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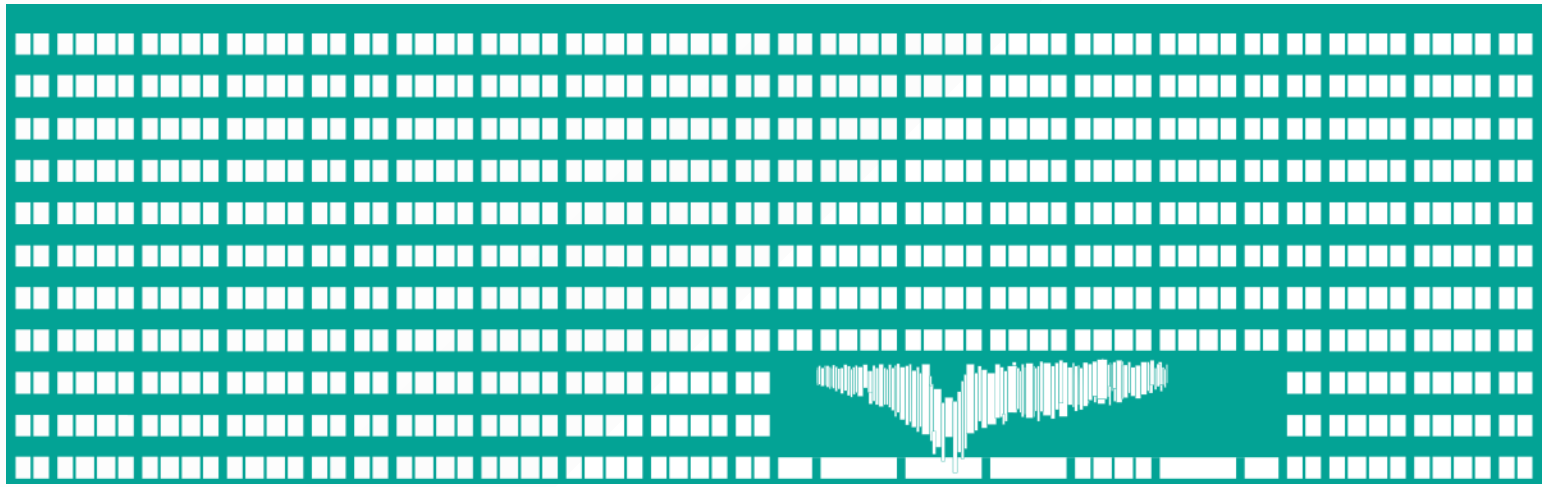

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VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE | DEPARTMENT OF TELECOMMUNICATIONS

Modeling and Dimensioning of Networks

Network Topologies in Data Center Networks

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Key Concepts to know

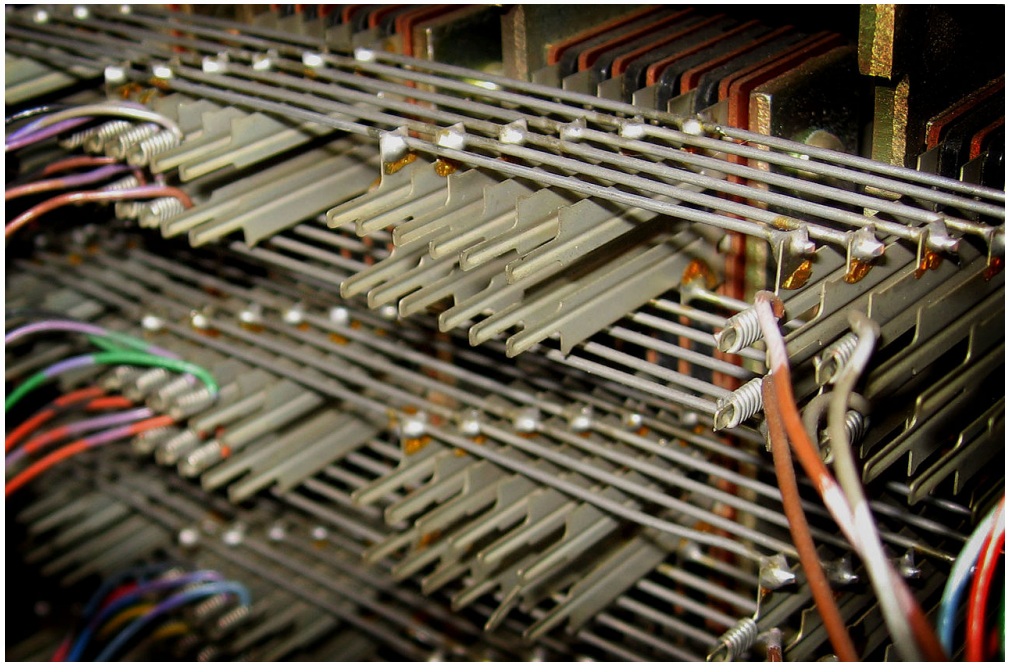
- switching:
  - circuit vs packet
  - space vs time
- evolution of switching systems
  - telephony networks (generations 0 -> 5)
  - computer networks (DARPA, ethernet, TCP/IP stack)

Key Concepts to know

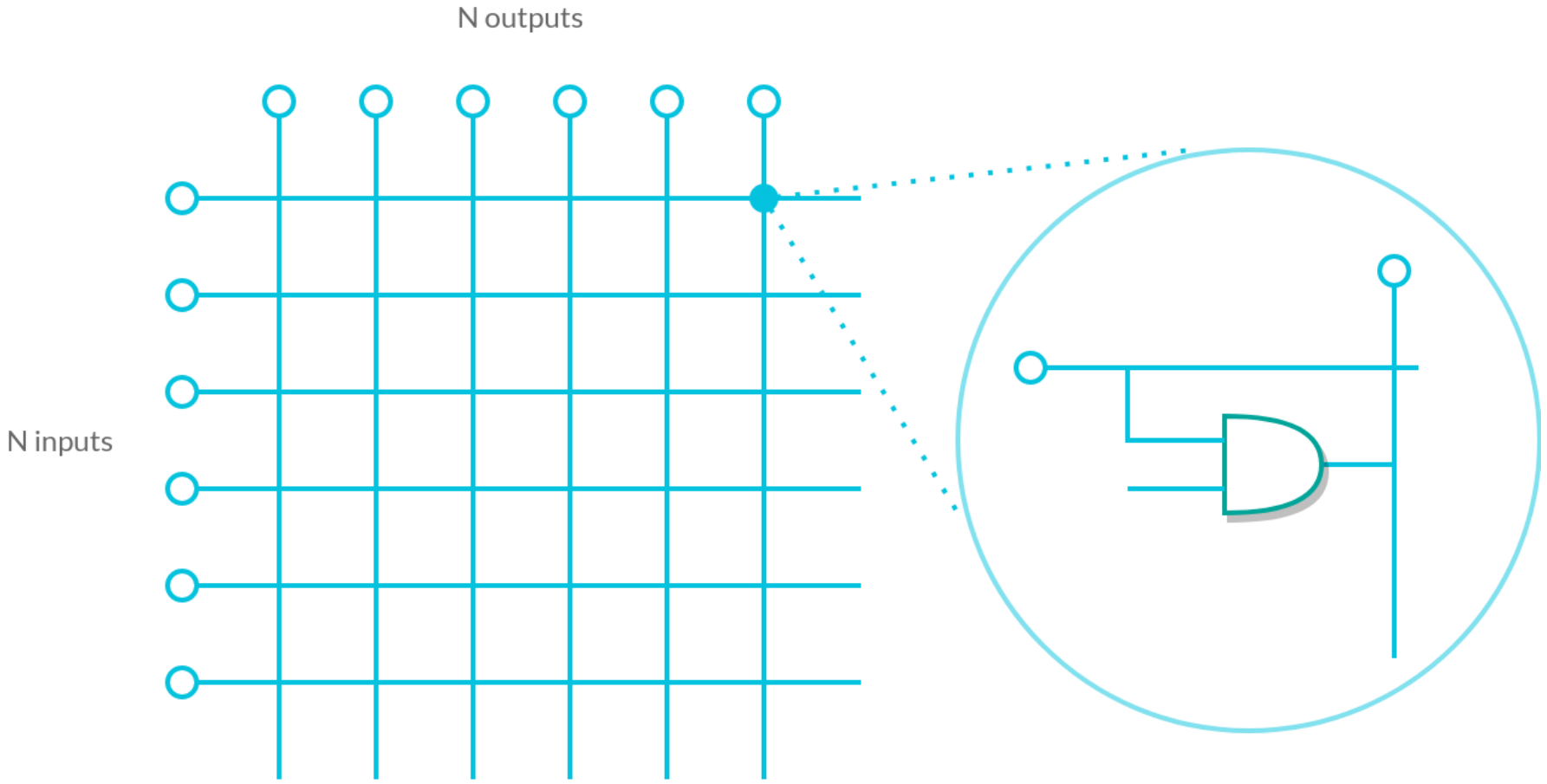
- basic network topologies:
  - point-to-point
  - bus
  - star
  - mesh
  - ring
  - tree

Historical Context

- space switching in 2nd gen. = **crossbar** switch (image source)



Crossbar switch



Crossbar switch

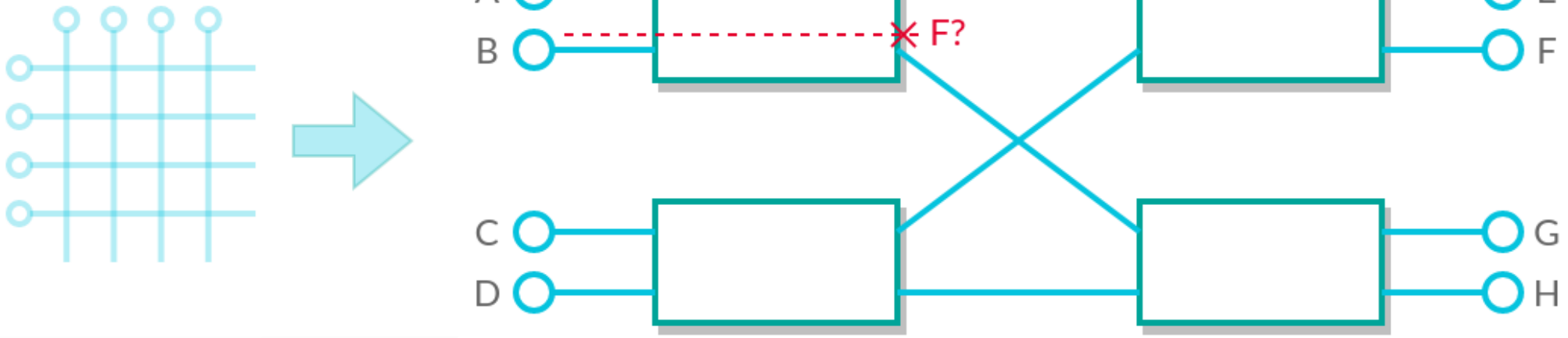
- number of inputs/outputs does not have to be the same
- number of crosspoints defines the complexity of the switch

$$C(N) = N^2 \quad [-]$$

- PRO: non-blocking architecture
- CON: very difficult to scale (until high density microcontrollers/processors)

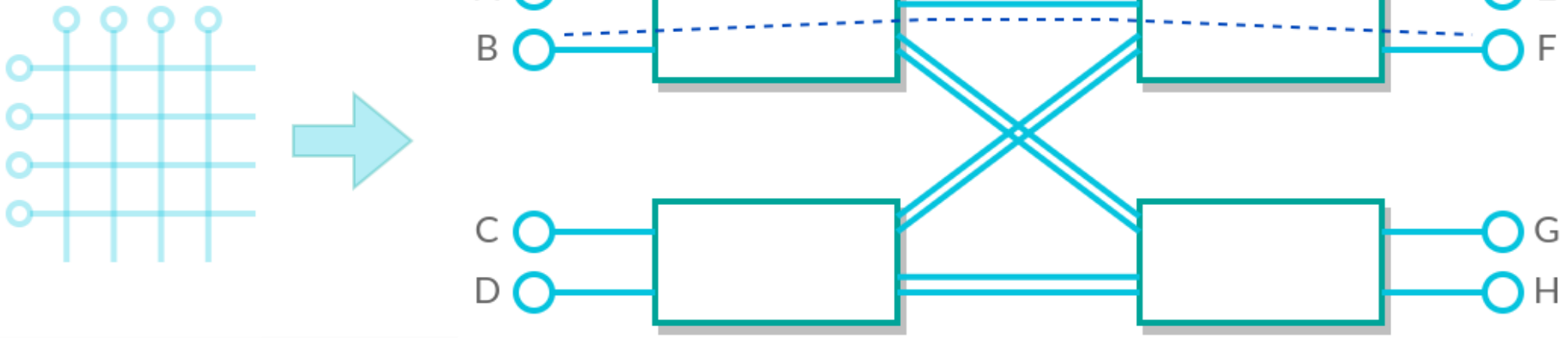
Improving scaling capabilities

- splitting monolithic switch into a network of simpler switches
- 2-stage?



Improving scaling capabilities

- Adding multiple connections?



Improving scaling capabilities

- Complexity now:

$$C(n) = 2 \cdot mn^2$$

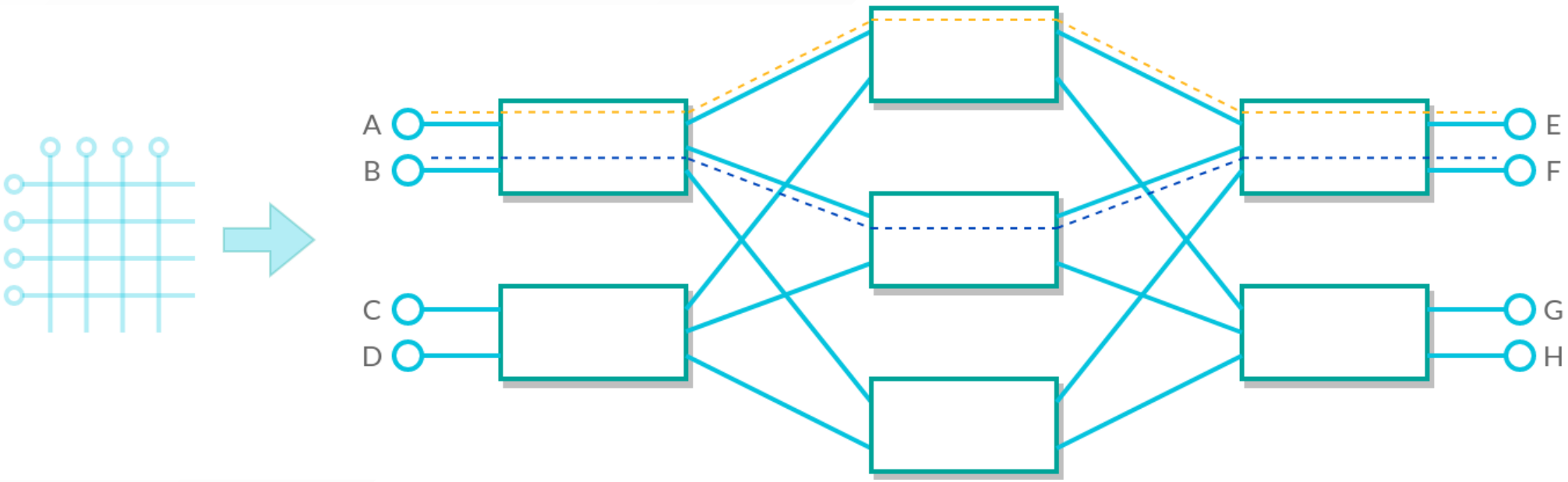
$$m = n^2$$

$$C(N) = 2N^2 \quad [-]$$

- n - inputs/input switches
- m - outputs

Clos Networks

- a network with 3 stages (or odd number of stages)
- exactly one link between switches in neighboring stages



Clos Networks

Strictly non-blocking

$$C(n) = 3 \cdot mn^2$$

$$m \geq 2n - 1$$

$$C(n) = 3 \cdot (2n - 1)n^2$$

$$C(N) = 6N^{\frac{3}{2}} - 3N \approx 6N^{\frac{3}{2}} \ [-]$$

Rearrangably non-blocking

$$C(n) = 3 \cdot mn^2$$

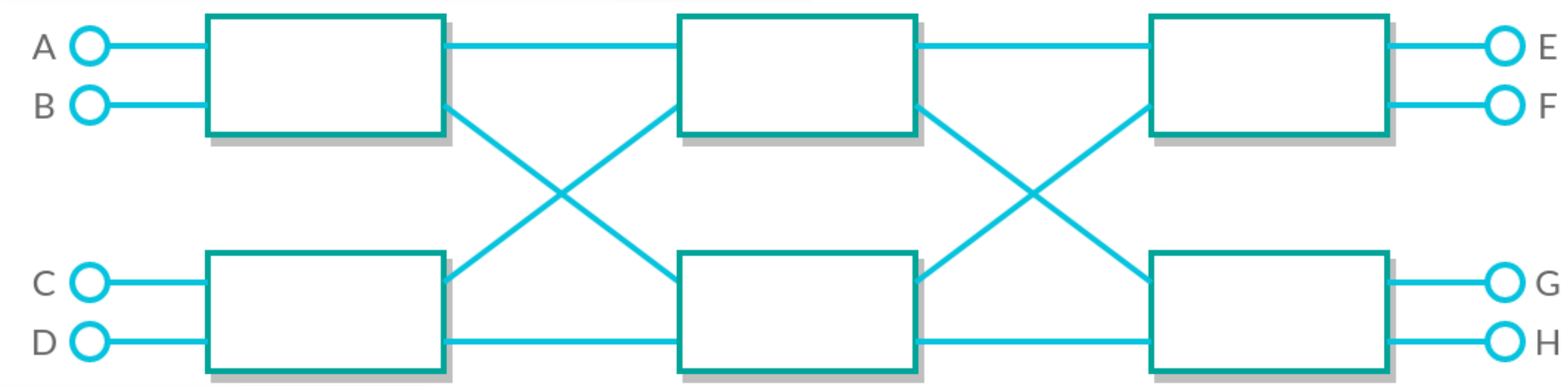
$$m \geq n$$

$$C(n) = 3 \cdot n^3$$

$$C(N) = 3N^{\frac{3}{2}} \ [-]$$

Benes Networks

- special case of rearrangably non-blocking Clos network
- m=n=2



Q: How do we construct networks with more inputs?

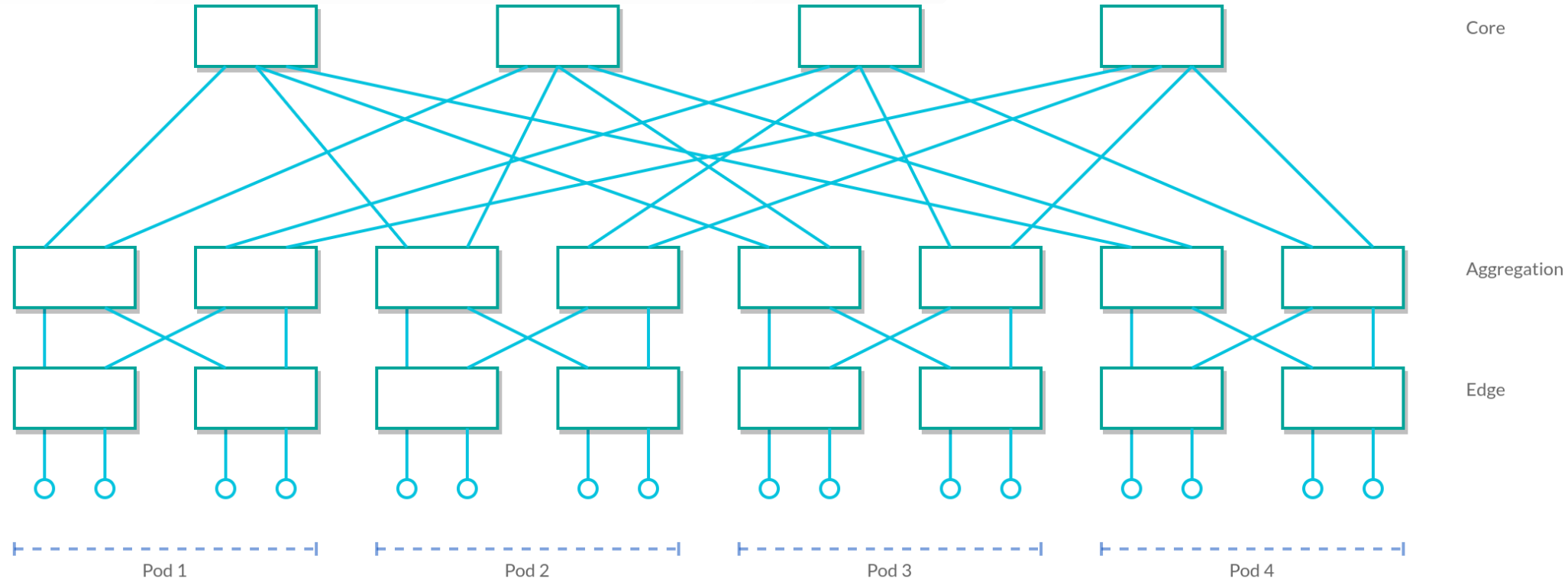
Transition to modern topologies

- extreme increase of elements in datacenter netwoks
- need for failover routes
- cabling complexity grows
- required scaling as the needs grow
- required low latency connections
- emergence of cloud computing and big data

Fat Tree Topology

- a special case of the Clos/Benes network
- efficient and fault-tolerant connectivity
- hierarchical design with multiple paths between nodes
- key features:
  - uniform bandwidth
  - redundancy
  - load balancing

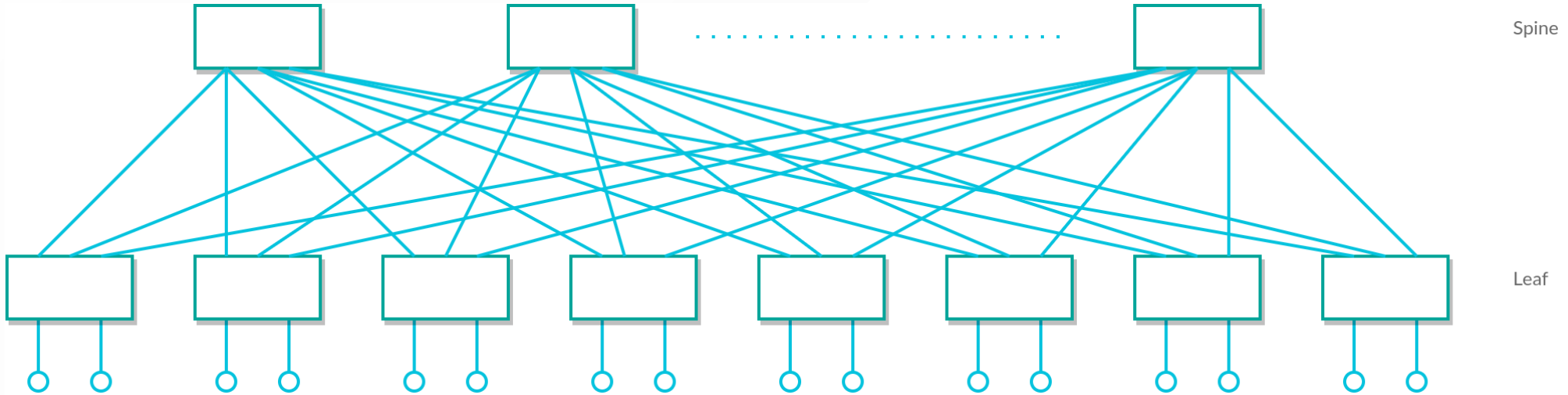
Fat Tree Topology



Spine-Leaf Topology

- a two-tier architecture:
  - spine = backbone switches
  - leafs = access switches
- every leaf switch is connected to every spine switch
- key features:
  - scalability - a bit easier than for fat tree
  - reduced latency
  - fault tolerance

Spine-Leaf Topology



And many more

- butterfly networks
- omega networks
- hypercube
- torus
- etc.

In the Lab

- modeling of simple network elements using ns-3
- topological aspects of the simulation
  - standard topologies
  - clos network/spine-leaf network
- protocol stack
- application layer simulation

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