High Performance Computing Systems (CMSC714)

Lecture 22: Topology Aware Mapping

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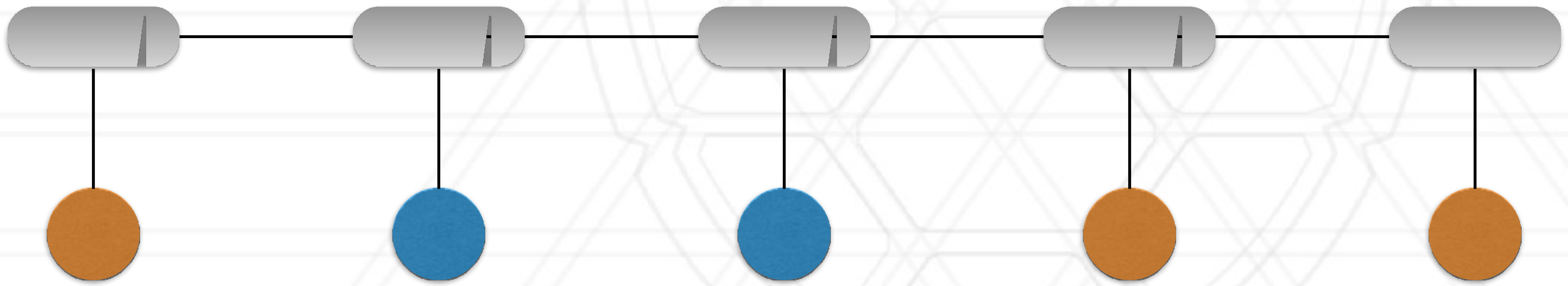
Notes

- Graded exams returned on Tuesday
- Group Project presentations scheduled for Dec. 6, and Dec. 8 (if needed)
    - final report due Monday, December 12

Congestion due to network sharing

- Sharing refers to network flows of different programs using the same hardware resources: links, switches
- When multiple programs communicate on the network, they all suffer from congestion on shared links



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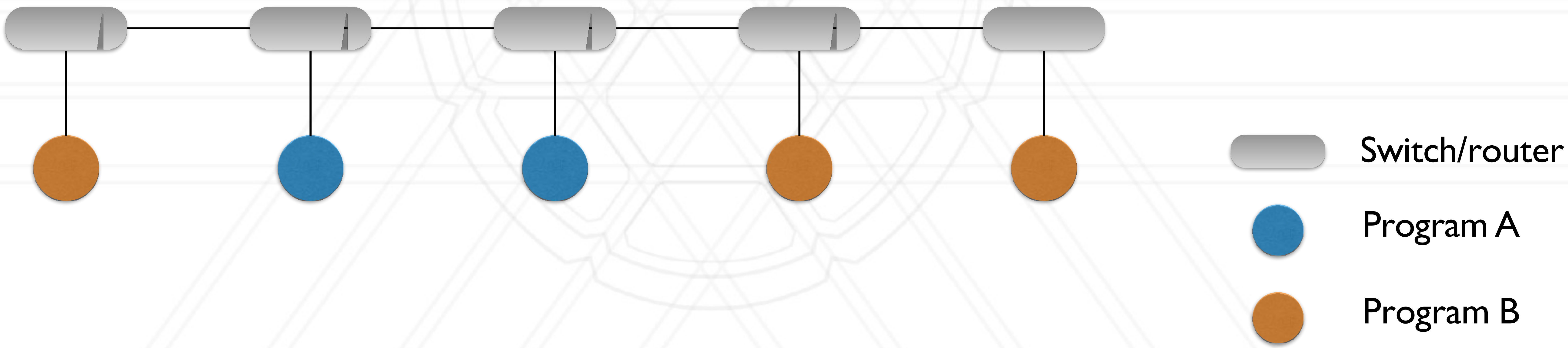

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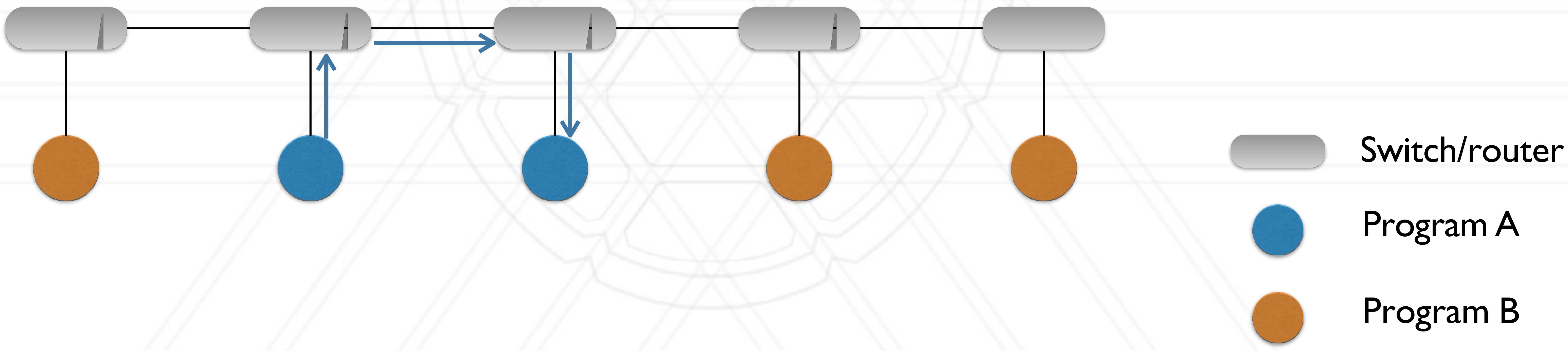

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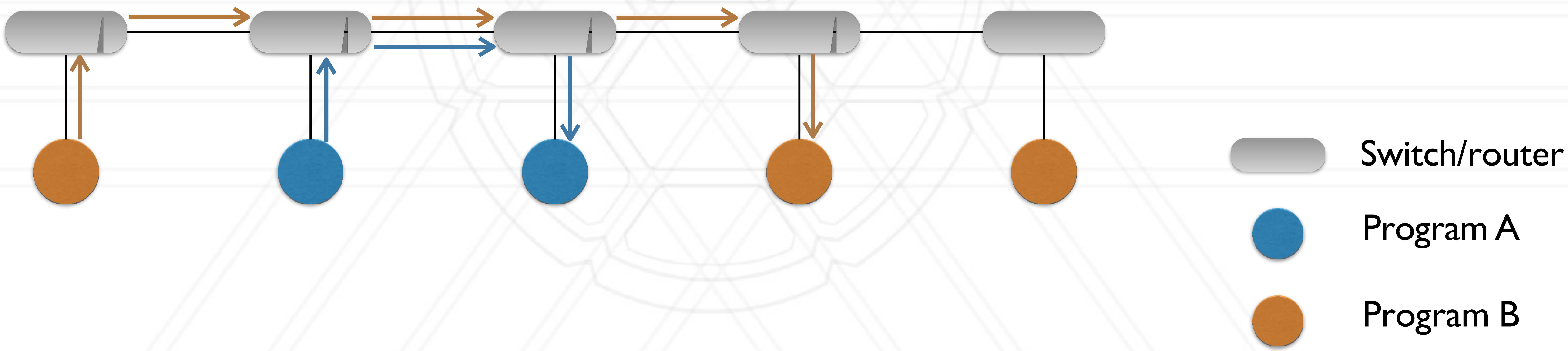

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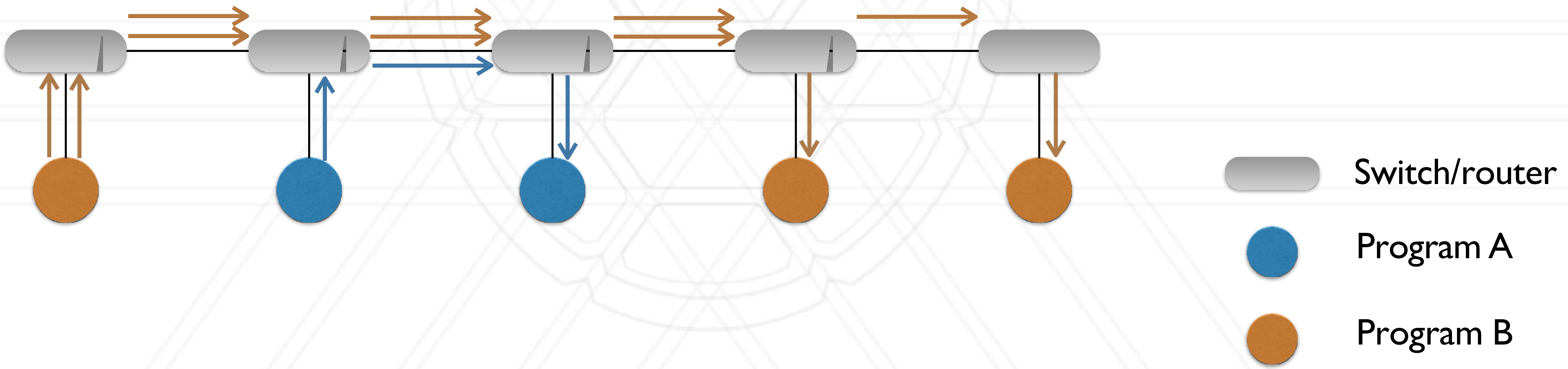

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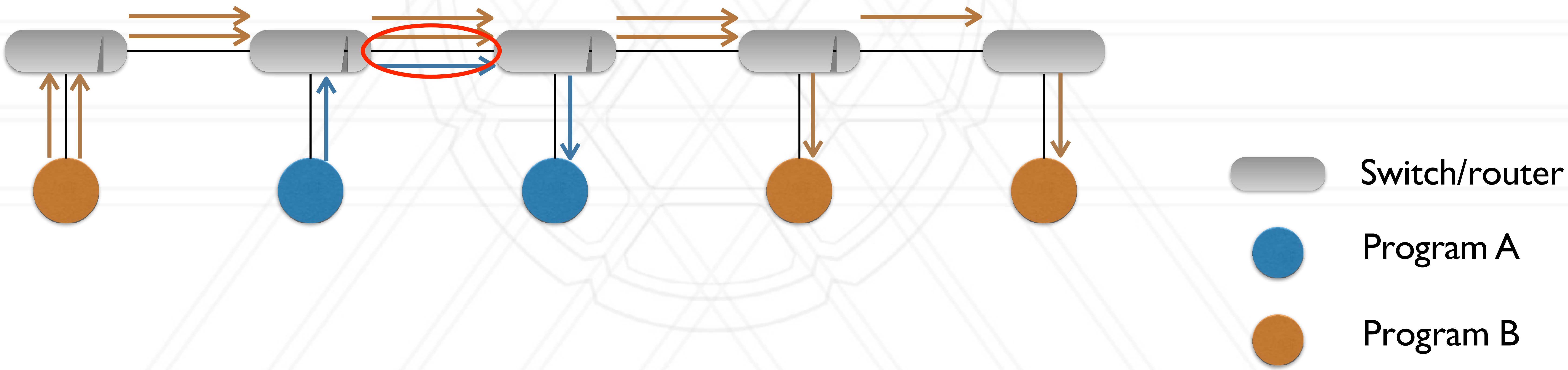


Communication is a bottleneck at scale

- GPU-based and multi-core CPU-based platforms have a large number of flop/s per node
  - Network bandwidths have not increased proportionally
- More energy is spent on sending data across the network

	Time (ns)	Energy spent (pJ)
Floating point operation	< 0.25	30-45
Access DRAM	50	128
Get data from another node	> 1000	128-576

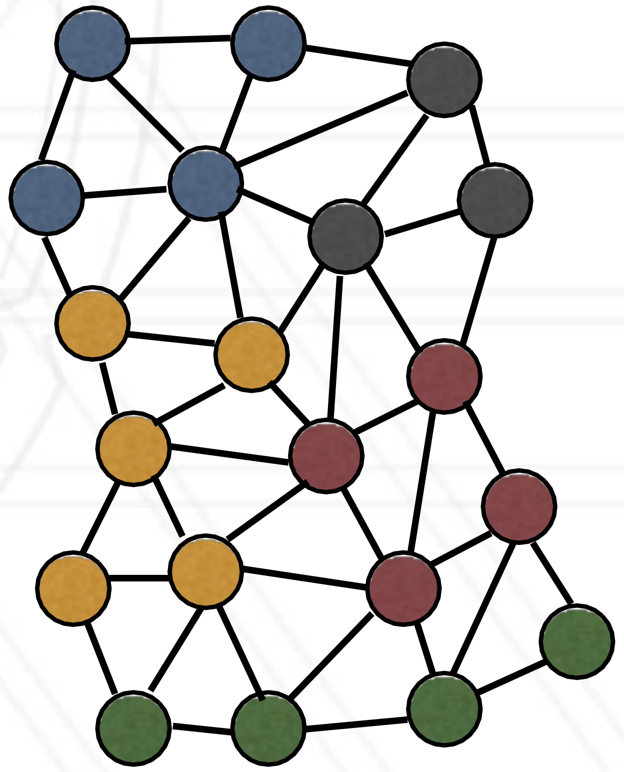
P. Kogge et al., Exascale computing study: Technology challenges in achieving exascale systems, *Technical Report*, 2008.

Different approaches to mitigate congestion

- At the system level
  - Network topology aware job scheduler — attempts to assign compact allocation to jobs
  - Congestion-mitigating routing algorithms - this is the hotspot paper, assuming the job scheduler already assigned a set of nodes to the job
- At the individual job level
  - Users can try to optimize the mapping of MPI processes to allocated nodes – this is the BlueGene/L paper

Topology aware task mapping

- Also referred to as task placement or node mapping
- Given an allocation, decide which MPI processes are placed on which physical nodes/ cores
  - In case of task-based models, map finer-grained tasks to cores
- Goal:
  - Minimize communication volume and/or number of messages on the network
  - Optimize "unavoidable" communication on the network



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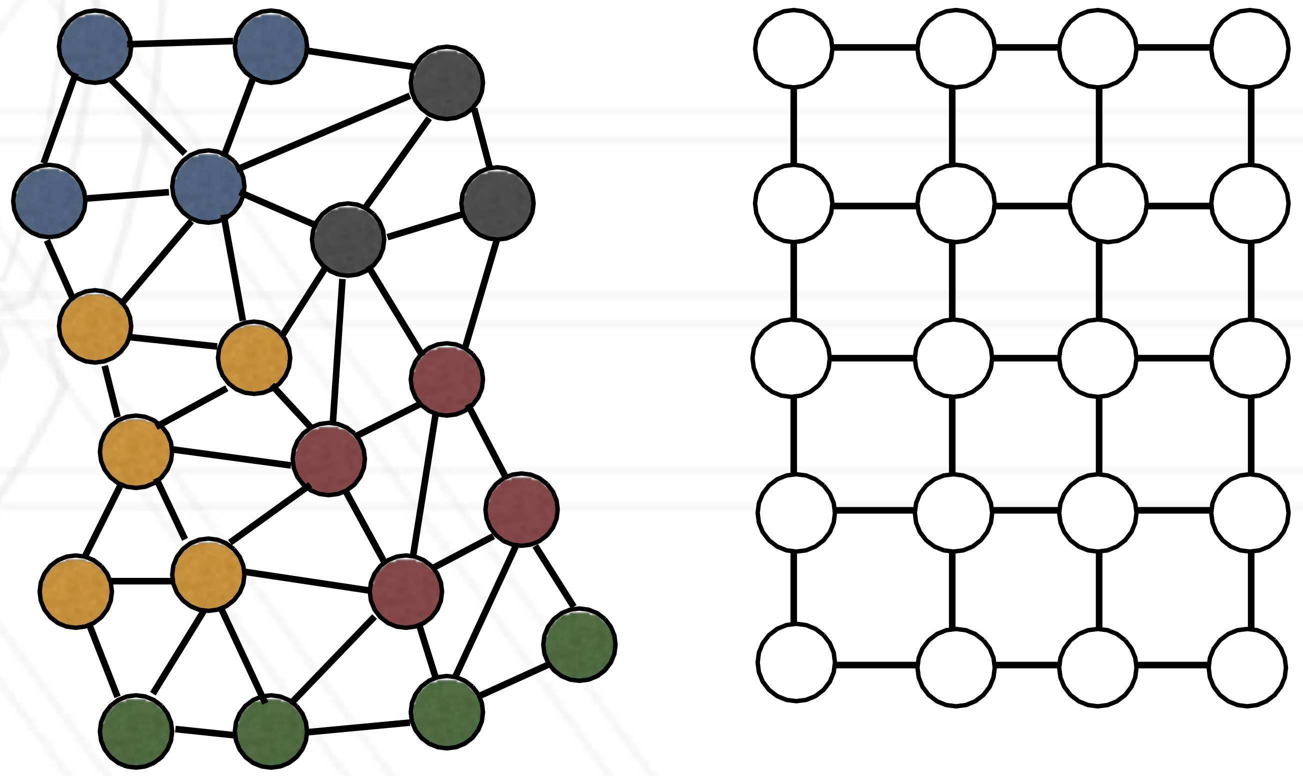

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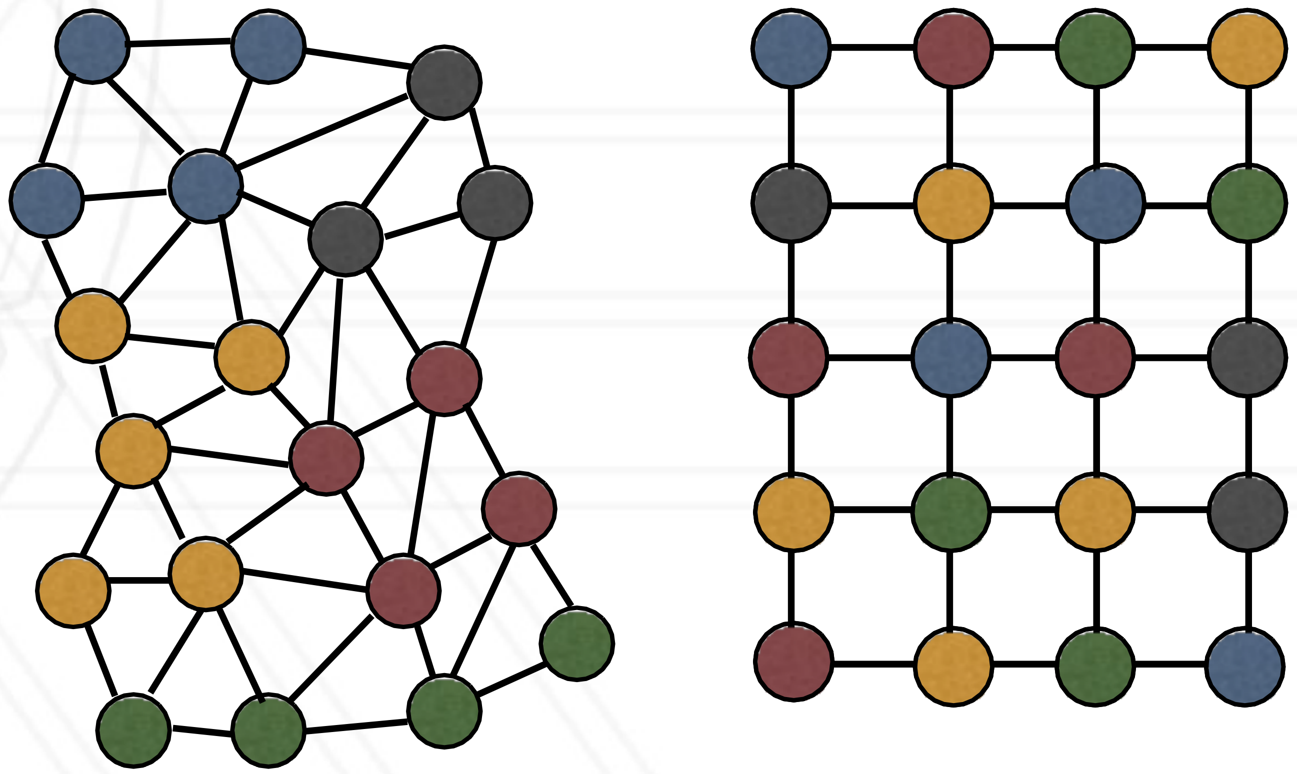

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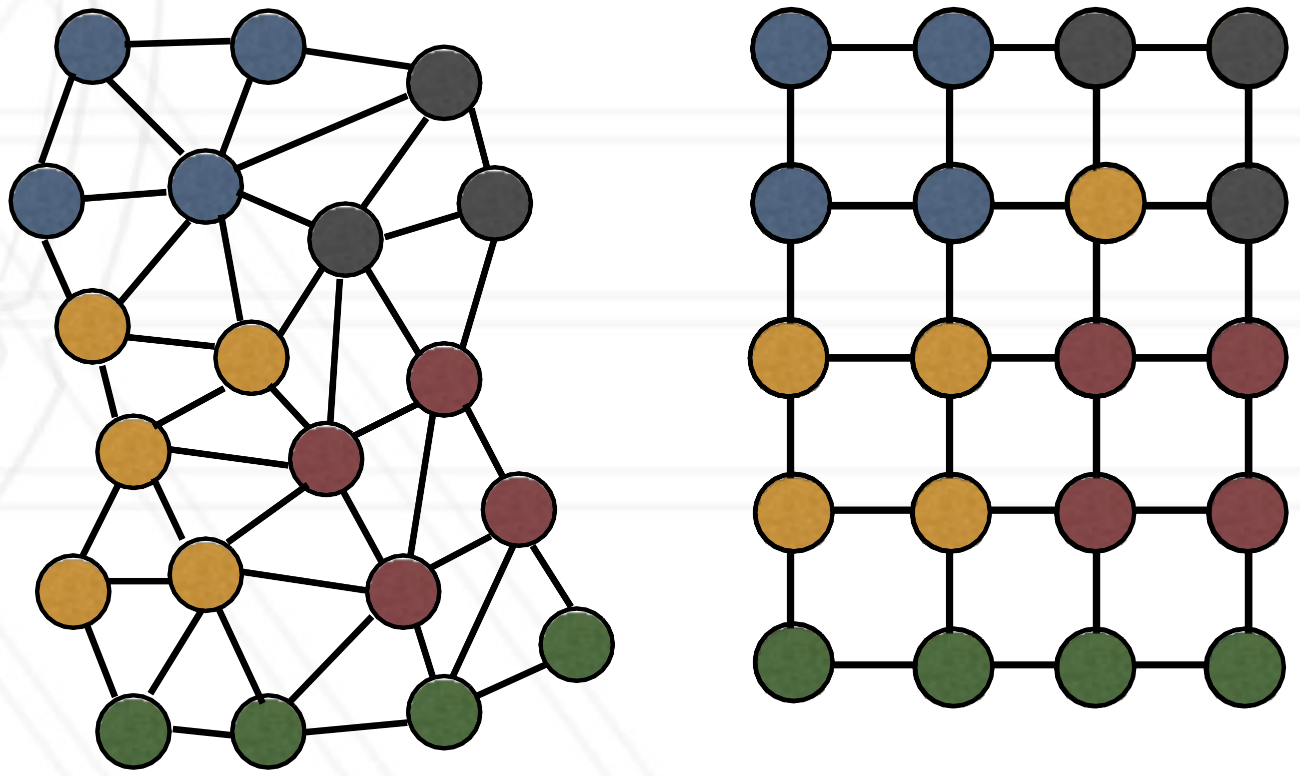


Graph embedding problem

- Inputs: Application communication graph, network topology graph (of one's job allocation)
- Output: Process-to-node/core mapping – BlueGene/L paper describes and evaluates a simulated annealing algorithm for the optimization problem of mapping processes to nodes
- Most mapping algorithms do not consider that communication patterns might evolve over time

Metrics to evaluate mapping

- Hop-count

$$\sum_{(i,j)} H(i,j)$$

- Hop-bytes

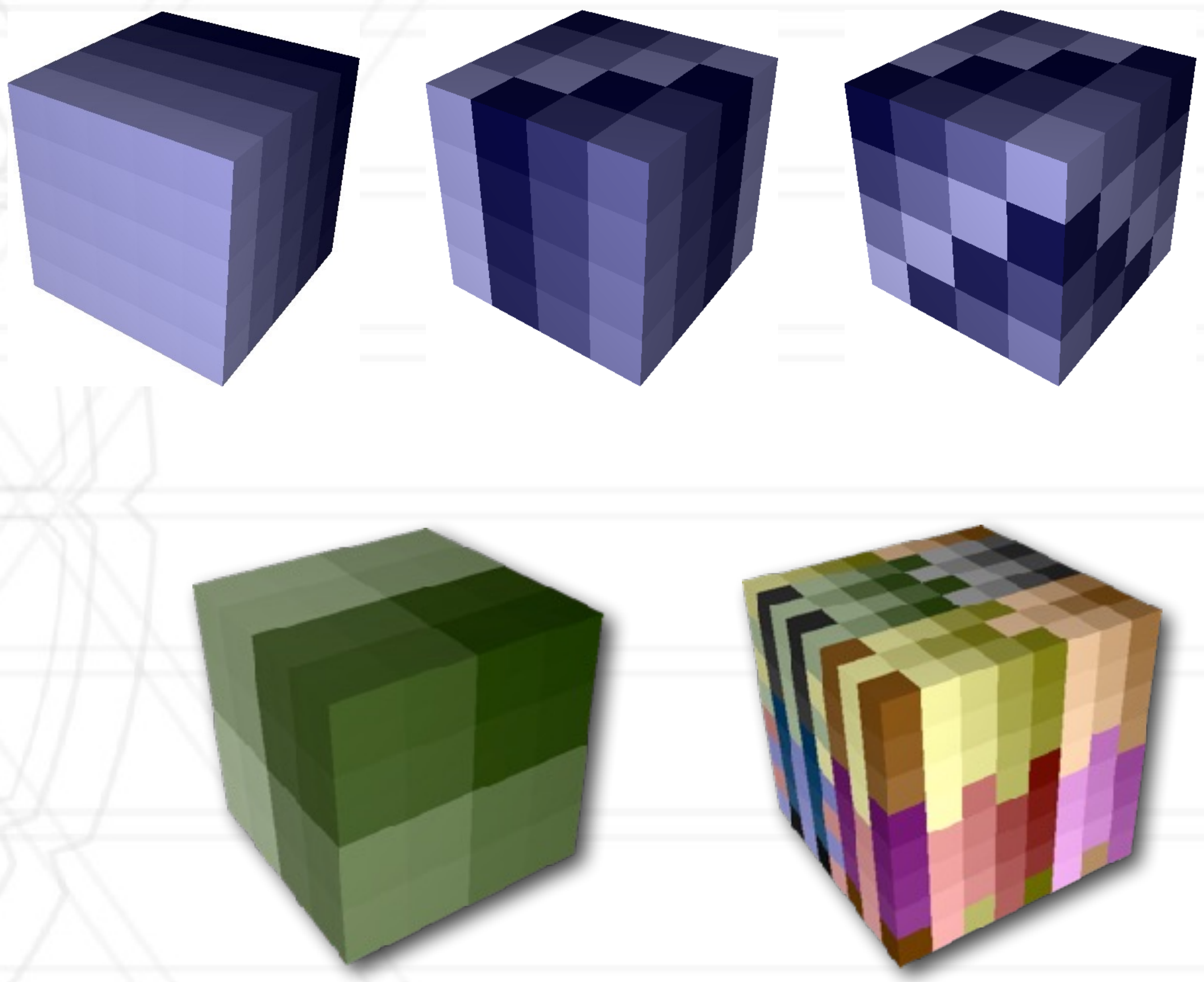
$$\sum_{(i,j)} C(i,j) \times H(i,j)$$

Different techniques

- Heuristics-based
  - Recursive bi-partitioning
  - Random pairwise swaps
- Physical optimization algorithms
  - Simulated annealing
  - Genetic algorithms

Rubik: Python tool for mapping

- Define various operations on prisms
  - Partitioning or blocking
  - Permuting operations



https://github.com/LLNL/rubik

Rubik: Python tool for topology-aware mapping from LLNL

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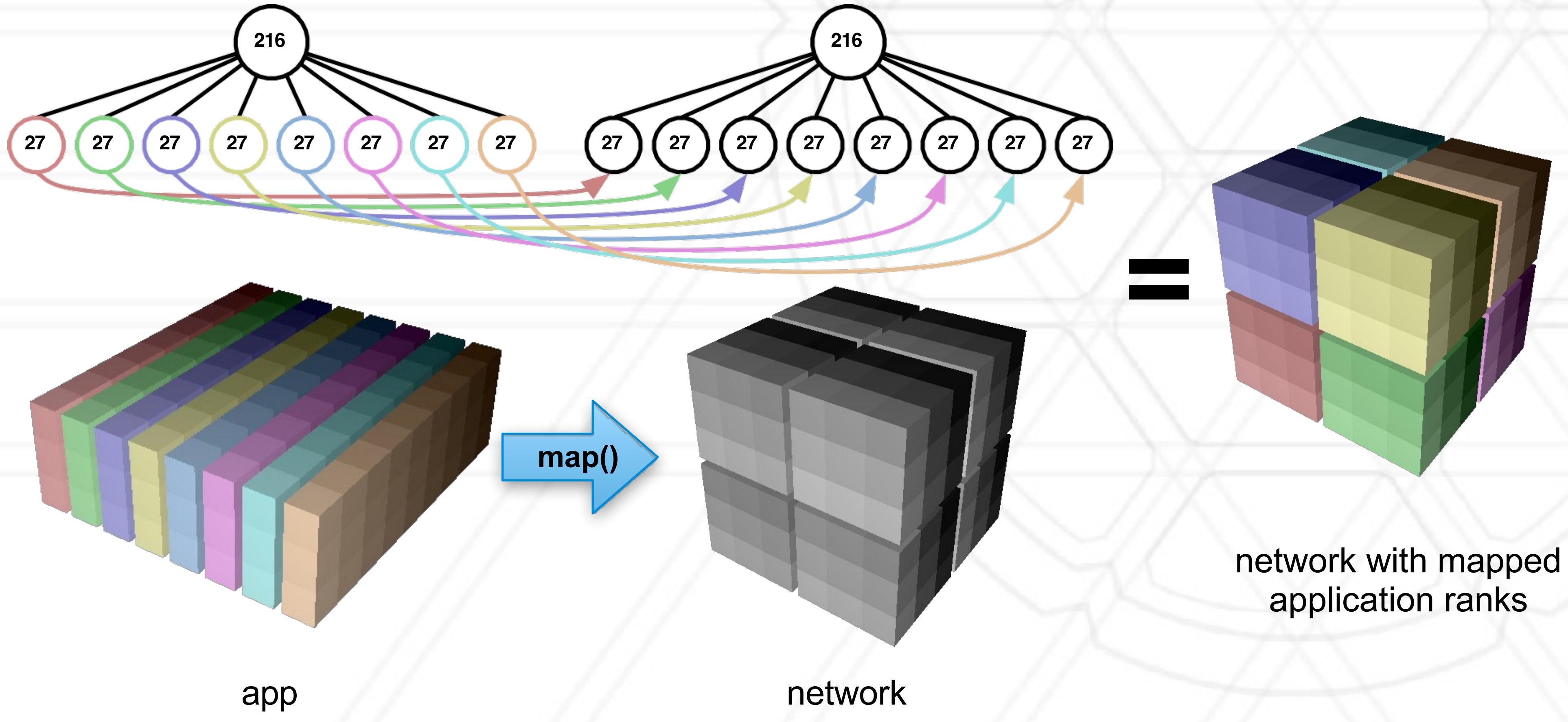

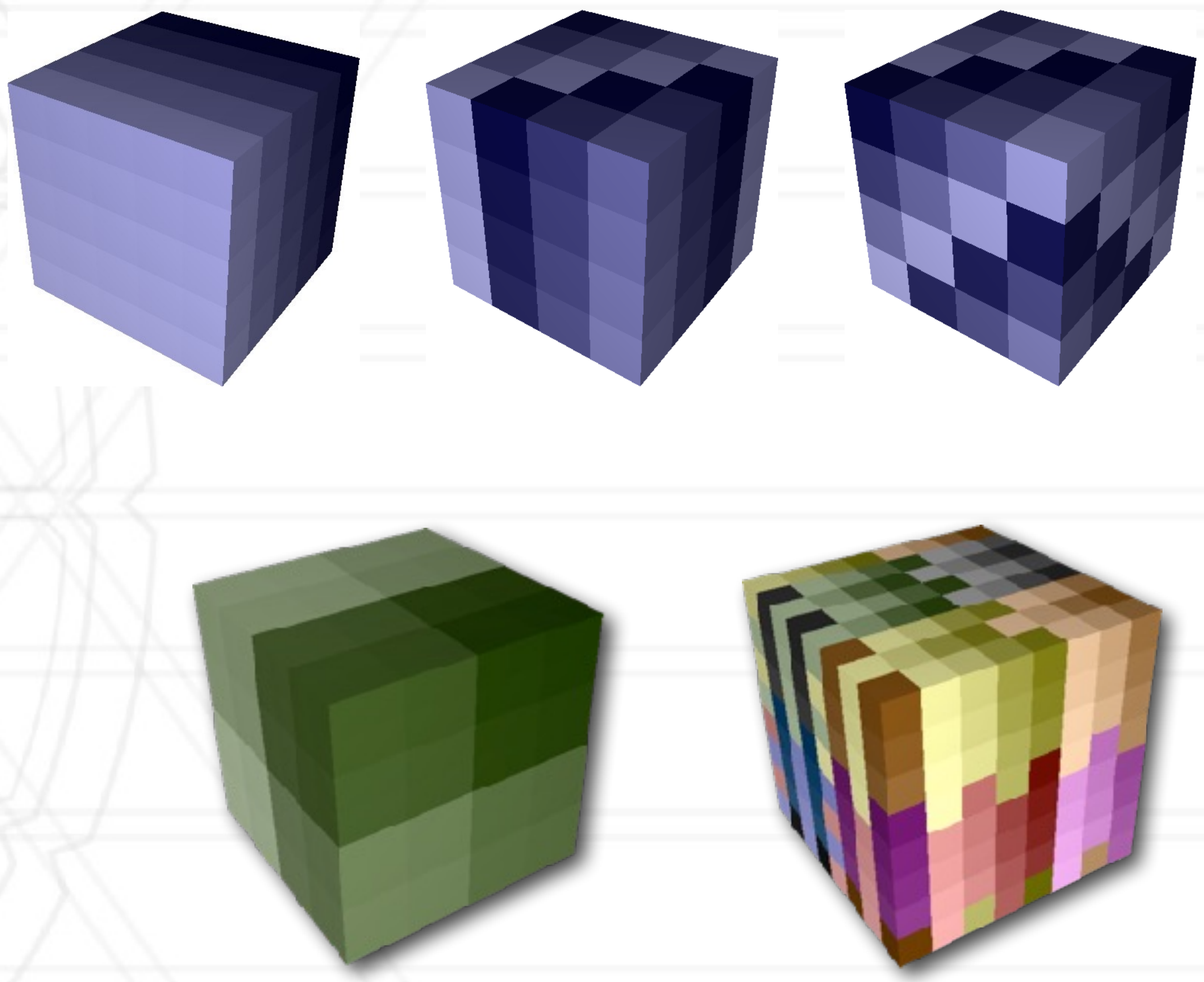

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Global link bottleneck in dragonfly systems

- Relatively few global links when building a smaller than full-sized system
- And that can create hotspots/bottlenecks for some communication patterns