High Performance Computing Systems (CMSC714)

Lecture 12: Fat-tree and Dragonfly Networks

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Summary of last lecture

- Key requirements of HPC networks
  - extremely low latency, high bandwidth, scalable
  - low network diameter, high bisection bandwidth
- Torus networks (less common now)
  - Network diameter grows as O($\sqrt[3]{N}$) where N is the number of nodes
- Different types of routing algorithms:
  - Shortest path vs. non-minimal
  - Static vs. dynamic

Fat-tree network

- Most popular network topology
  - Low network diameter, high bandwidth

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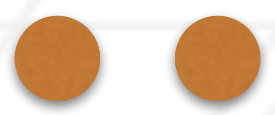

Compute Nodes

Fat-tree network

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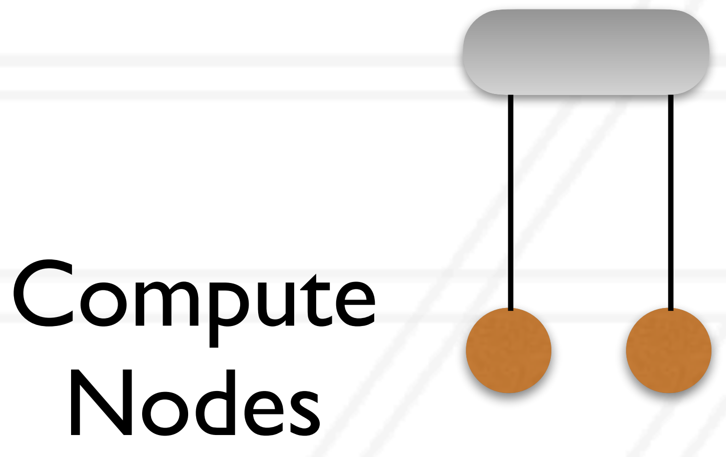

Router/switch radix = number of ports = k

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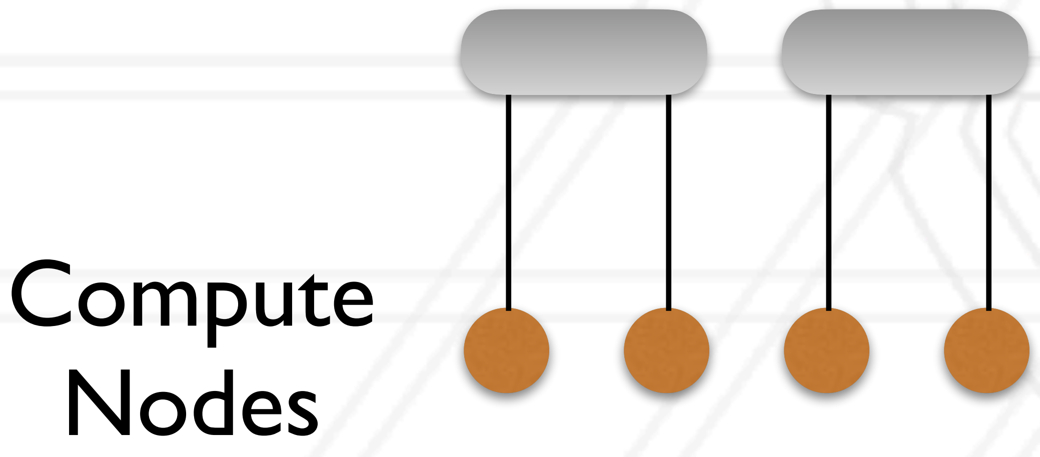

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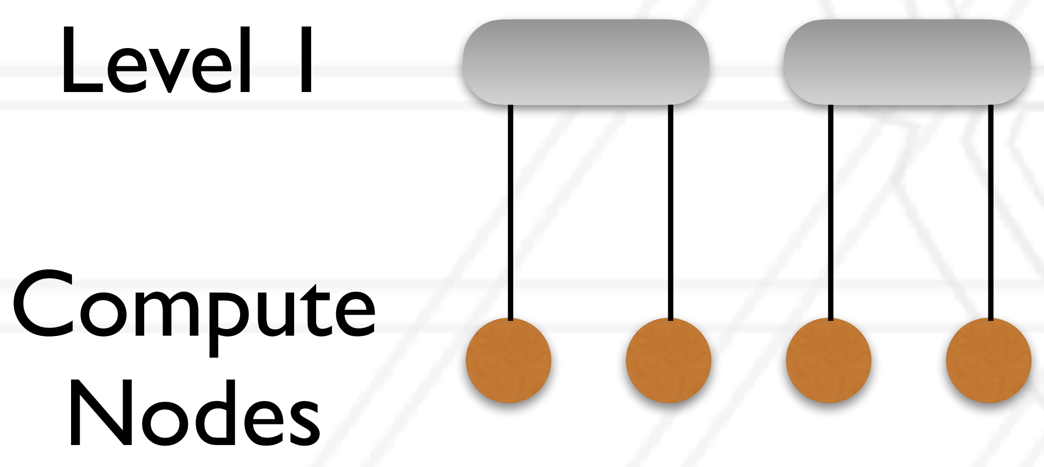

Level 1

Compute Nodes

Router/switch radix = number of ports = k

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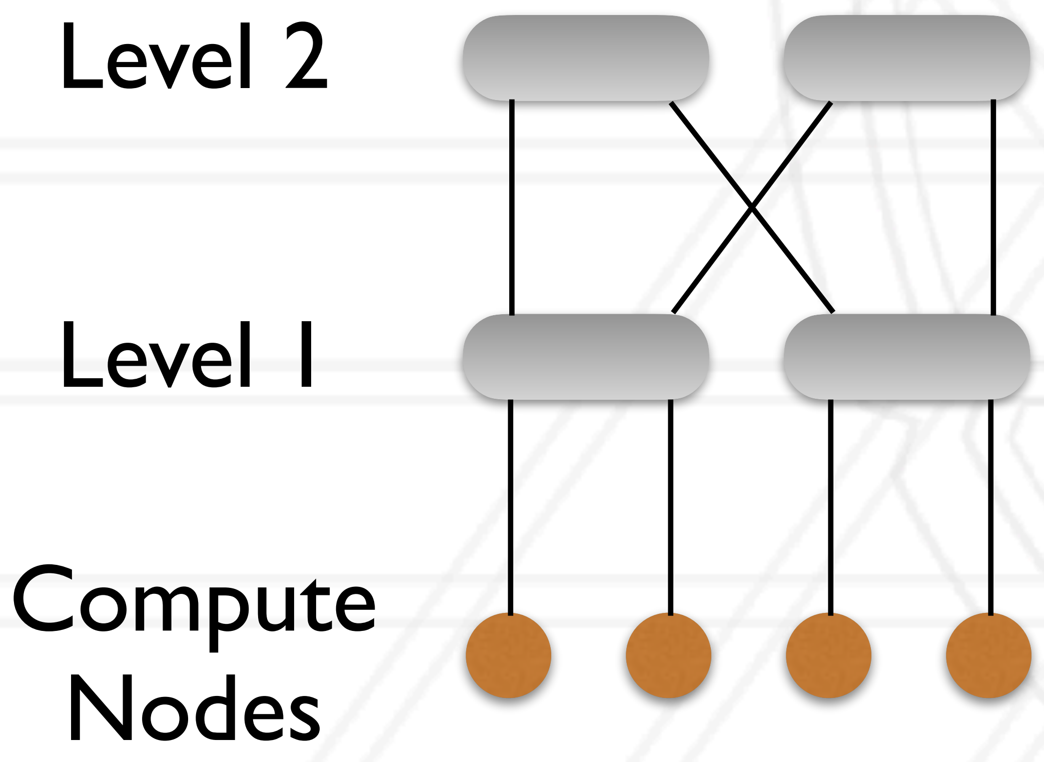

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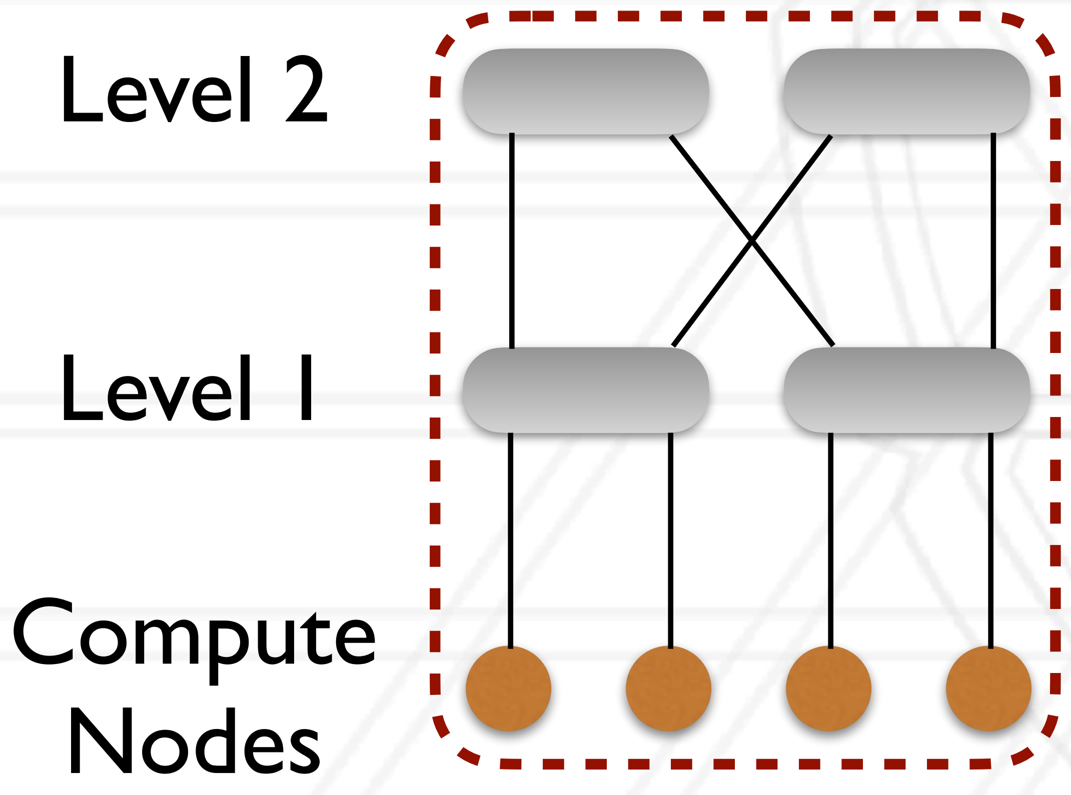

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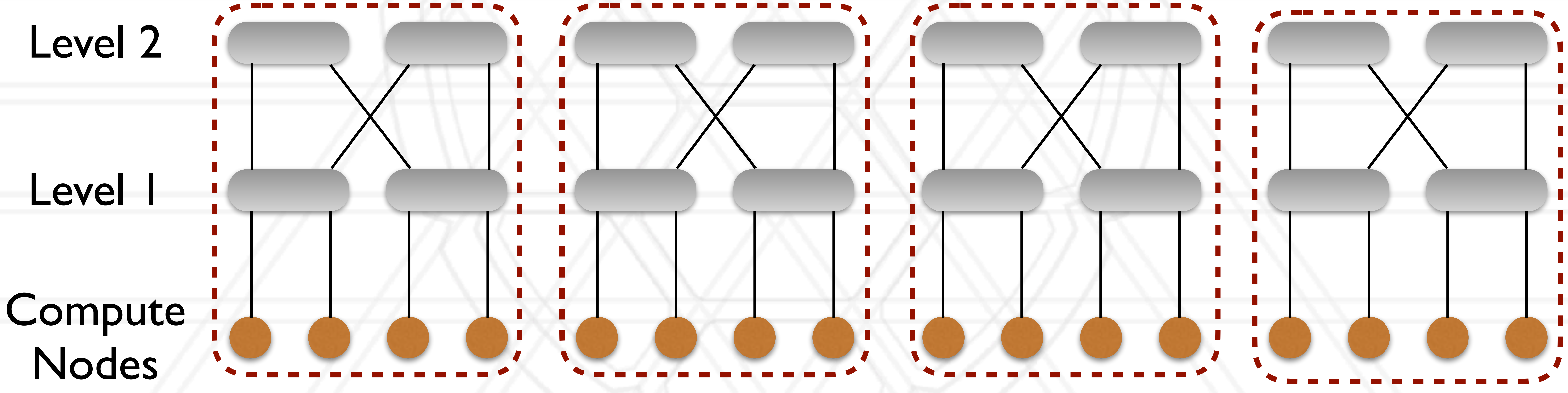

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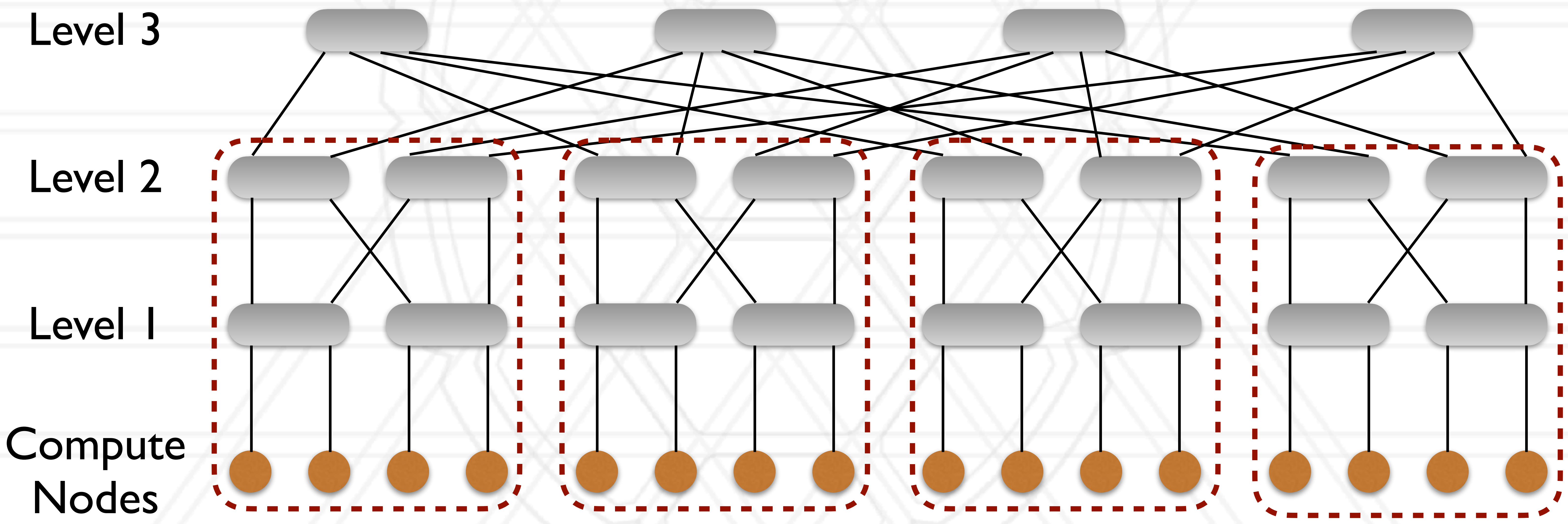

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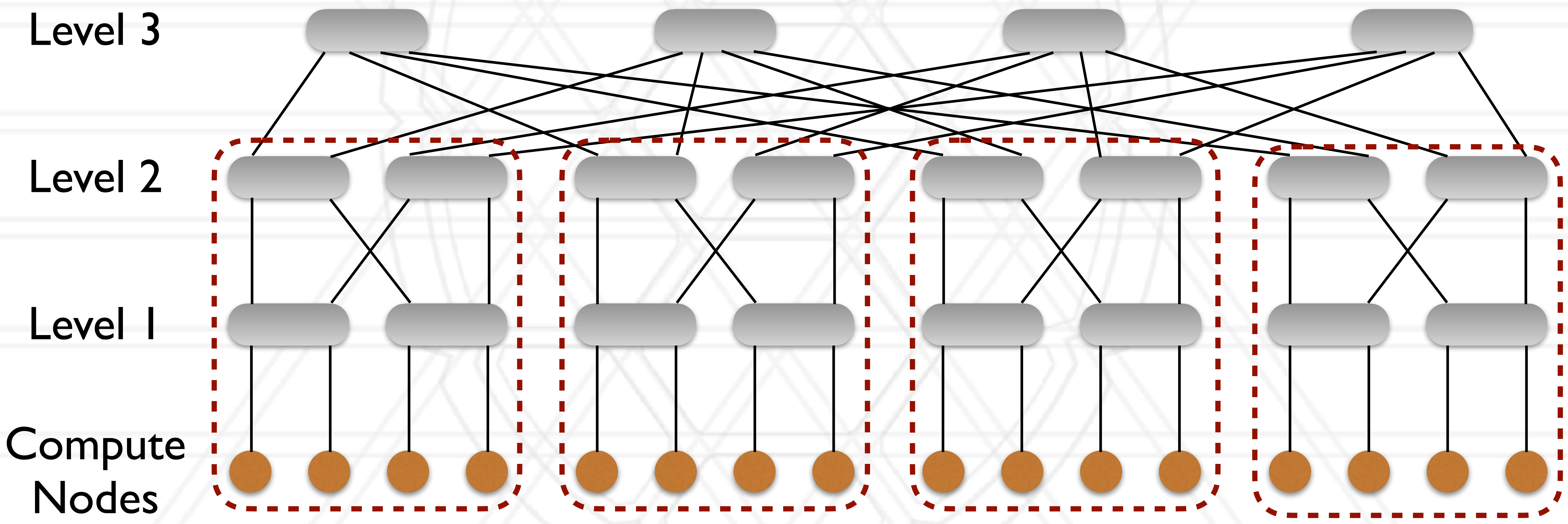
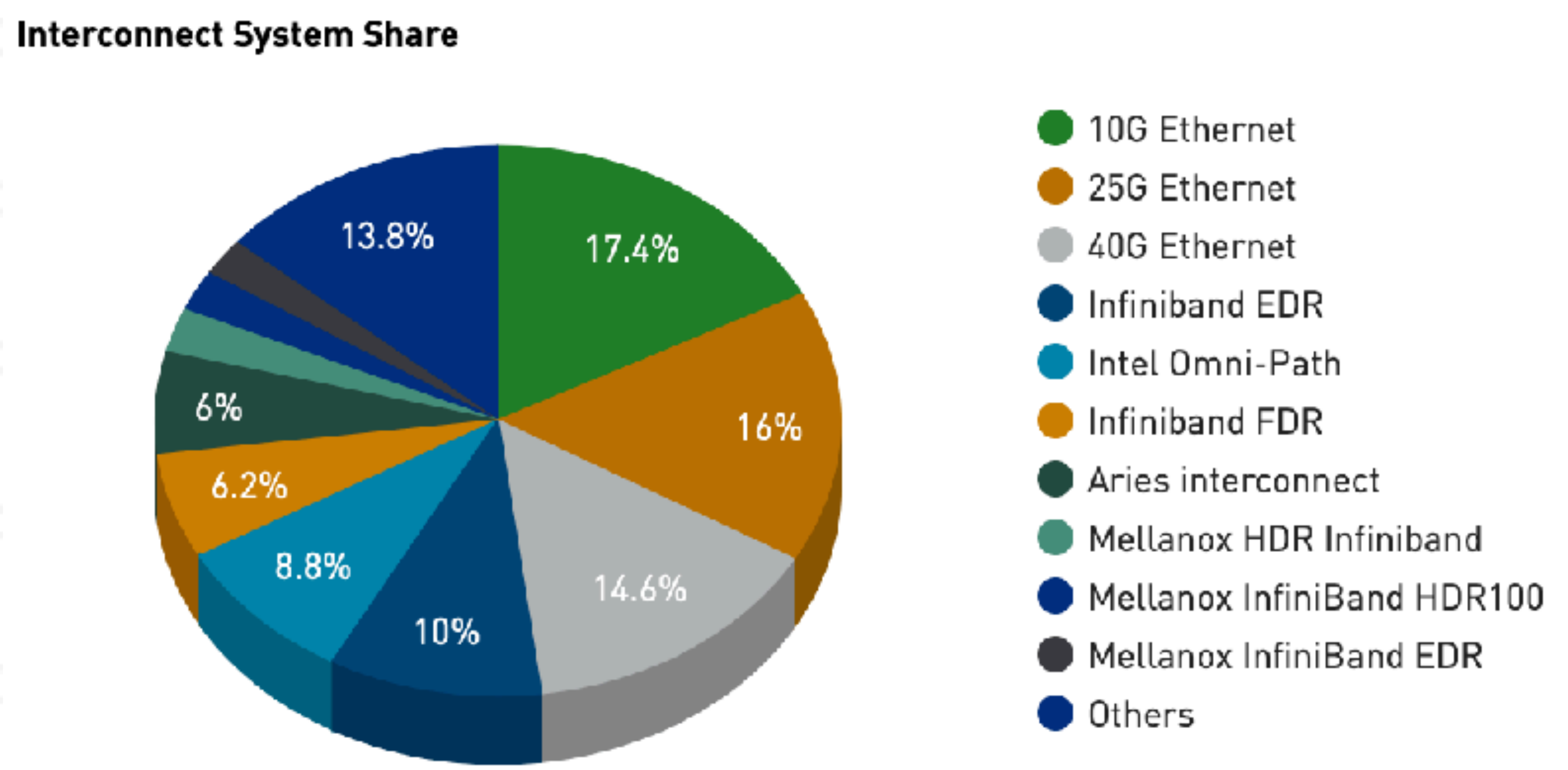


Router/switch radix = number of ports = k

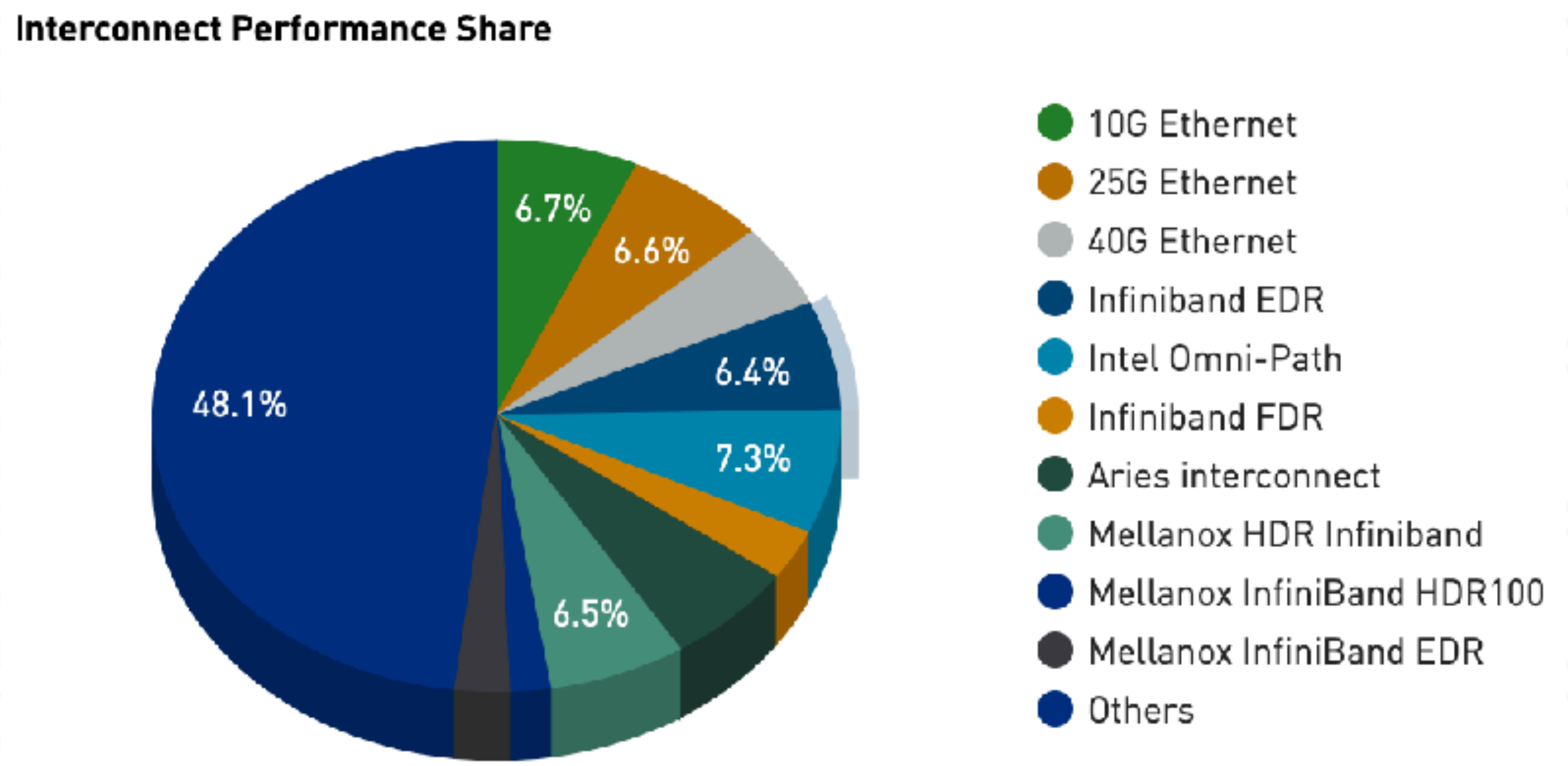
Pod = group of switches = k/2 switches   Max. number of pods = k

Fat-tree networks on the top500 list

- Infiniband EDR/FDR/HDR, Intel Omni-Path



Interconnect System Share



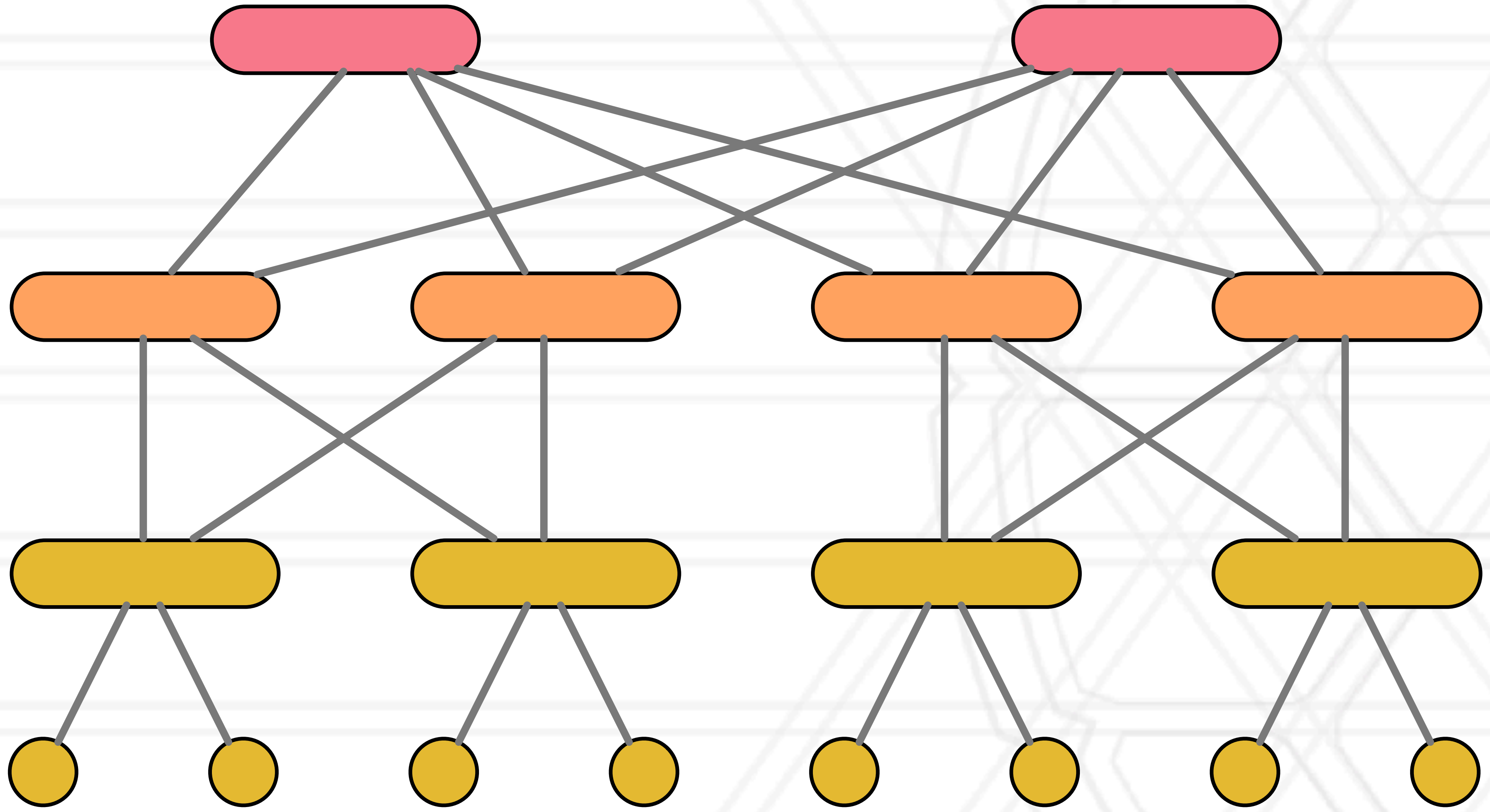
Interconnect Performance Share

https://www.top500.org/statistics/list, November 2020

Routing on a fat-tree

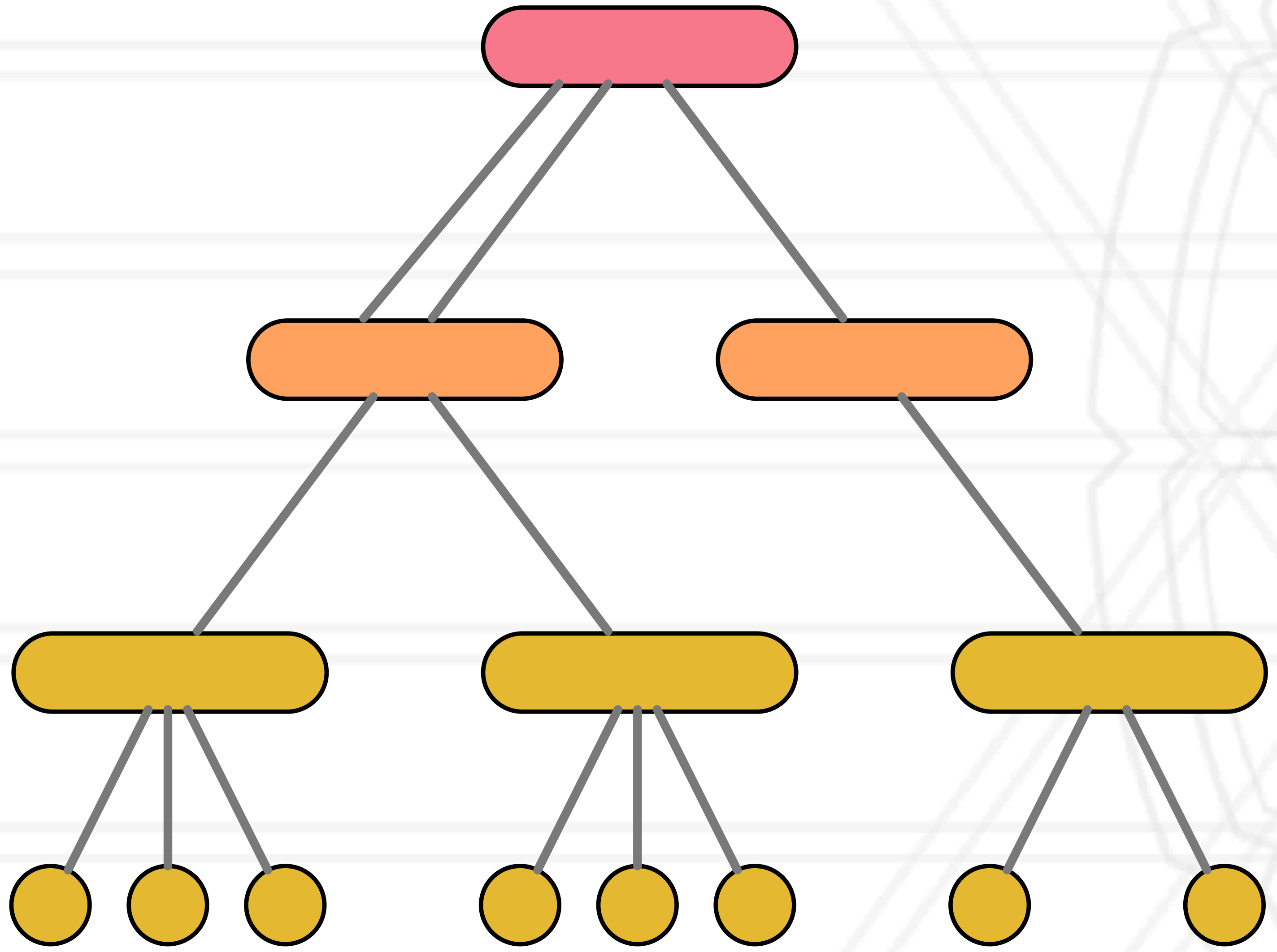
- Until recently, most fat-tree installations used static routing
  - Destination-mod-k (D-mod-k) routing
- Adaptive routing is now starting to be used

Variations on a full bandwidth fat-tree



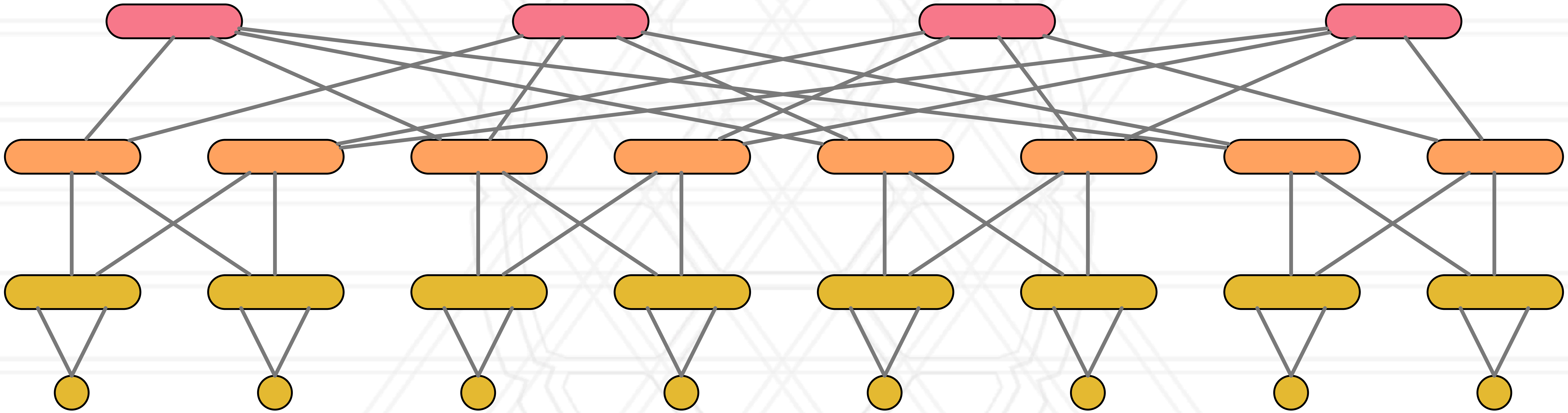
Single-rail single-plane fat-tree

Variations on a full bandwidth fat-tree



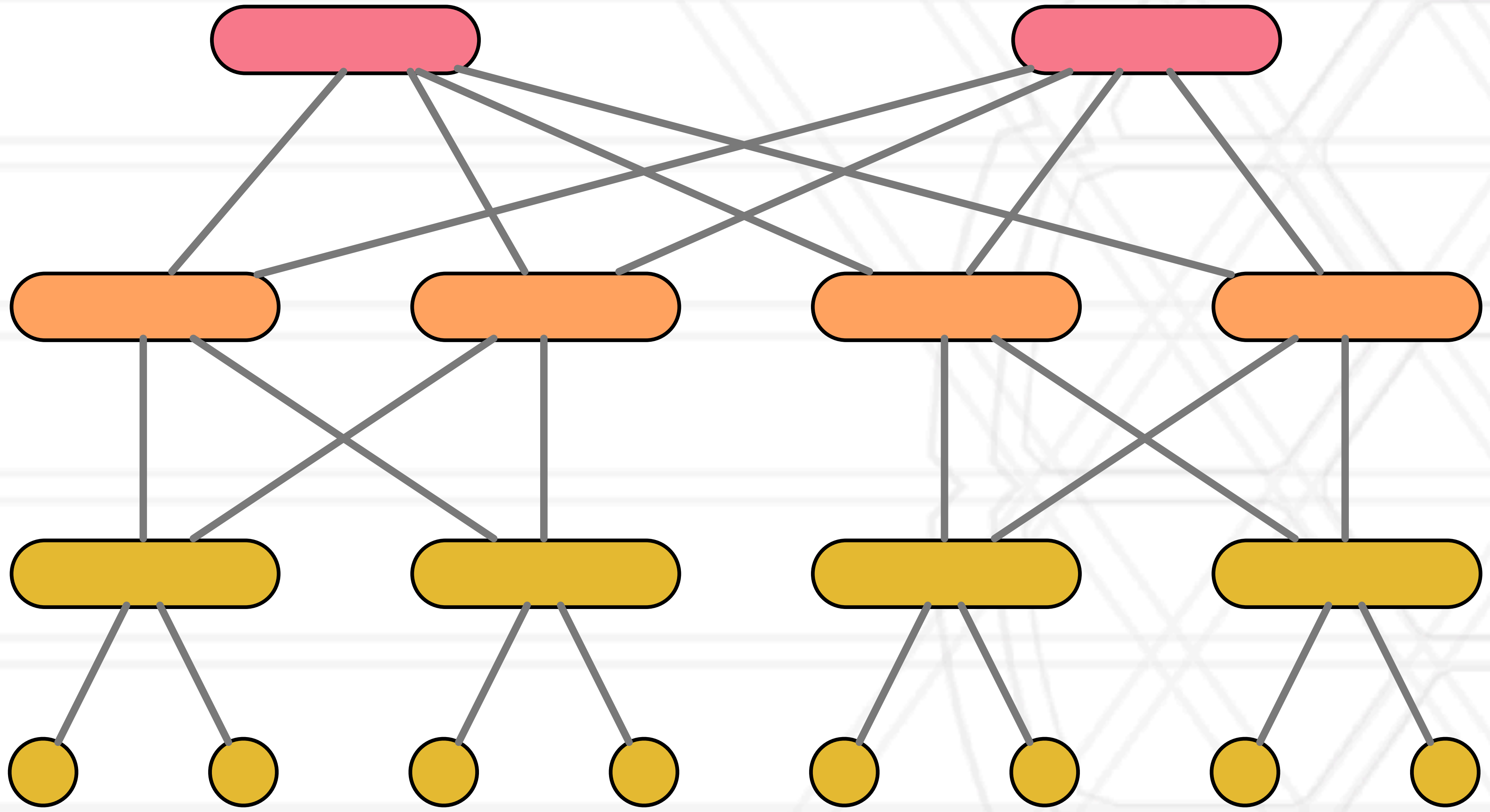
Single-rail single-plane fat-tree (tapered)

Variations on a full bandwidth fat-tree



Dual-rail single-plane fat-tree

Variations on a full bandwidth fat-tree



Single-rail single-plane fat-tree

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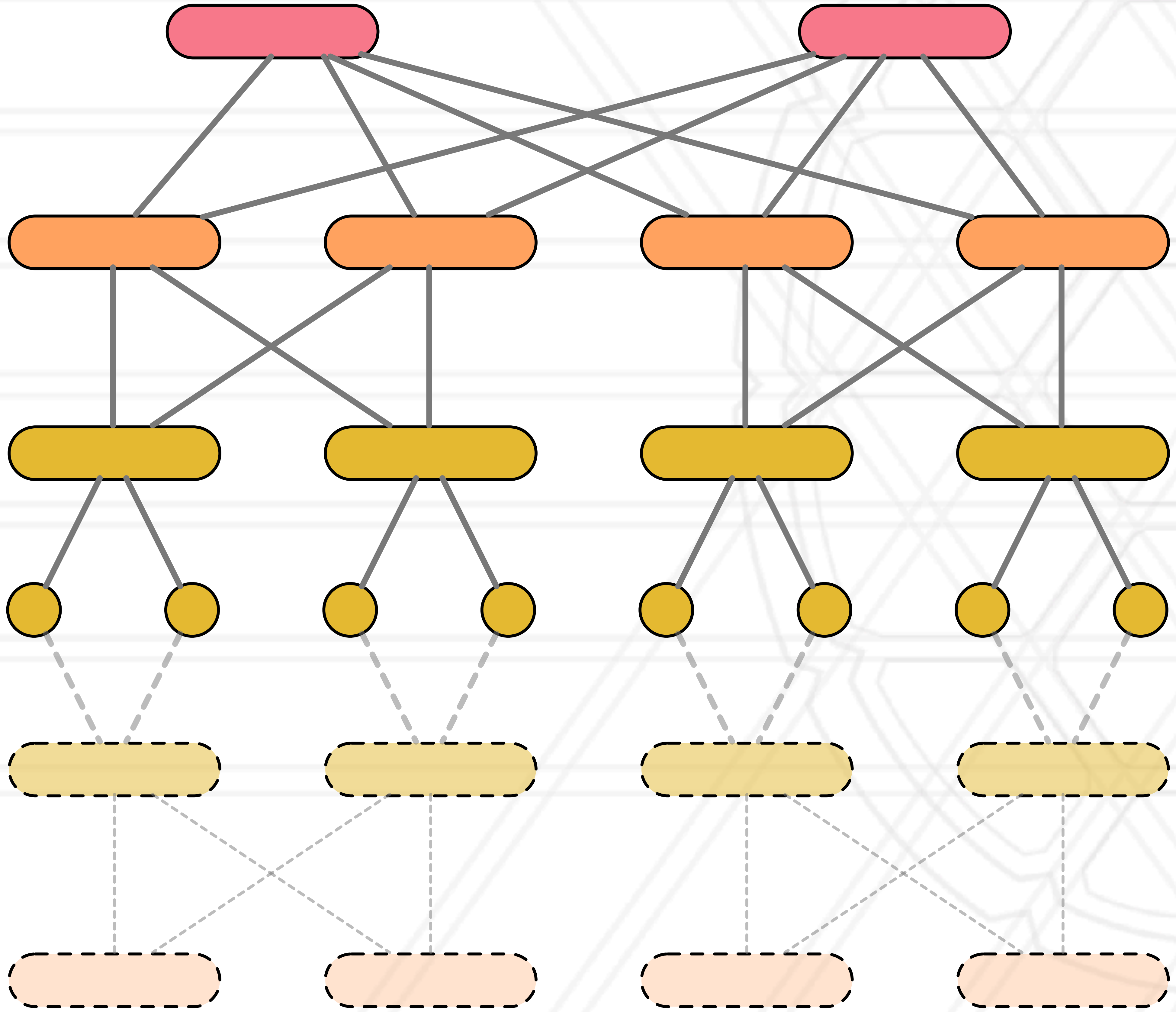
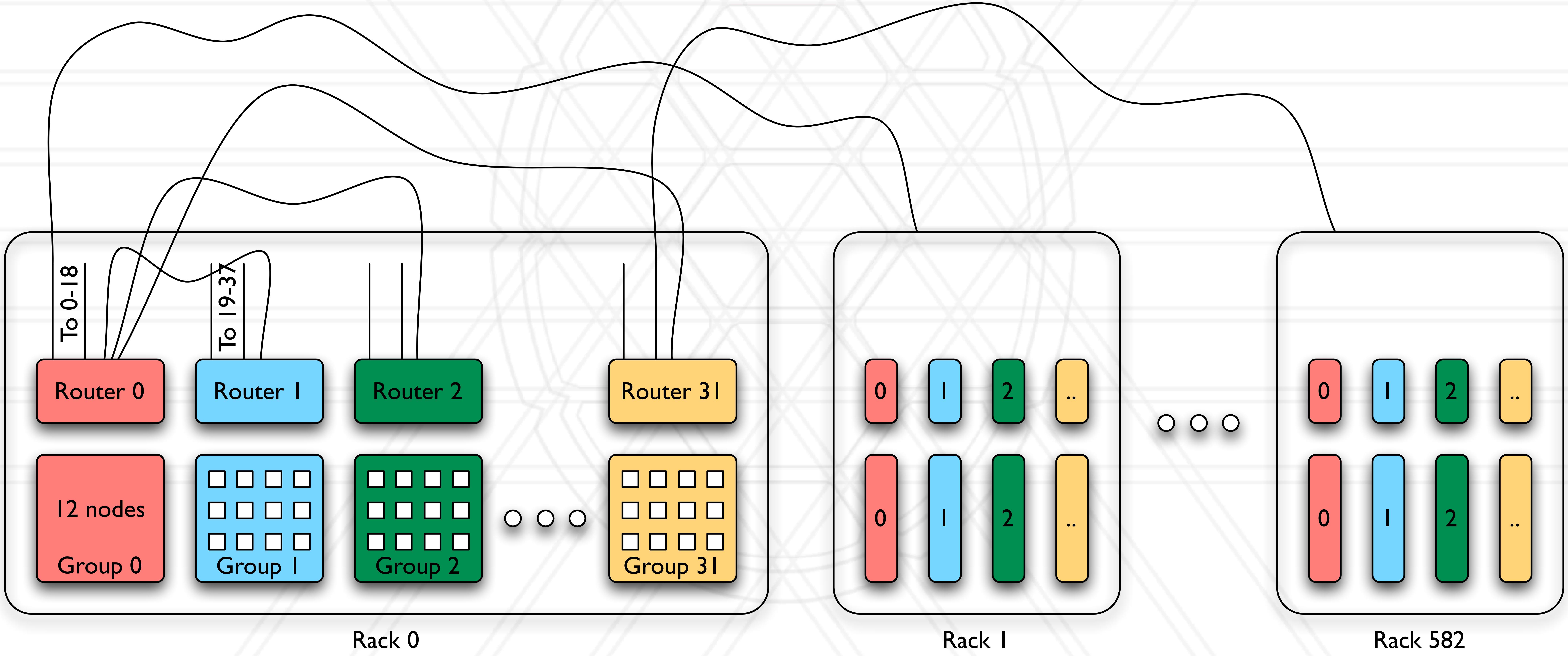


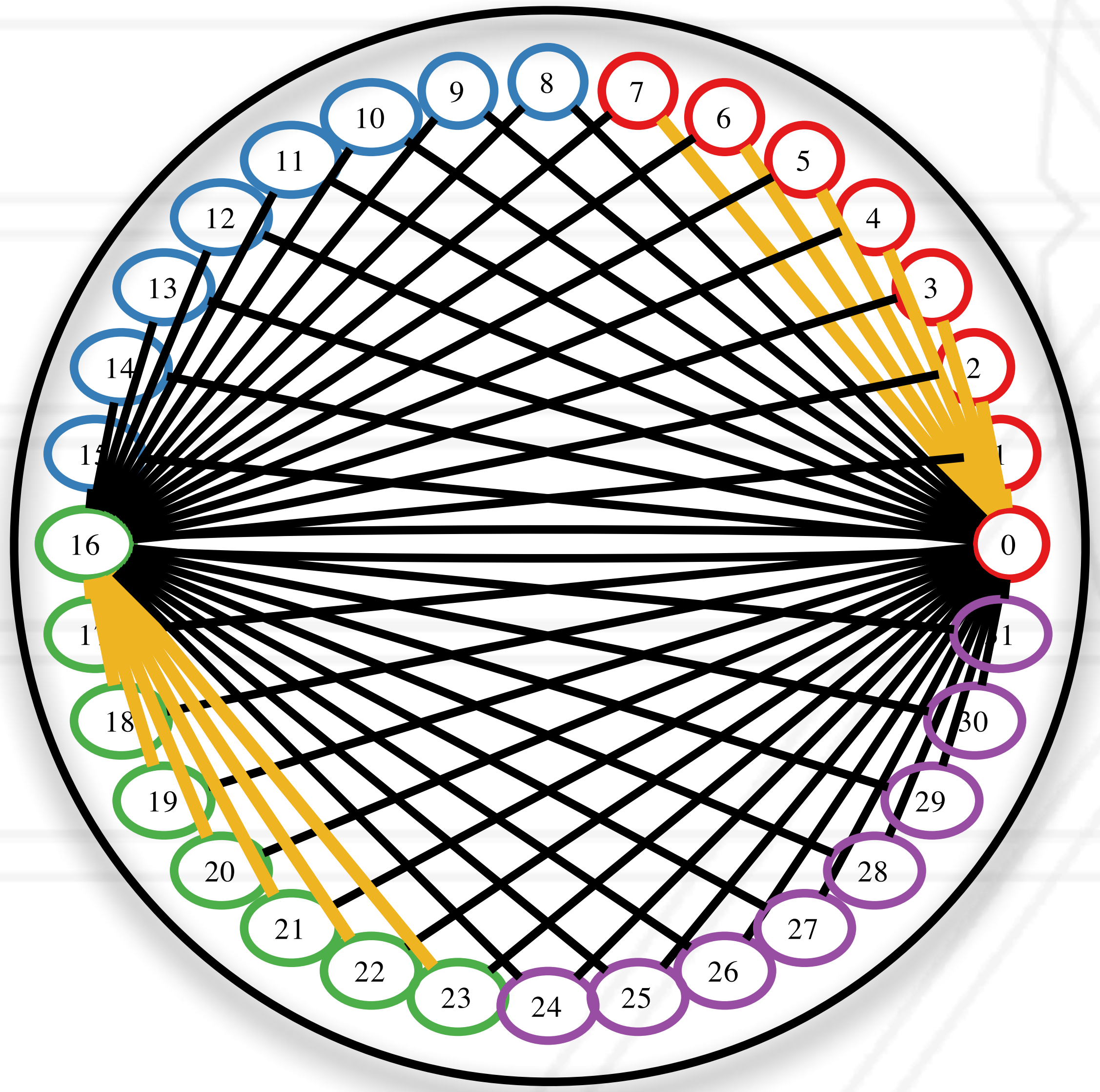
Dual-rail dual-plane fat-tree

Dragonfly network



IBM PERCS network

- All-to-all connections within each group



One supernode in the PERCS topology

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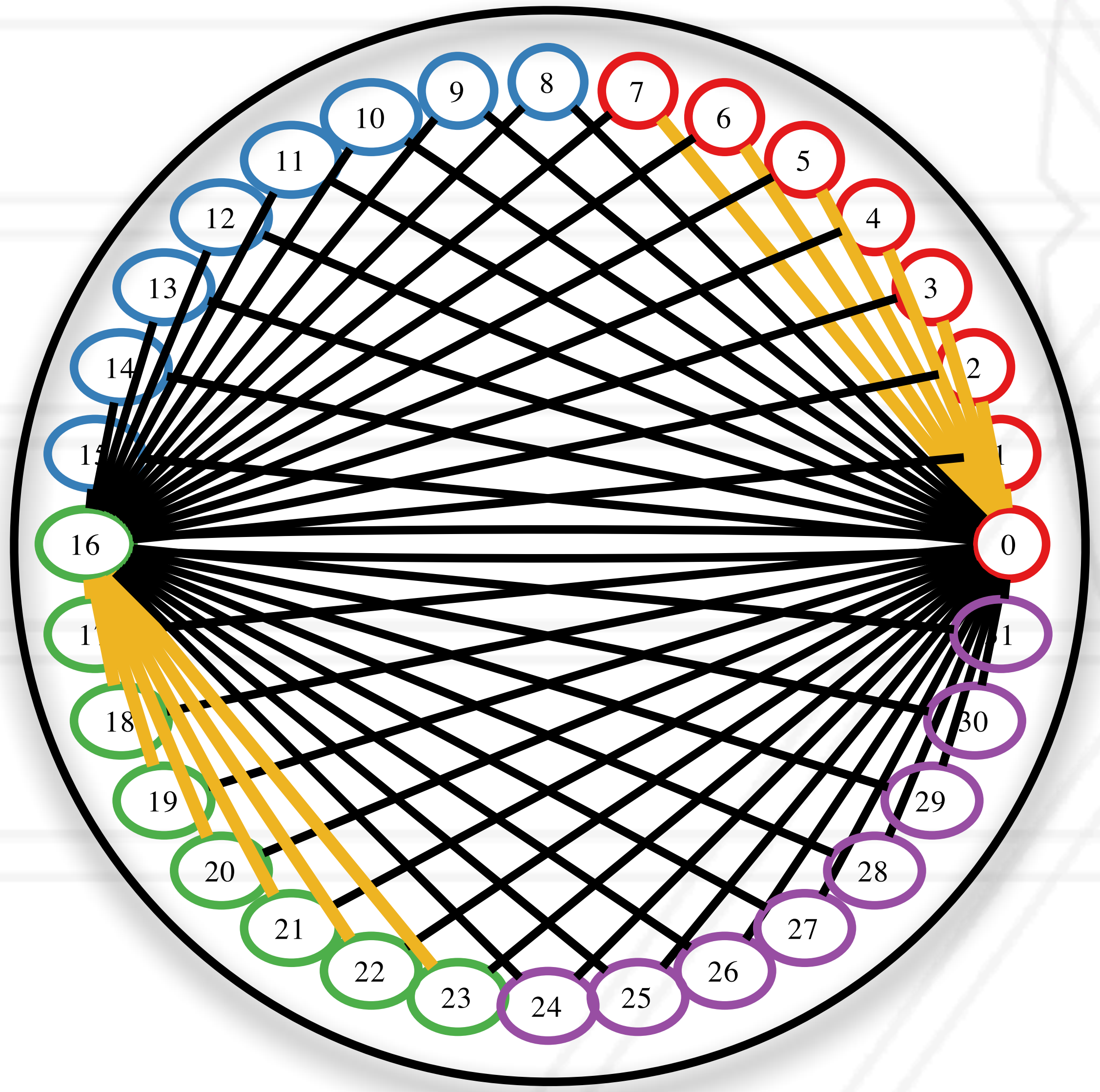

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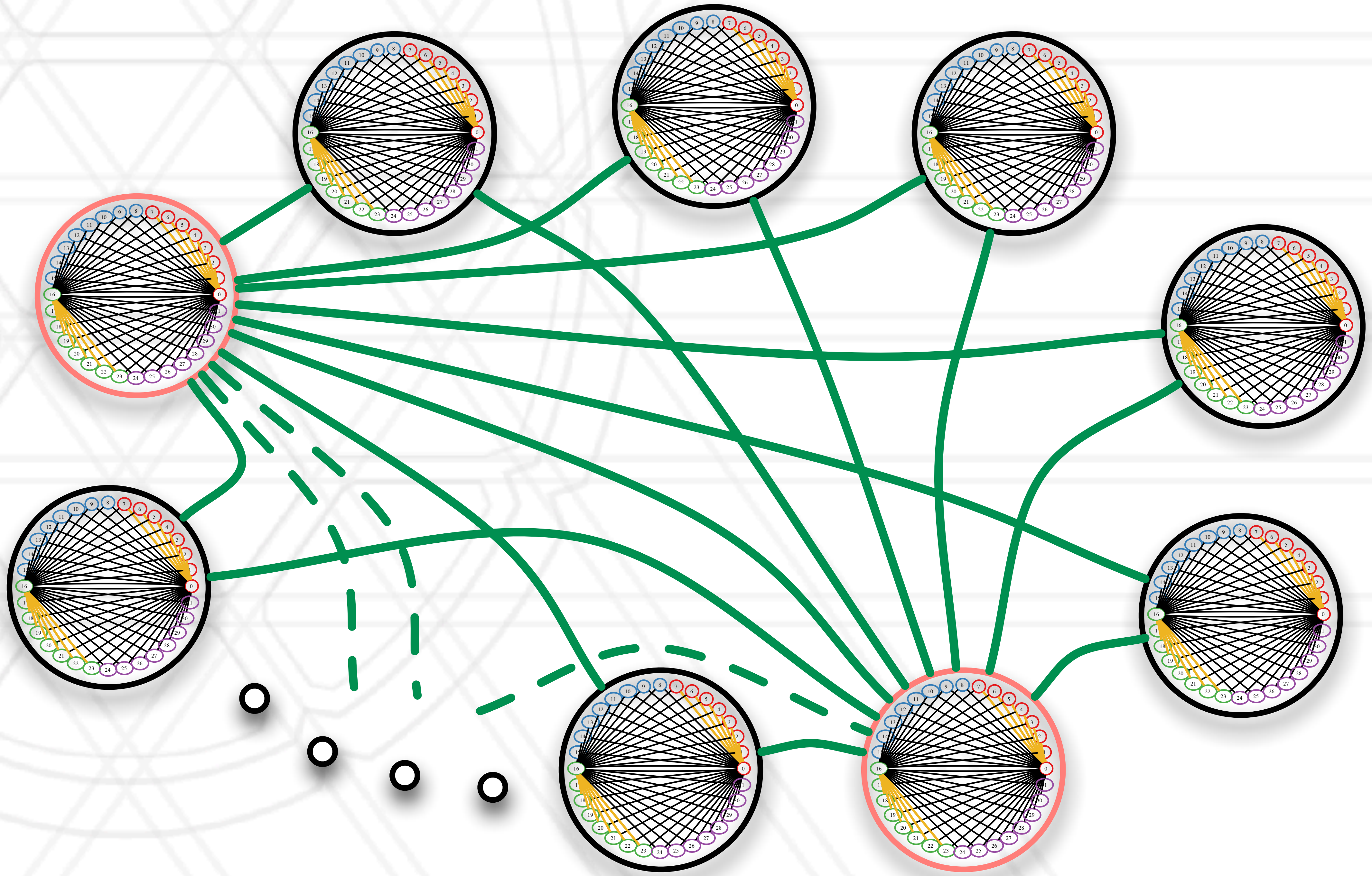
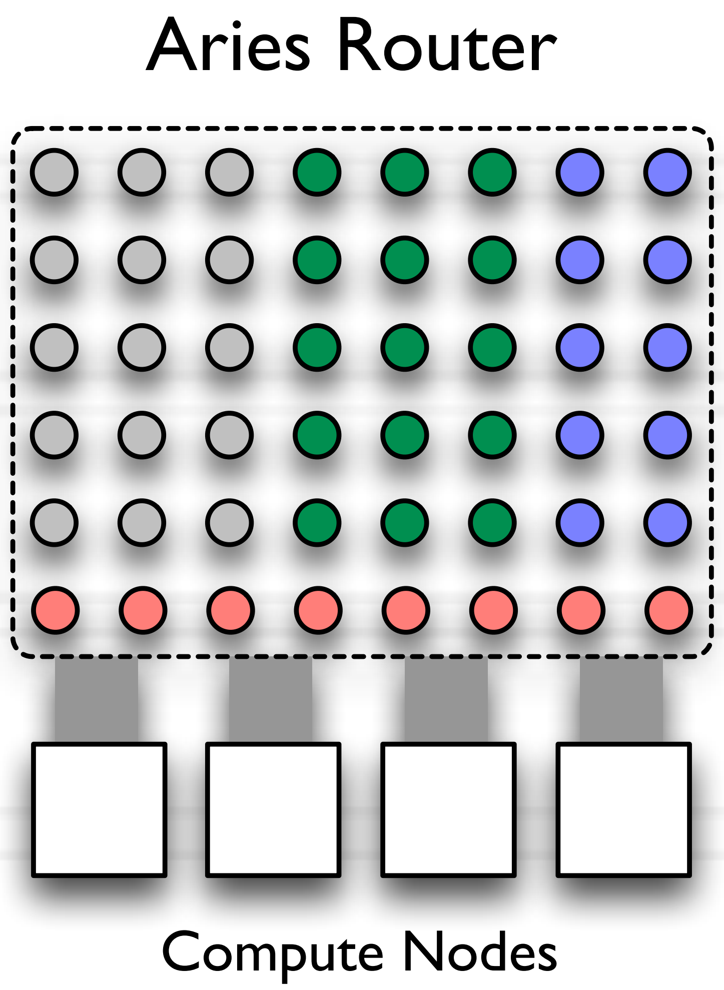


Cray Aries network

- Row and column all-to-all connections within each group



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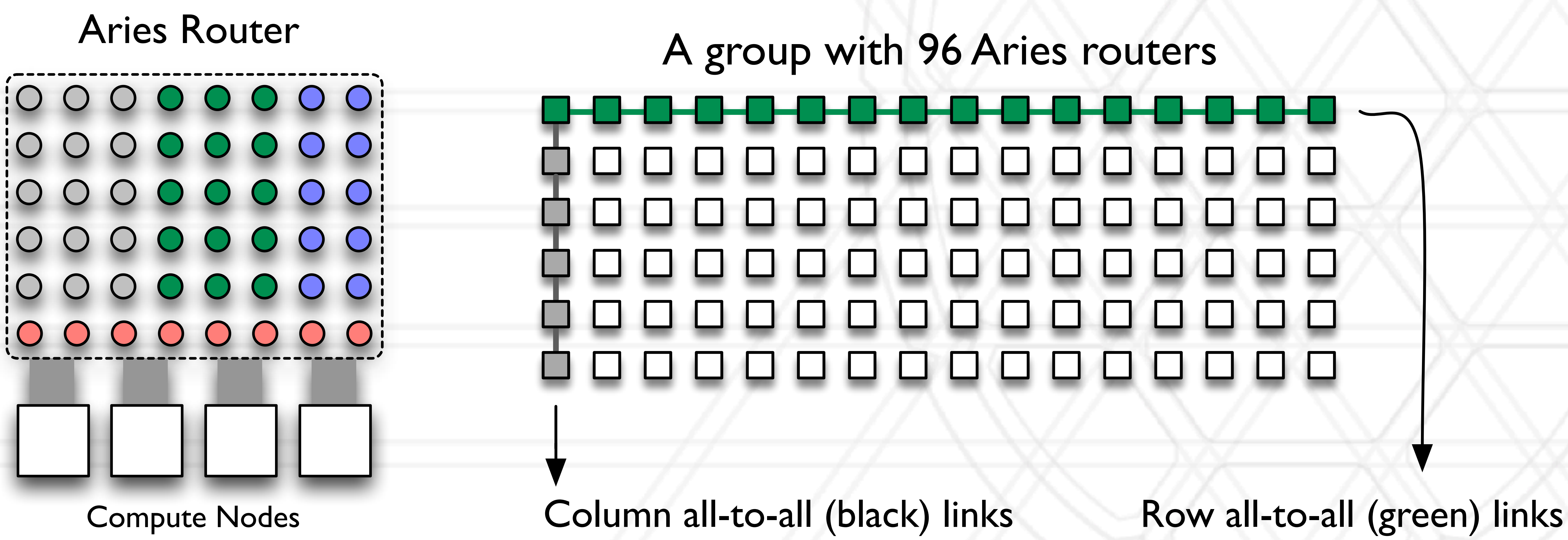


Aries Router

Compute Nodes

A group with 96 Aries routers

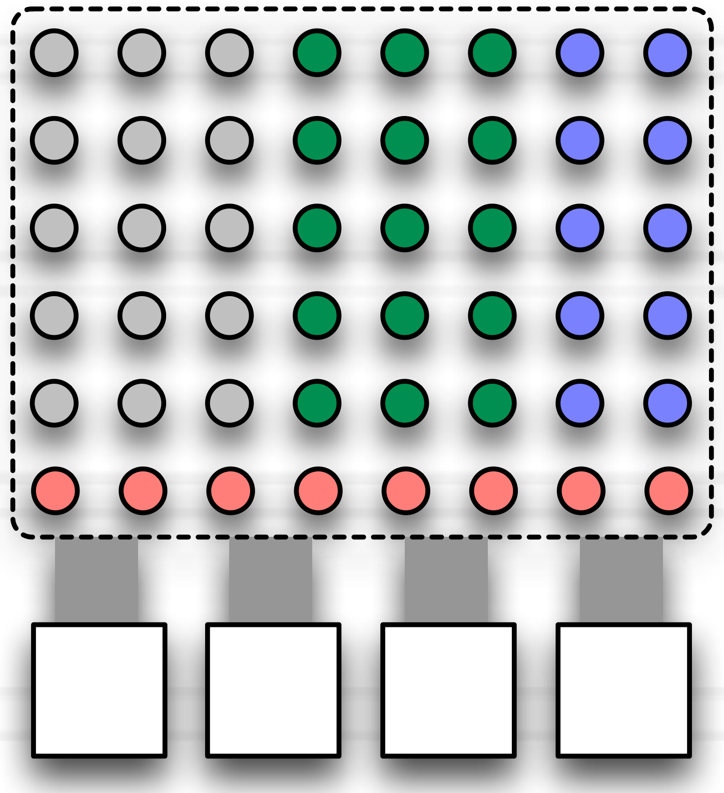
Column all-to-all (black) links

Row all-to-all (green) links

Cray Aries network

- Row and column all-to-all connections within each group

Aries Router



Compute Nodes

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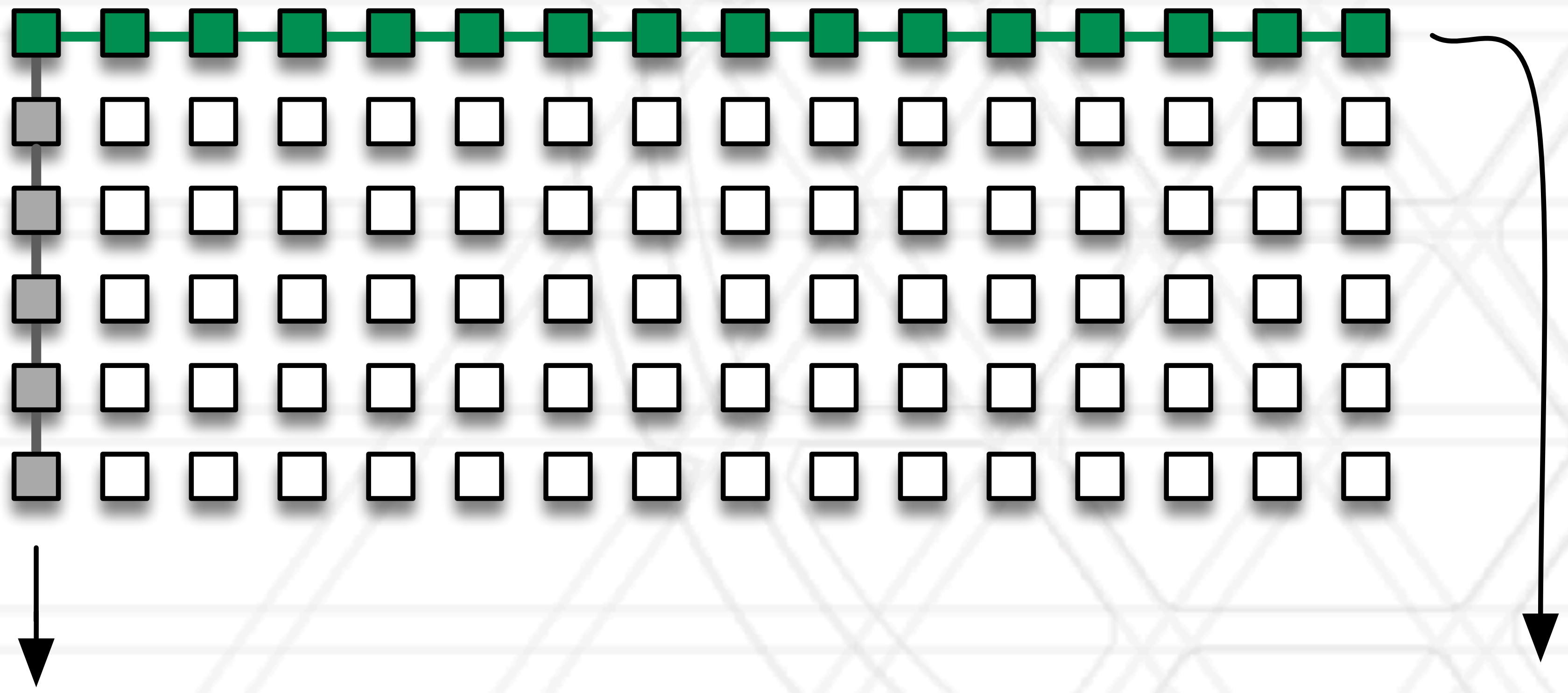
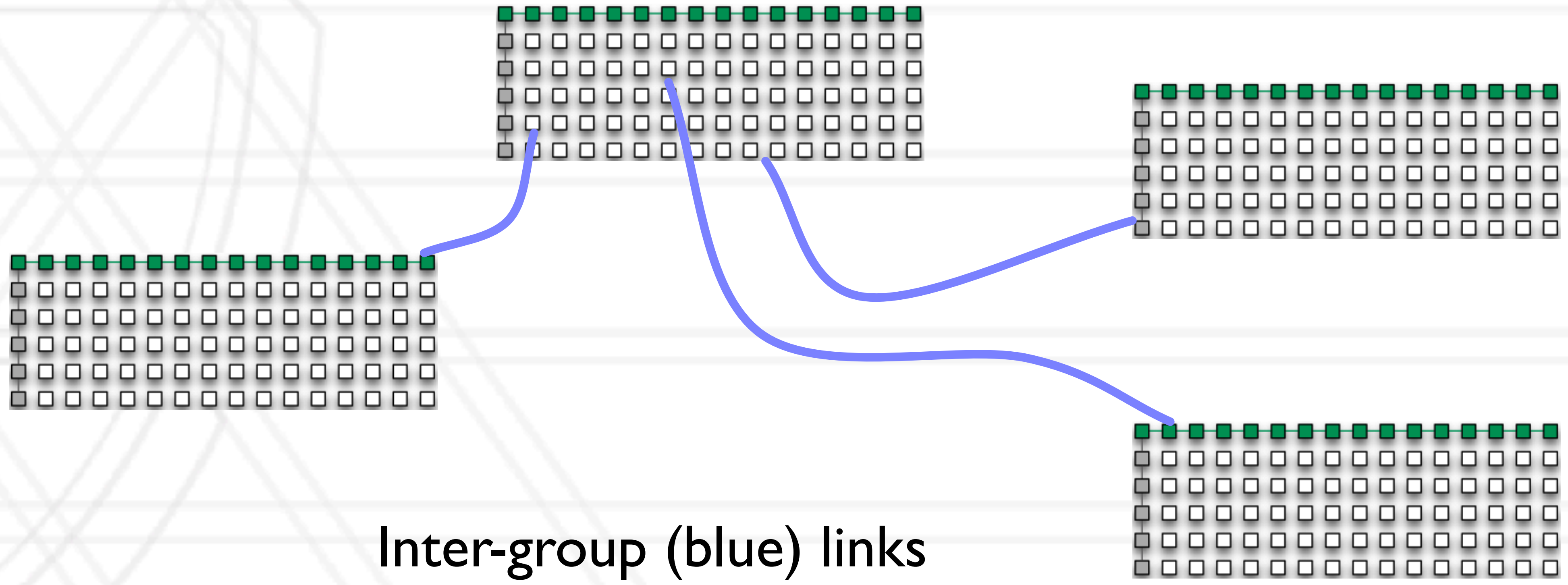


Column all-to-all (black) links

Row all-to-all (green) links

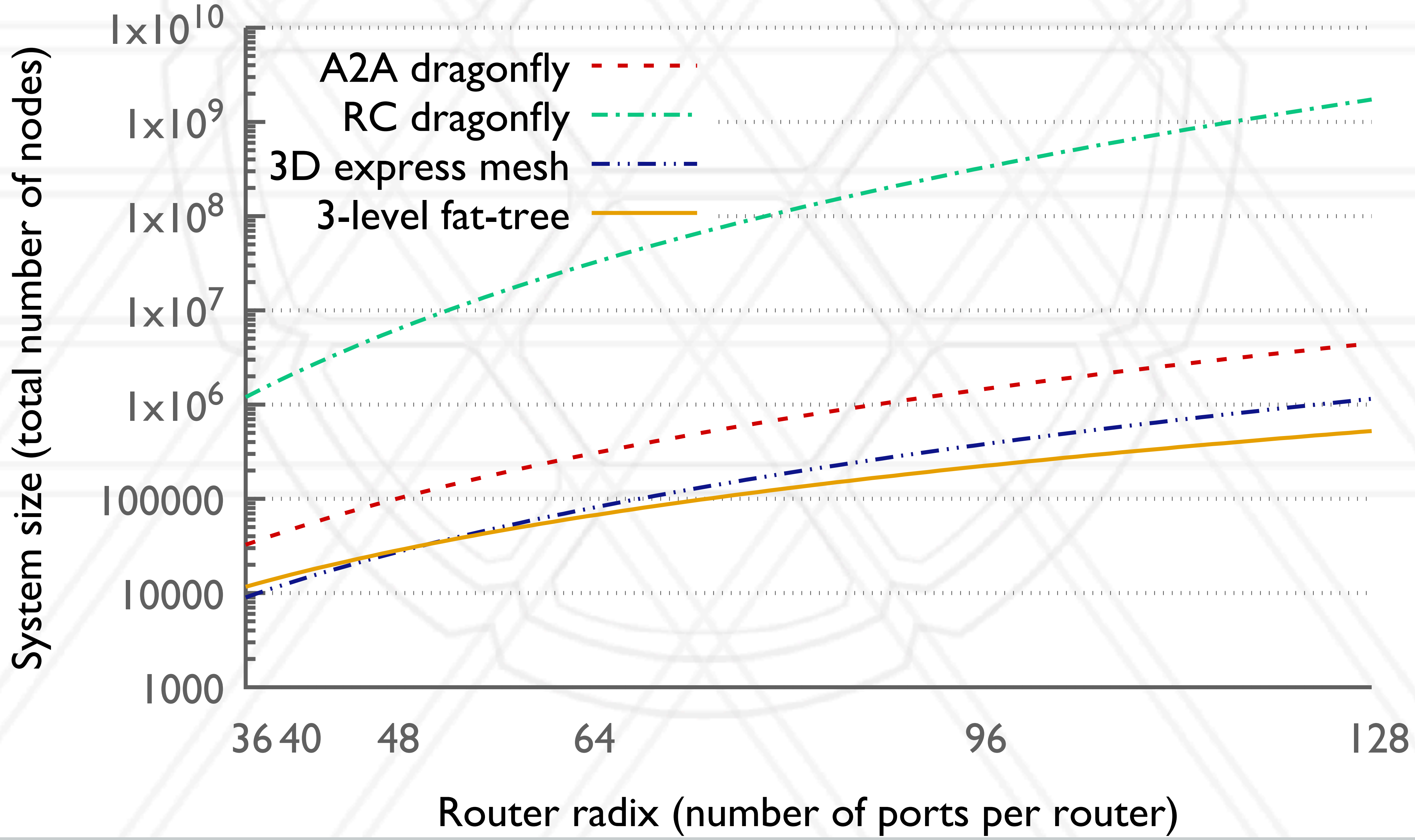
Two-level dragonfly with multiple groups



Inter-group (blue) links
(not all links are shown)

Network comparisons

Network topology	#nodes/router	#links/router	Maximum system size (#nodes)
All-to-all (A2A) dragonfly	k/4	k/2 (**L**), k/4 (**G**)	$(k/2+1)^2 \times (k/4+1) \times k/4$
Row-column (RC) dragonfly	k/6	2k/3 (**L**), k/6 (**G**)	$(k/3+1)^4 \times (k/6+1) \times k/6$
Express mesh (3D, gap=1)	k/4	3k/4	$(k/4+1)^3 \times k/4$
Fat-tree (three-level)	k/2	k/2	$k/2 \times k/2 \times k$



Questions?

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