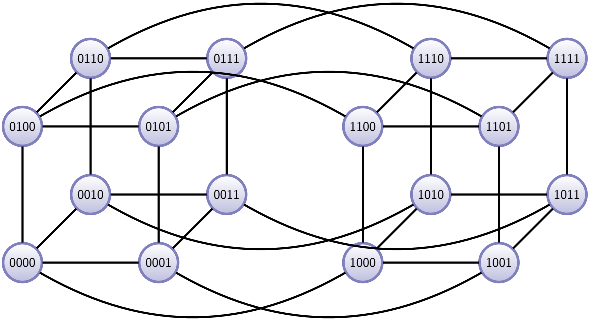

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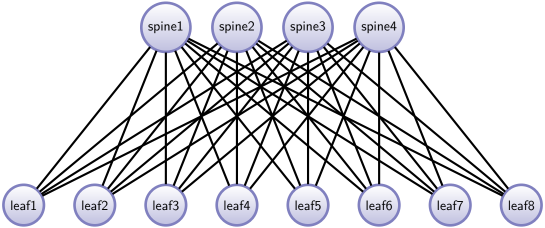

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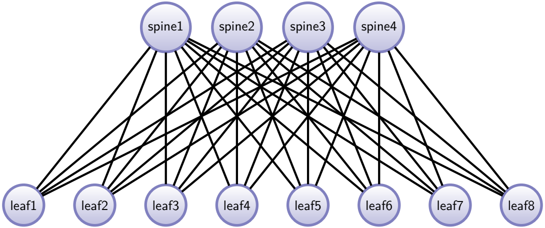

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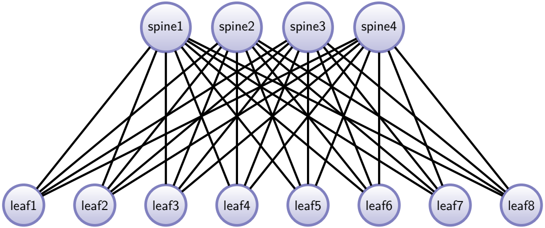

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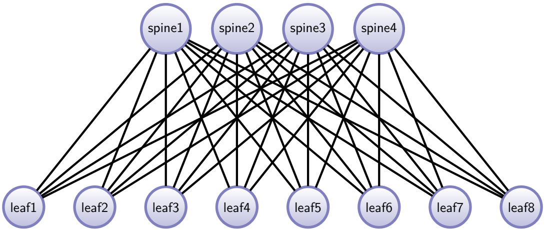

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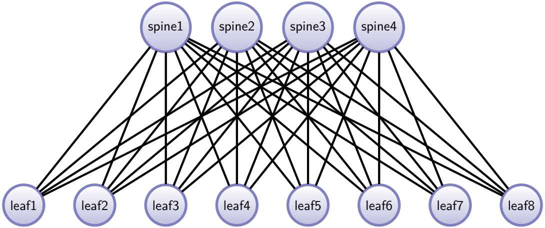
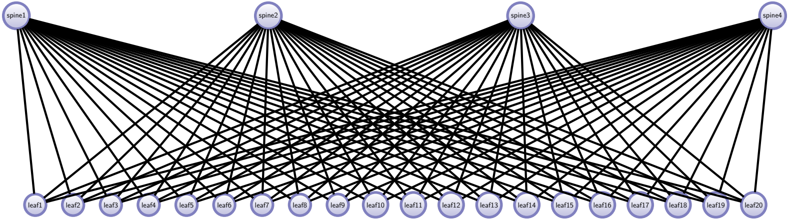
- Con: Scalability limited by the port count of spine & leaf switches



BYU Supercomputing's Clos Network

Note that this only shows the switches involved; there are 16 hosts attached to each leaf switch.



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- MBB to Client BW Ratio

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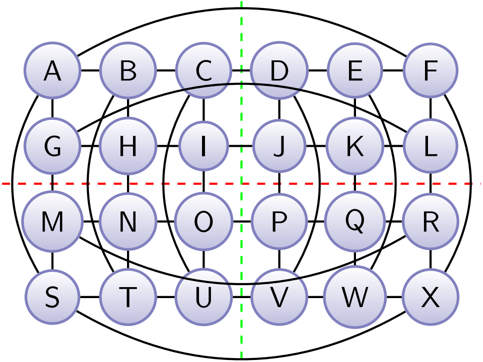
- Of all the possible *bisection bandwidth* lines, the one with the minimum bandwidth is called the *minimum bisection bandwidth*

MBB Example - Torus

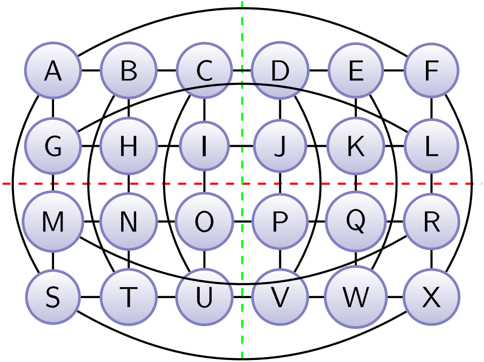
Which bisection line represents the minimum bandwidth bisection (assume all links are the same speed)?



MBB Example - Torus

Which bisection line represents the minimum bandwidth bisection (assume all links are the same speed)?

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



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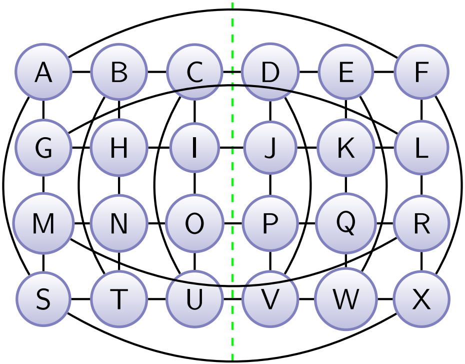
- MBB represents the available bandwidth during a worst-case scenario:
    - All the clients on one side of the MBB line are trying to communicate with someone on the other side of the line, as fast as possible

MBB Example - Torus (cont)



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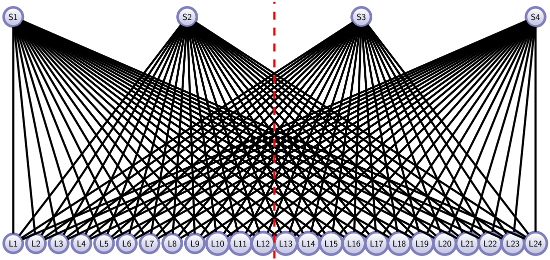
    - assume host-switch and switch-switch links are the same BW
  - Each half has 12 switches, or 12*16=192 hosts, and the green line bisects 8 links, for a ratio of 24:1

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 switch)



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- 192:48 => 4:1

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  - TRILL - Transparent Interconnection of Lots of Links - Multi-path layer-2 Ethernet[4]

[4] The 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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Questions?

Any questions?