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Interconnection Networks

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v. 1.0

Interconnection Networks

- Direct or static: integrated by direct point to point, permanent links connecting neighboring nodes.
- Indirect or dynamic: integrated by non permanent, non direct links. Connections are dynamically adjusted according to demands.

CONCEPTS

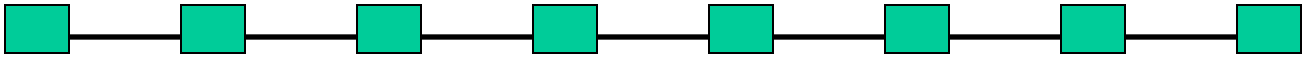
- Number of nodes on the network
- Degree: number of links per node
- Diameter: maximun shortest distance between two nodes
- Bisection bandwidth: number of links broken when dividing the network in two equal pieces (minimun cut).
- Cost: number of links on the network

Cost of the message

- Processing time: in both source and destination nodes. It is the time necessary tu issue an output message and to pick up an incoming one.
- Propagation delay: time taken by the header to move from one node to the next.
- Transmision time: determined by the link's bandwidth.
- Store time: in intermediate buffers (unless wormhole).
- Overlaping degree (wormhole)
- Copntention time: due to the lack of resources
- Latency: overall time taken to move from source to destination node.
- Throughput: network's capacity to issue informnation (packets per second).

STATIC (direct) TOPOLOGIES

Linear array



LINEAR ARRAY

Degree=1 on the ends

Degree=2 on the rest

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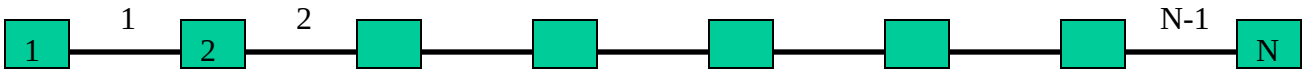
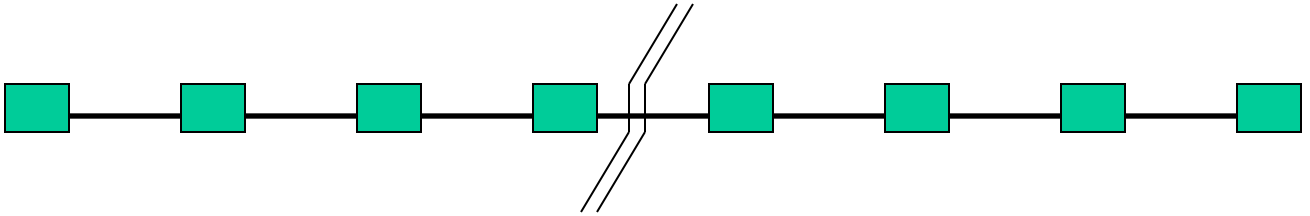
LINEAR ARRAY

Diameter = N-1= Cost



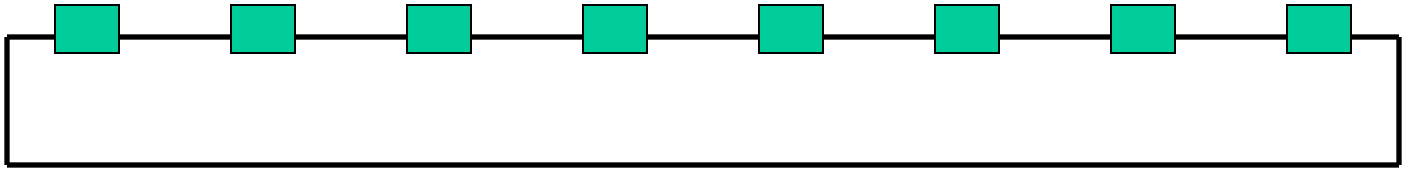
LINEAR ARRAY

Bisection bandwidth=1



STATIC (direct) TOPOLOGIES

Ring



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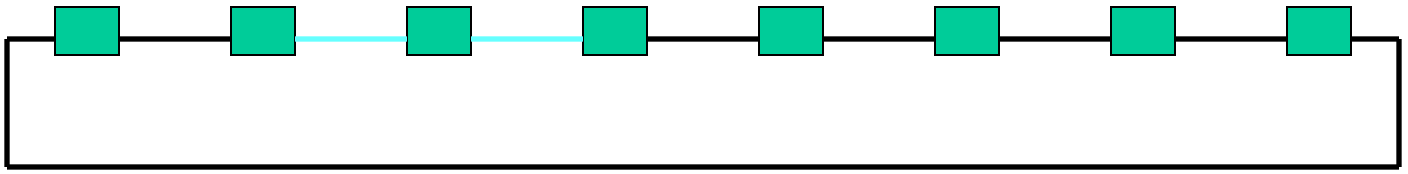
RING

Degree=2 all nodes



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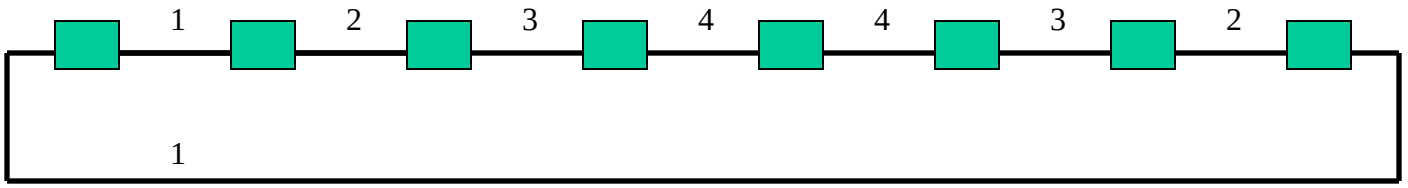
RING

Diameter = int (N/2)



Cost = N

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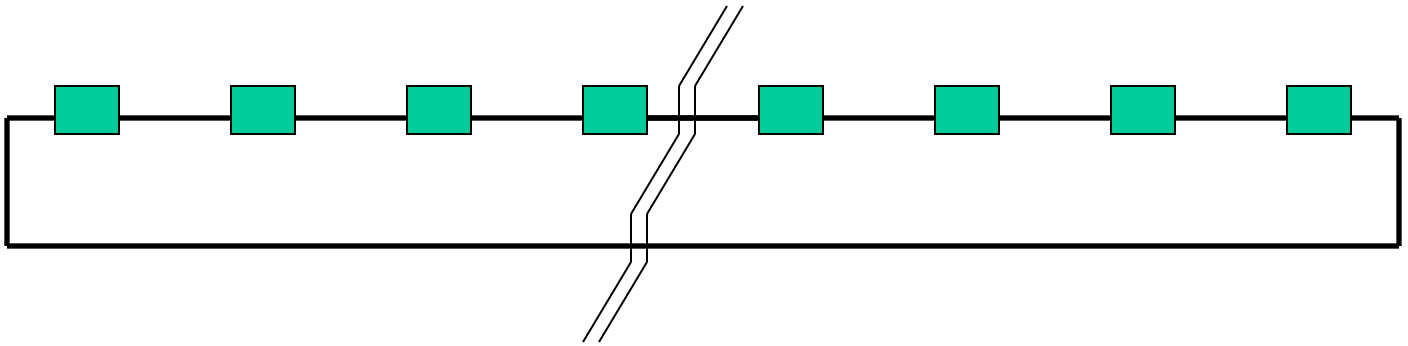
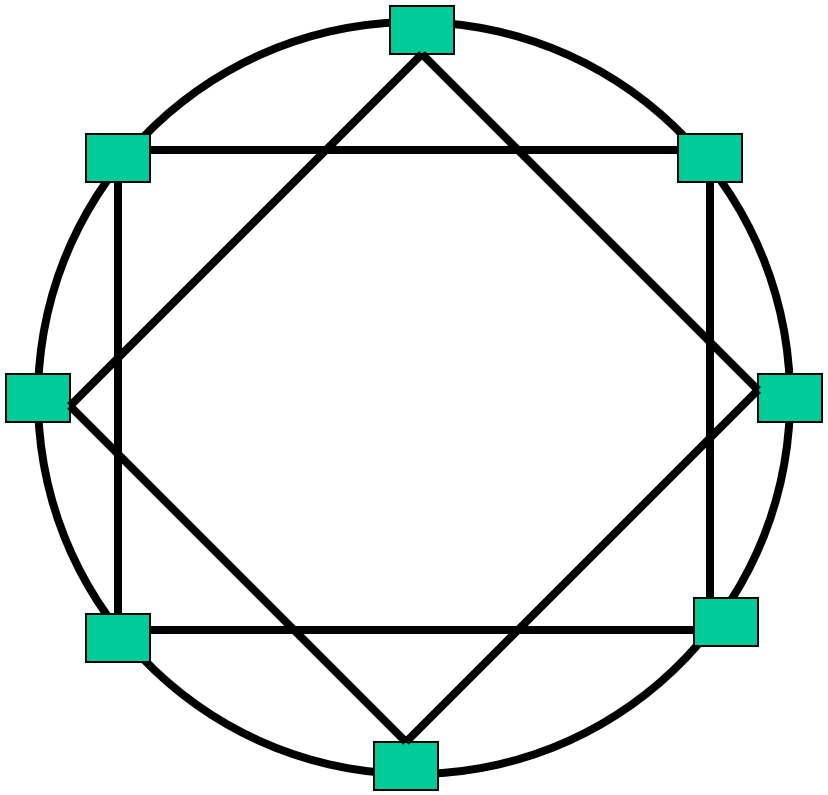
RING

Bbw= 2



STATIC (direct) TOPOLOGIES

Degree 4 chordal ring



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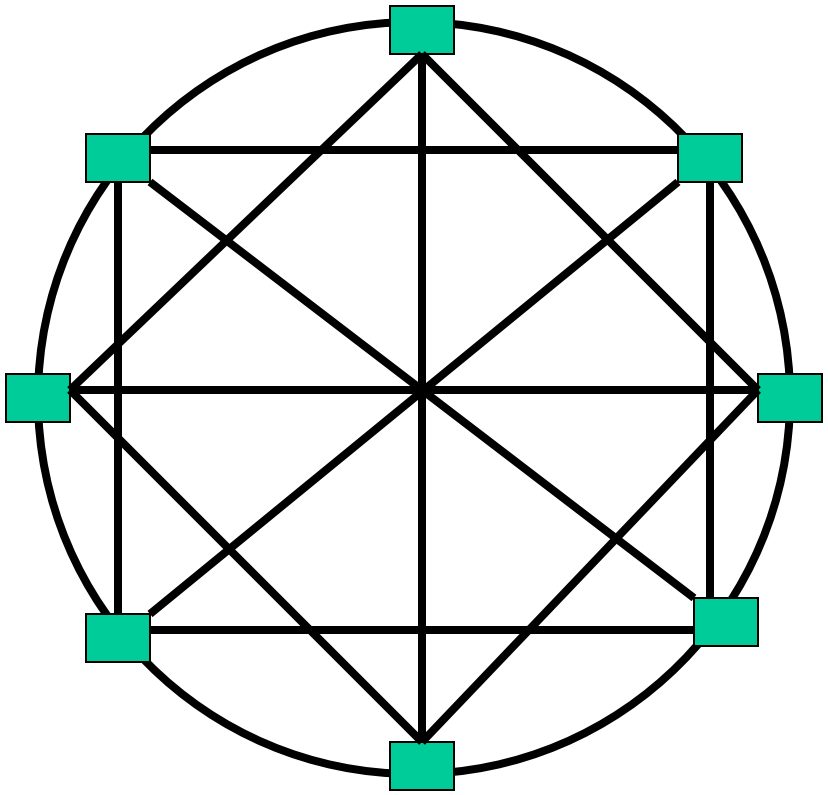
STATIC (direct) TOPOLOGIES

8 nodes barrell shifter



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BARRELL SHIFTER

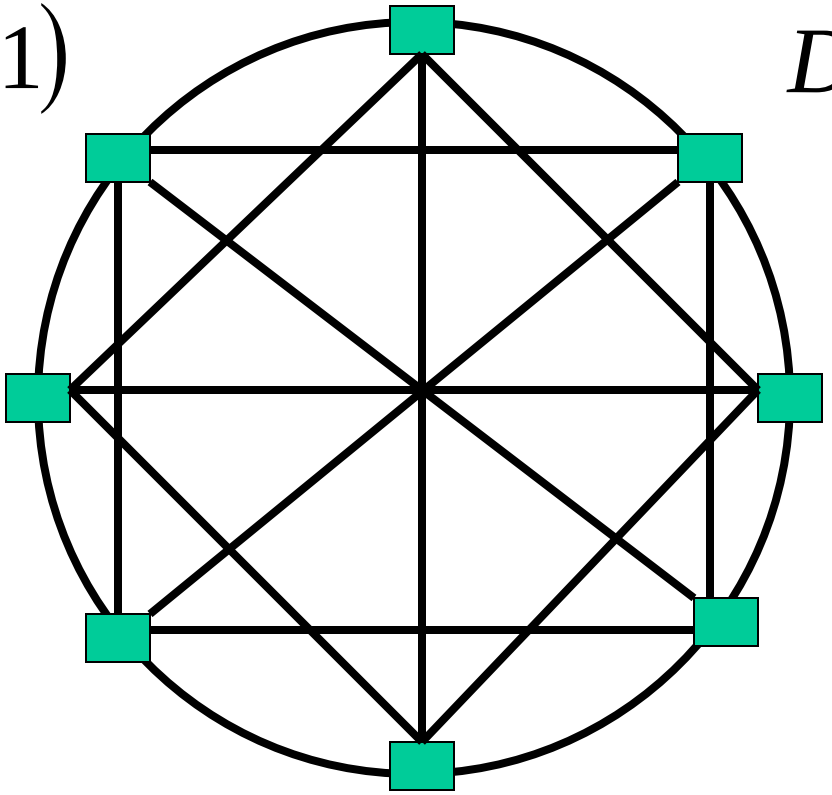
$$N = 2^n$$

$$Bbw = N - 2 + N/2$$

$$C = \frac{N}{2} + N(n-1)$$

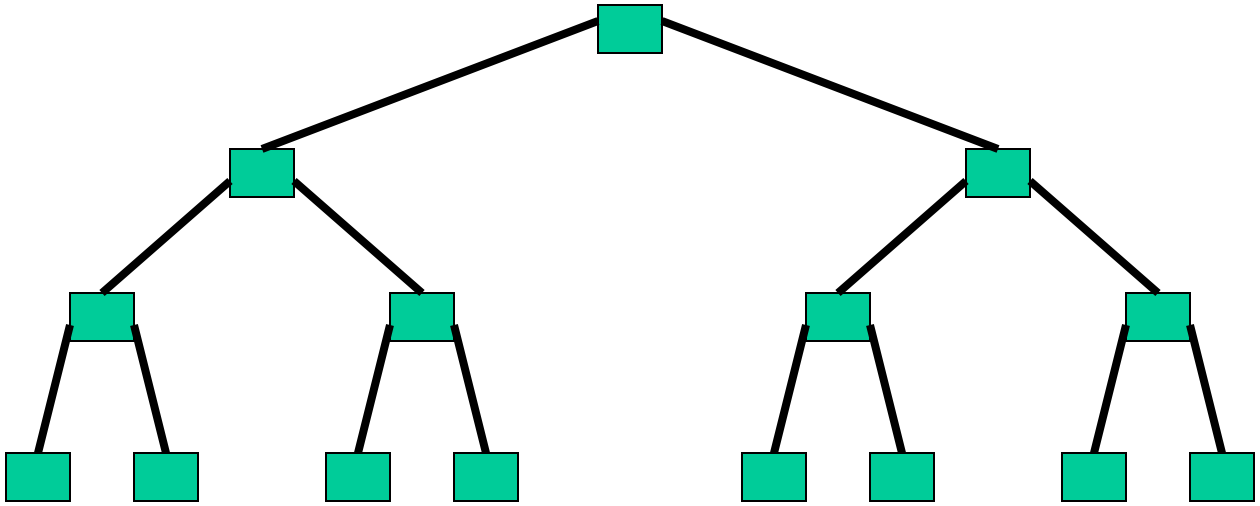
$$D = 2n - 1$$

$$k = 2$$



STATIC (direct) TOPOLOGIES

Tree



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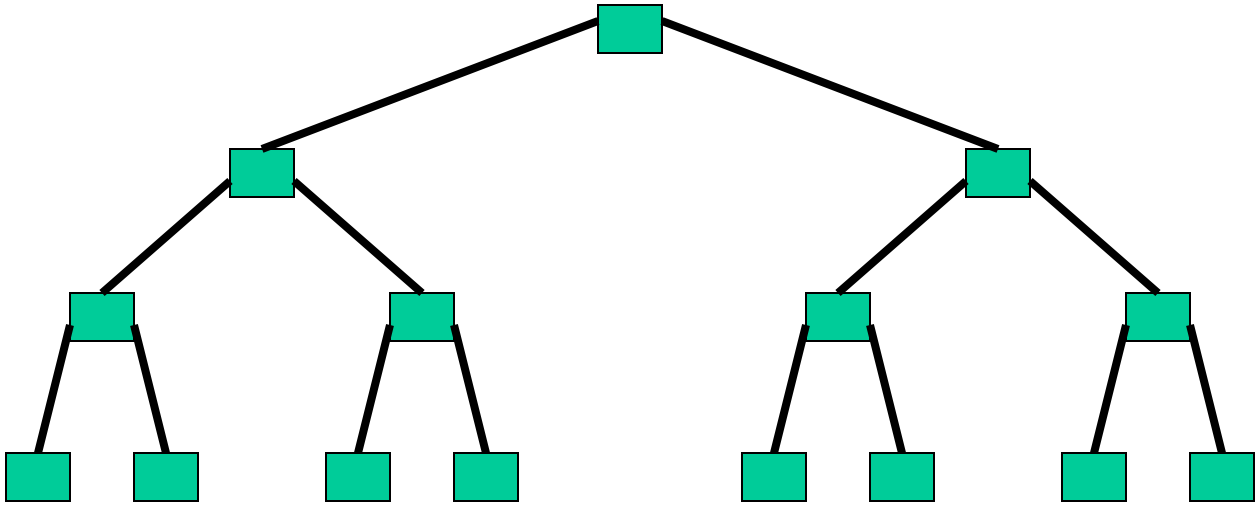
Tree

$N = 2^n - 1$ $\quad Bbw = 1$ $\quad k = 2(n-1)$

$D = 3$ $\quad C = N - 1$



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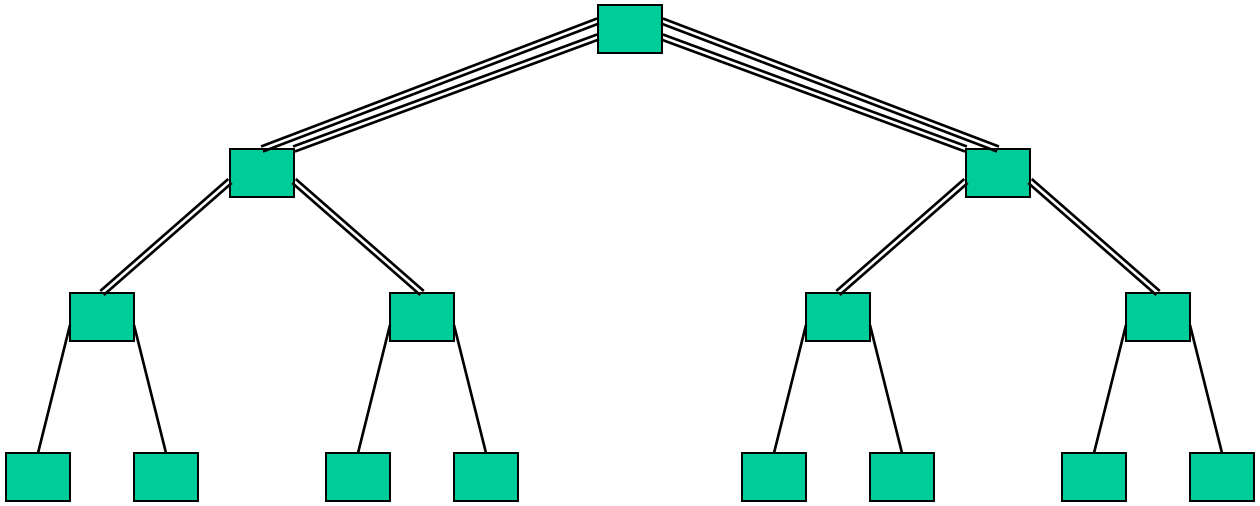
FAT TREE

$$N = 2^n - 1 \qquad Bbw = G/2 \qquad k = 2(n-1)$$

$$D = 2^{n-1} \qquad C = (n-1) \cdot 2^{n-1}$$



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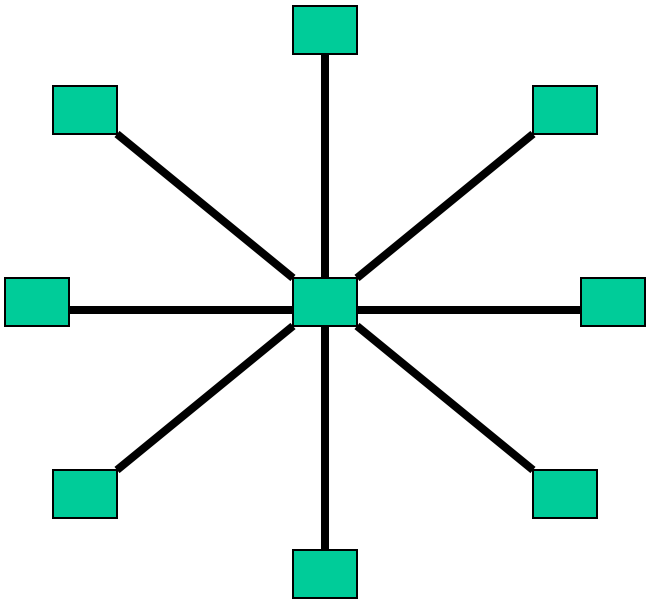
STATIC (direct) TOPOLOGIES

Star



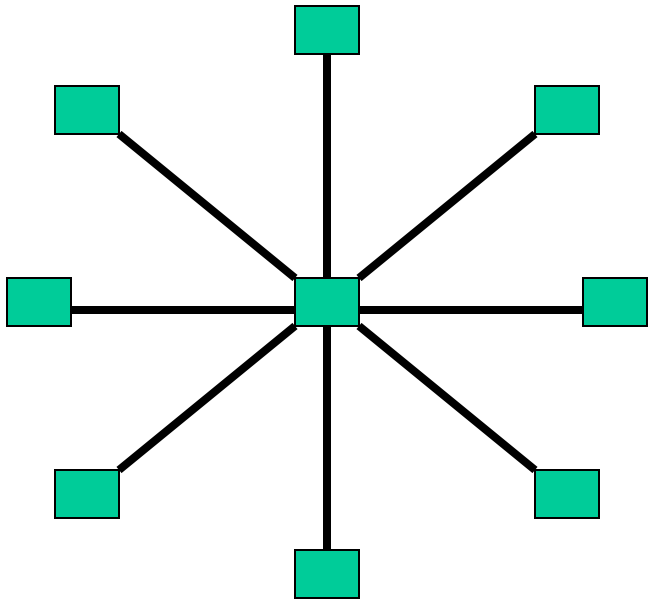
STAR

D=1

Bbw=1

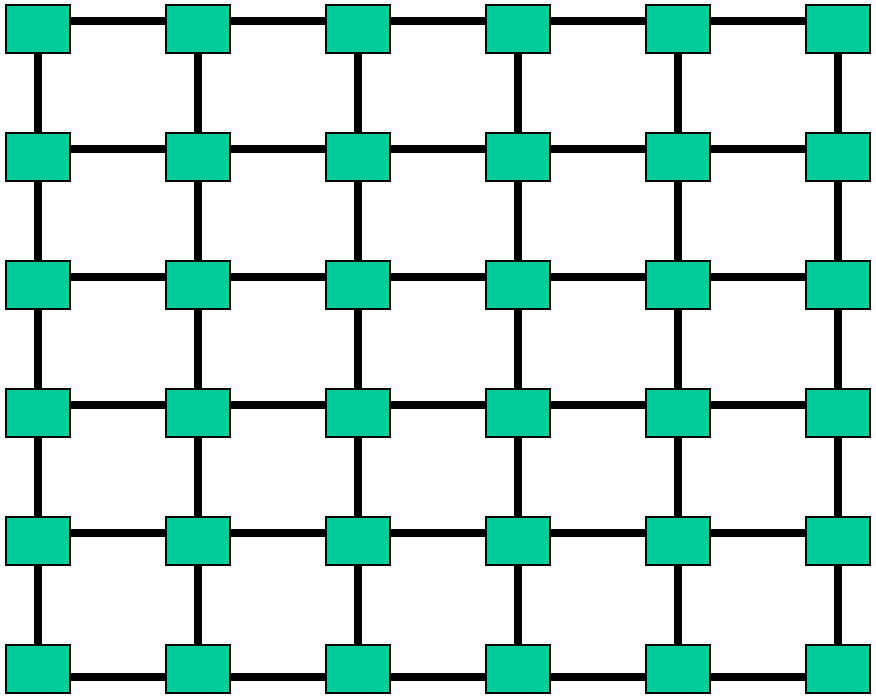
C=N-1

k=2



STATIC (direct) TOPOLOGIES

Mesh



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MESH

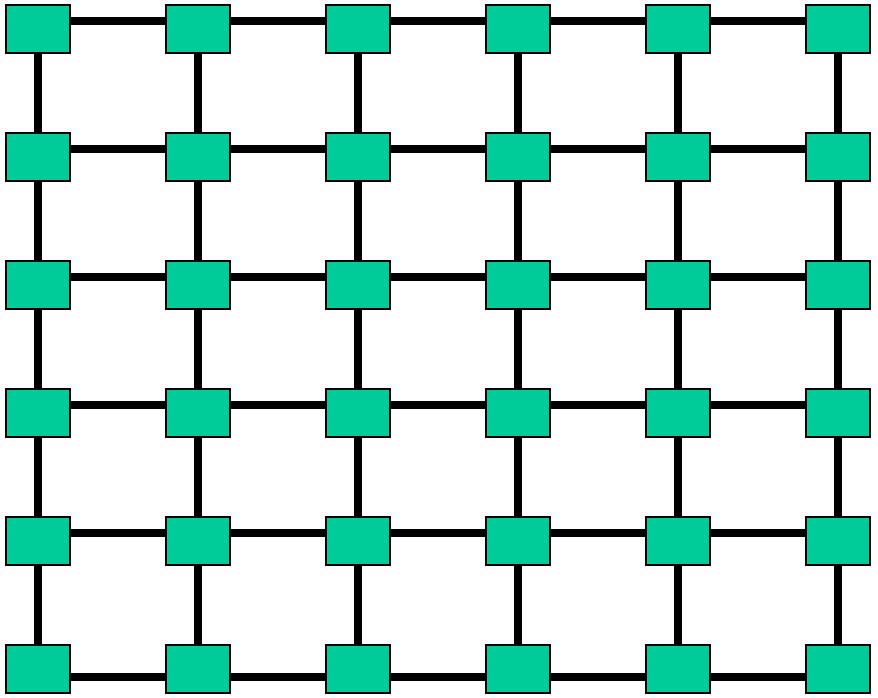
$$N = d^n$$

$$k = n(d-1)$$

$$Bbw = d^{n-1}$$

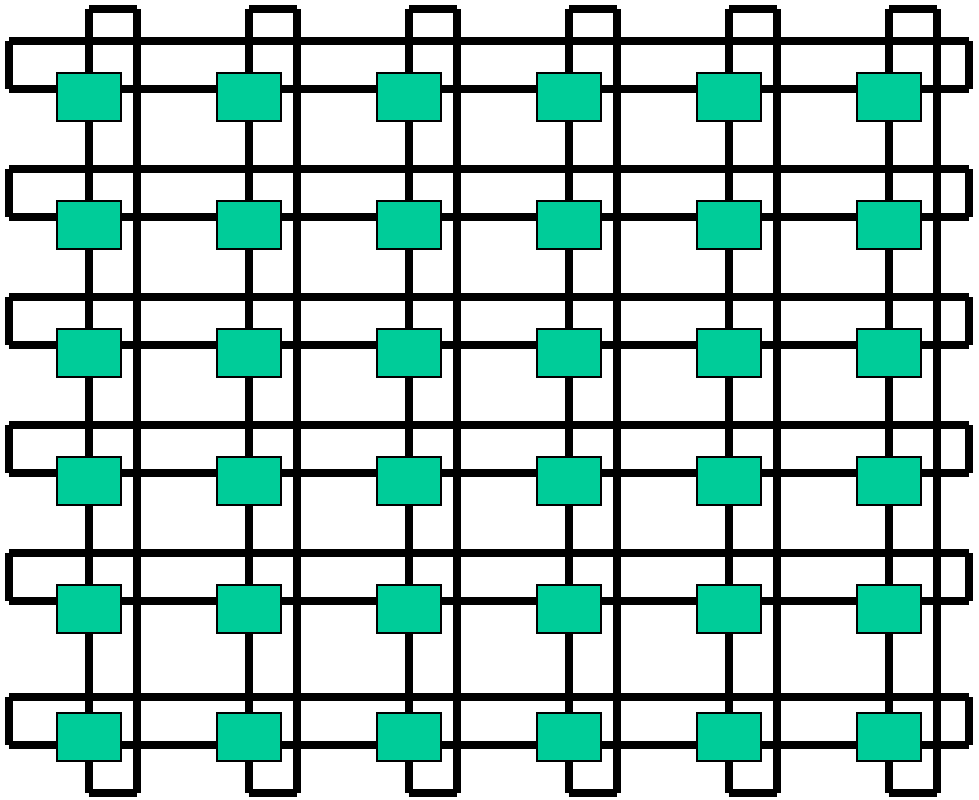
$$C = n \cdot d^{(n-1)}(d-1)$$

$$D = 2n$$



STATIC (direct) TOPOLOGIES

Torus



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TORUS

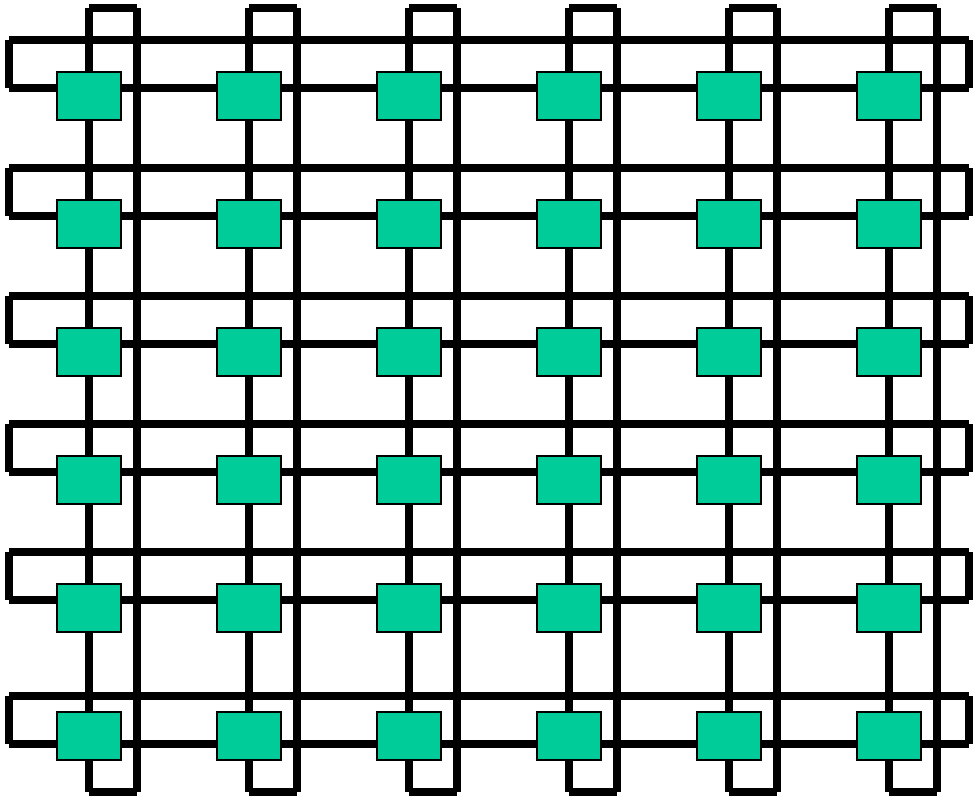
$$N = d^n$$

$$k = n \cdot \text{int}\left(d/2\right)$$

$$Bbw = 2d^{n-1}$$

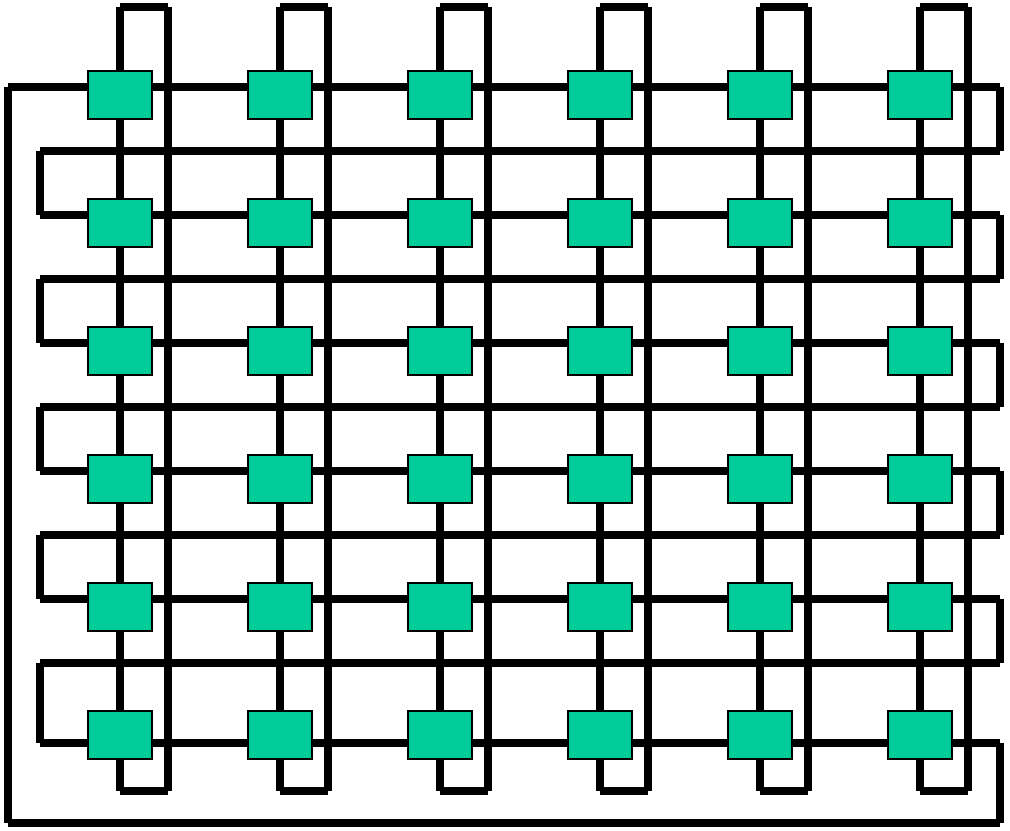
$$C = nd^n$$

$$D = 2n$$



STATIC (direct) TOPOLOGIES

Iliac
Mesh



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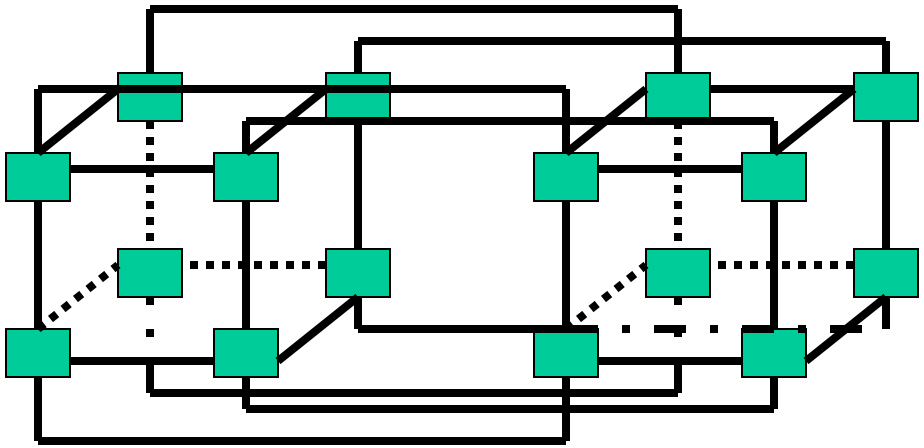
STATIC (direct) TOPOLOGIES

Hiper-cube



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Hiper-cube

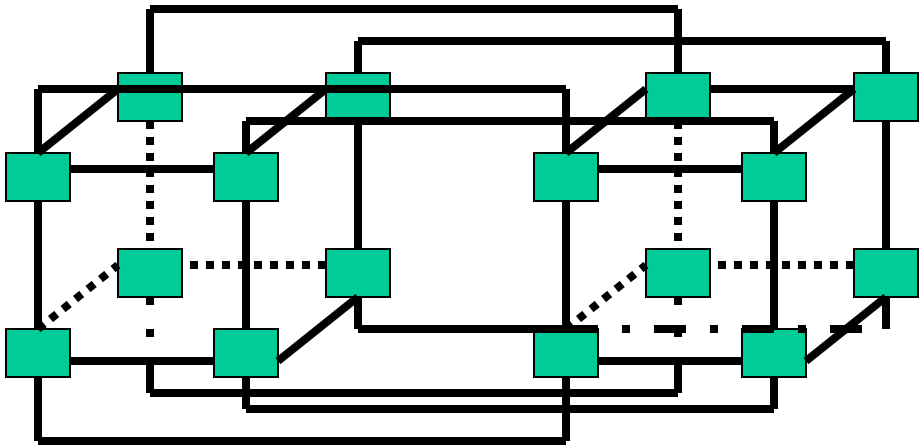
$N = 2^n$

$D = n$

$k = n$

$Bbw = 2^{n-1}$

$C = n \cdot 2^{n-1}$



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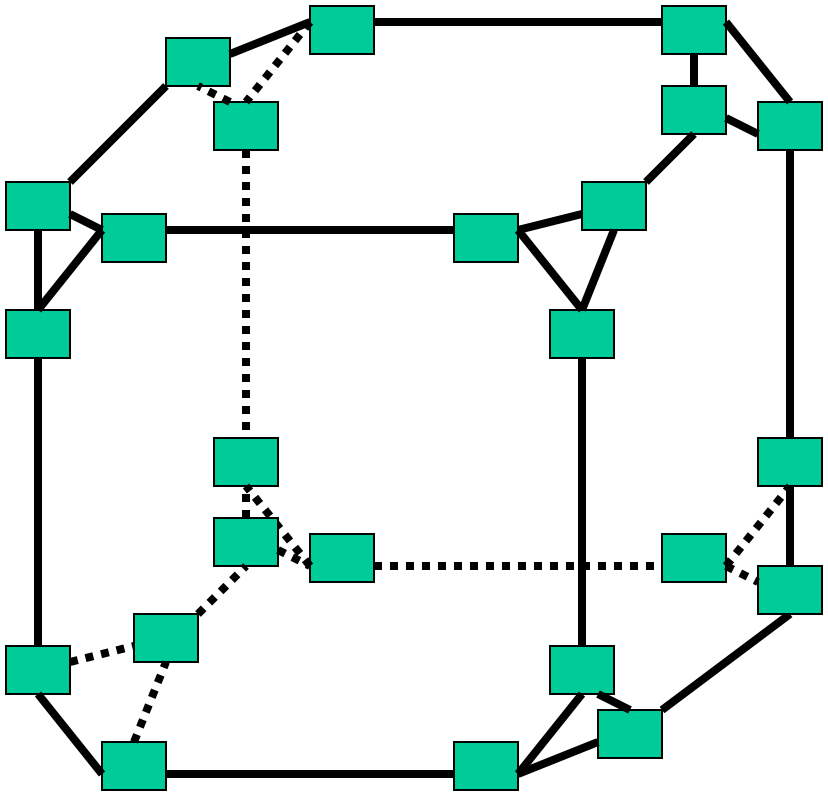
STATIC (direct) TOPOLOGIES

CCC



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Cicle connected cubes

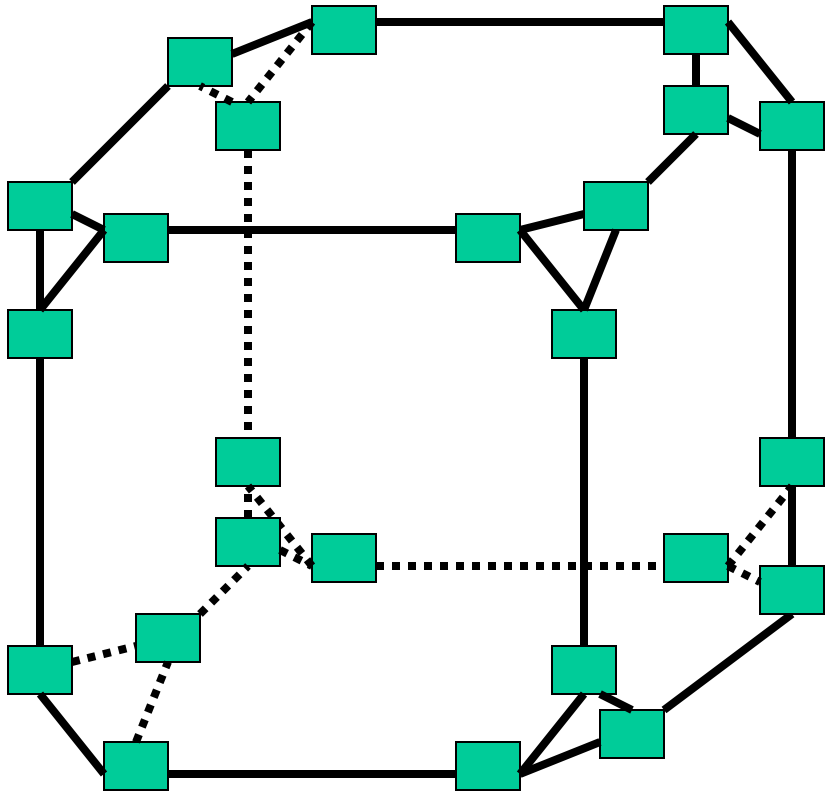
$$N = n \cdot 2^n$$

$$k = 2n$$

$$D = 3$$

$$Bbw = 2^{n-1}$$

$$C = 3n \cdot 2^{n-1}$$



DYNAMIC (indirect) TOPOLOGIES

- Blocking/non blocking: once a certain connection decision is made, some communicating pairs are not possible in blocking networks.
- Single stage/multistage: according to the number of switches packets need to cross to get to their destination.

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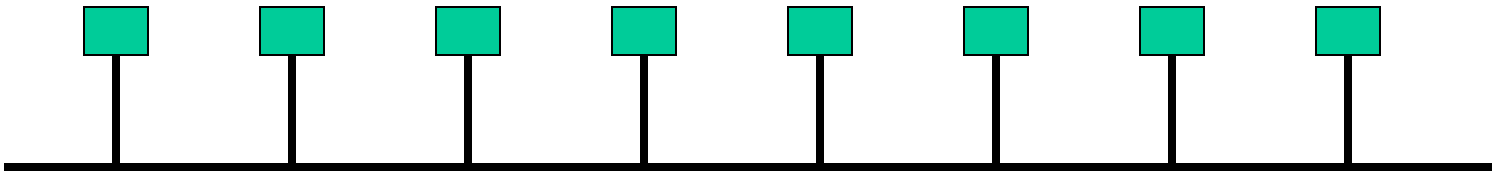
DYNAMIC (indirect) TOPOLOGIES

Bus



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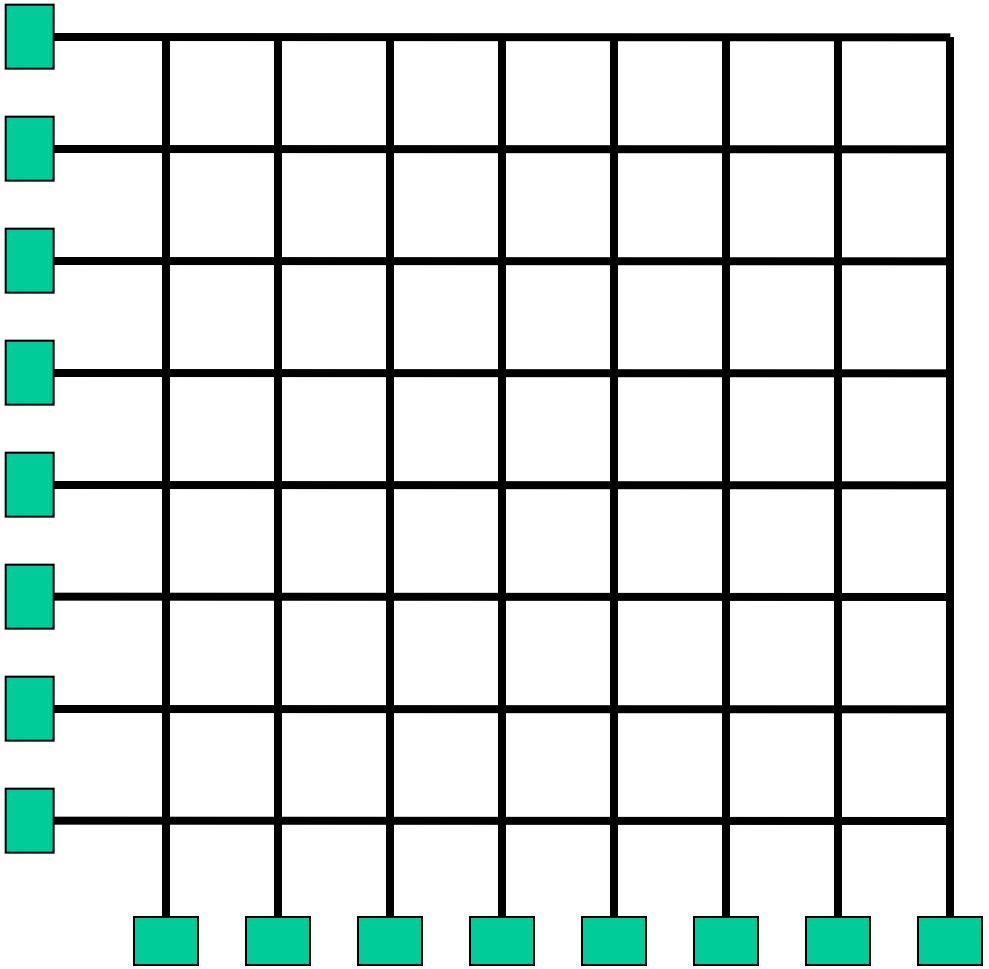
DYNAMIC (indirect) TOPOLOGIES

Crossbar



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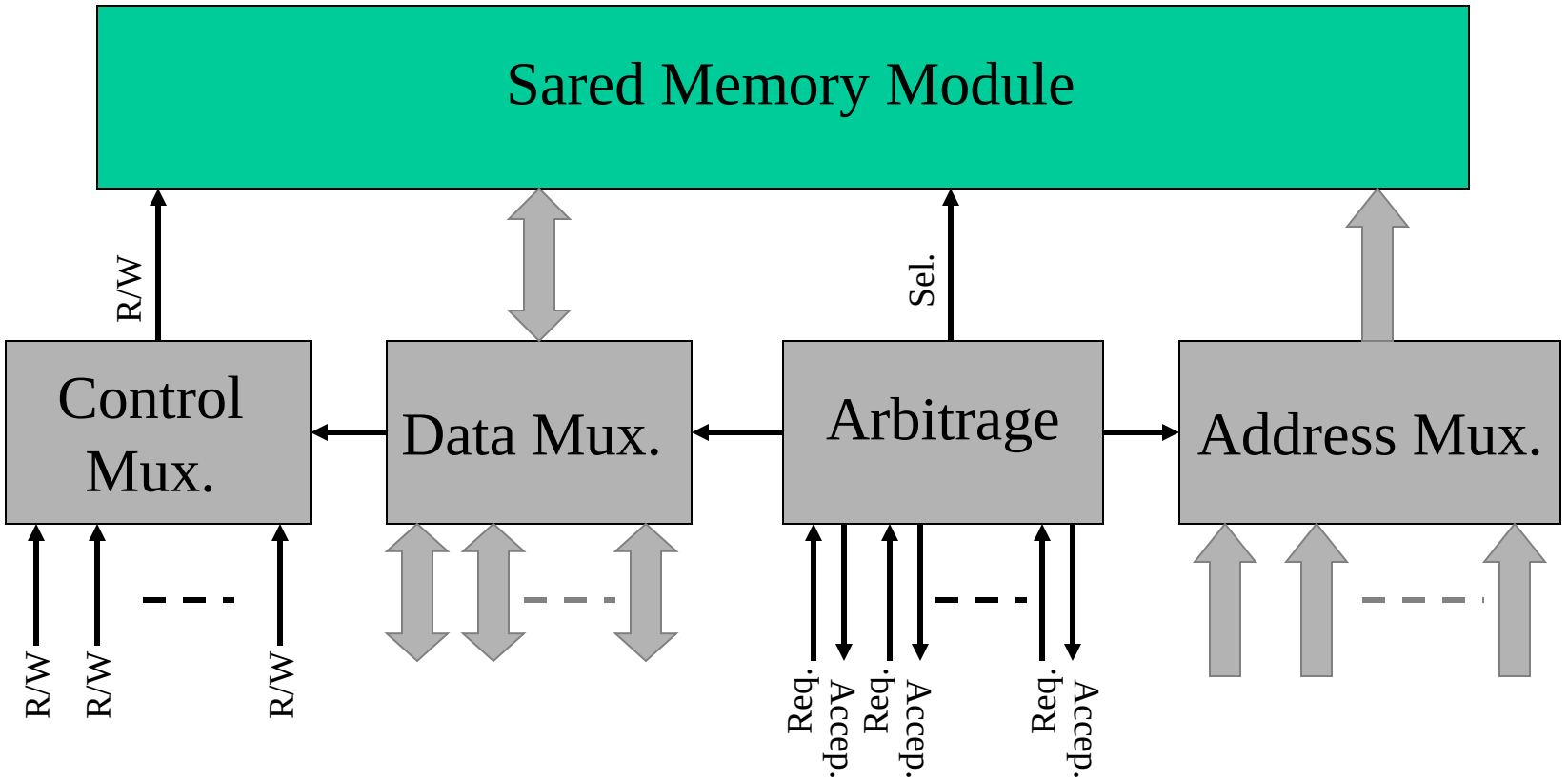
CROSSBAR: SWITCH POINT



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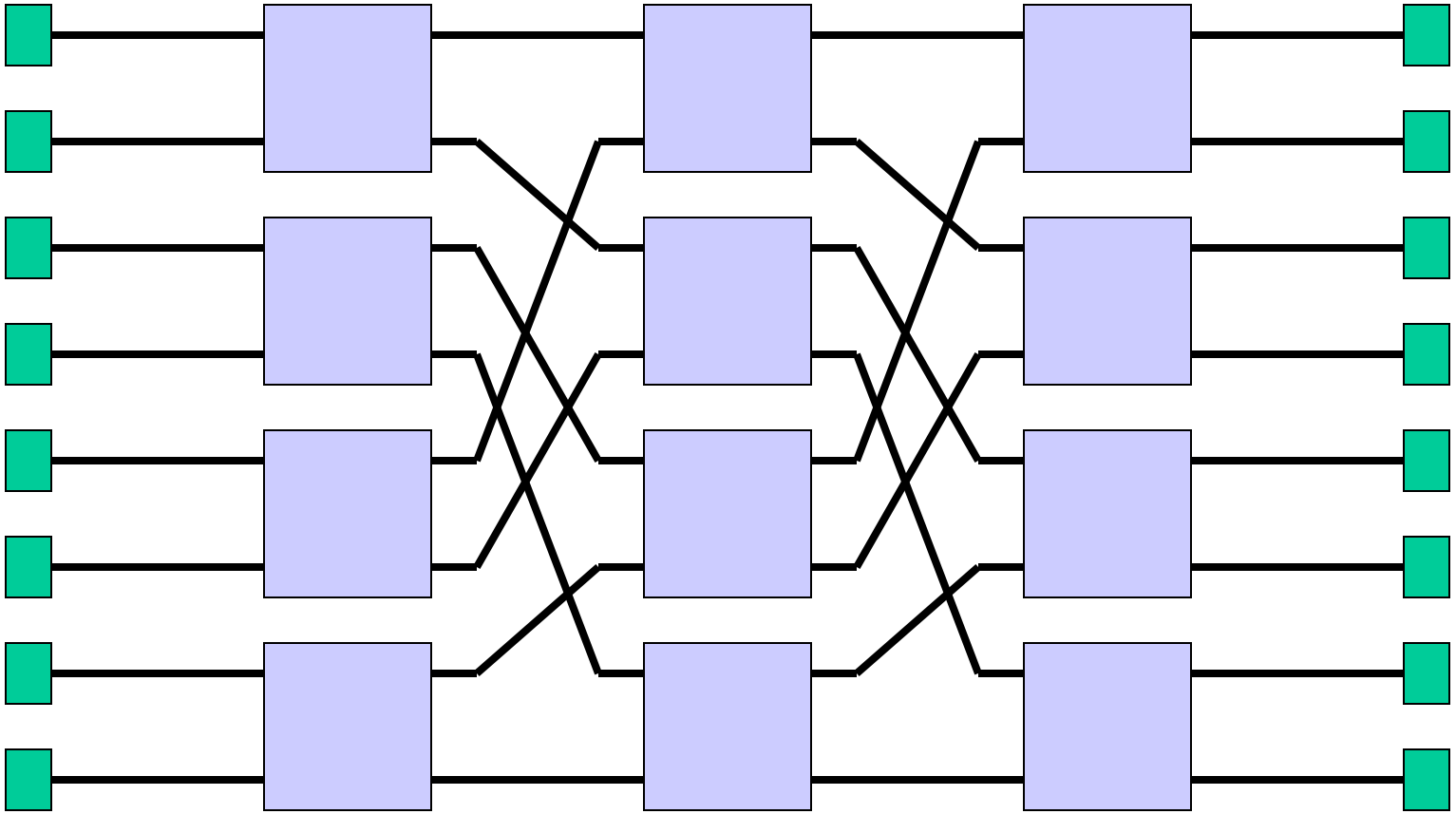
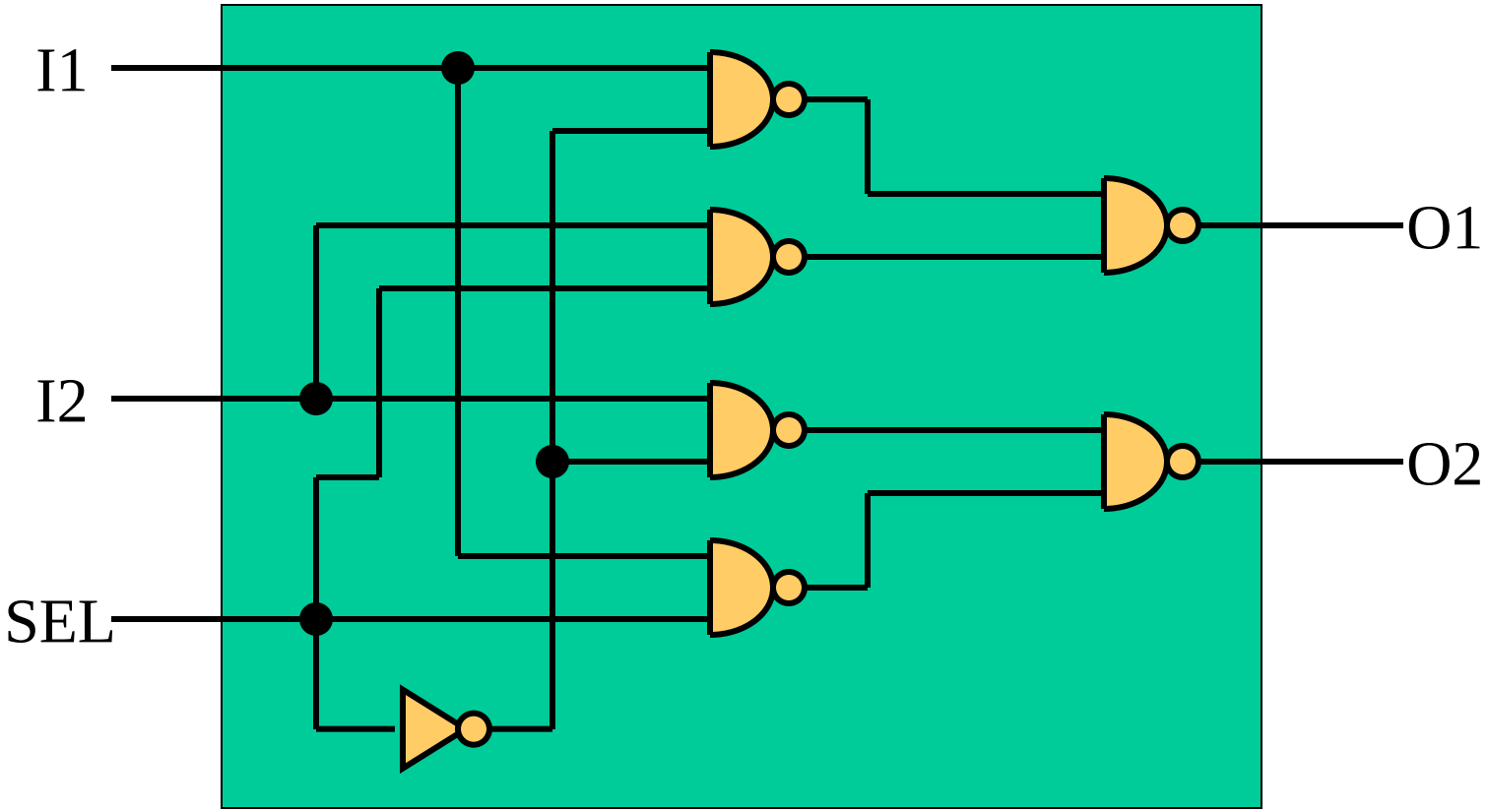
DYNAMIC (indirect) TOPOLOGIES

Omega Network



OMEGA NETWORK: SWITCH



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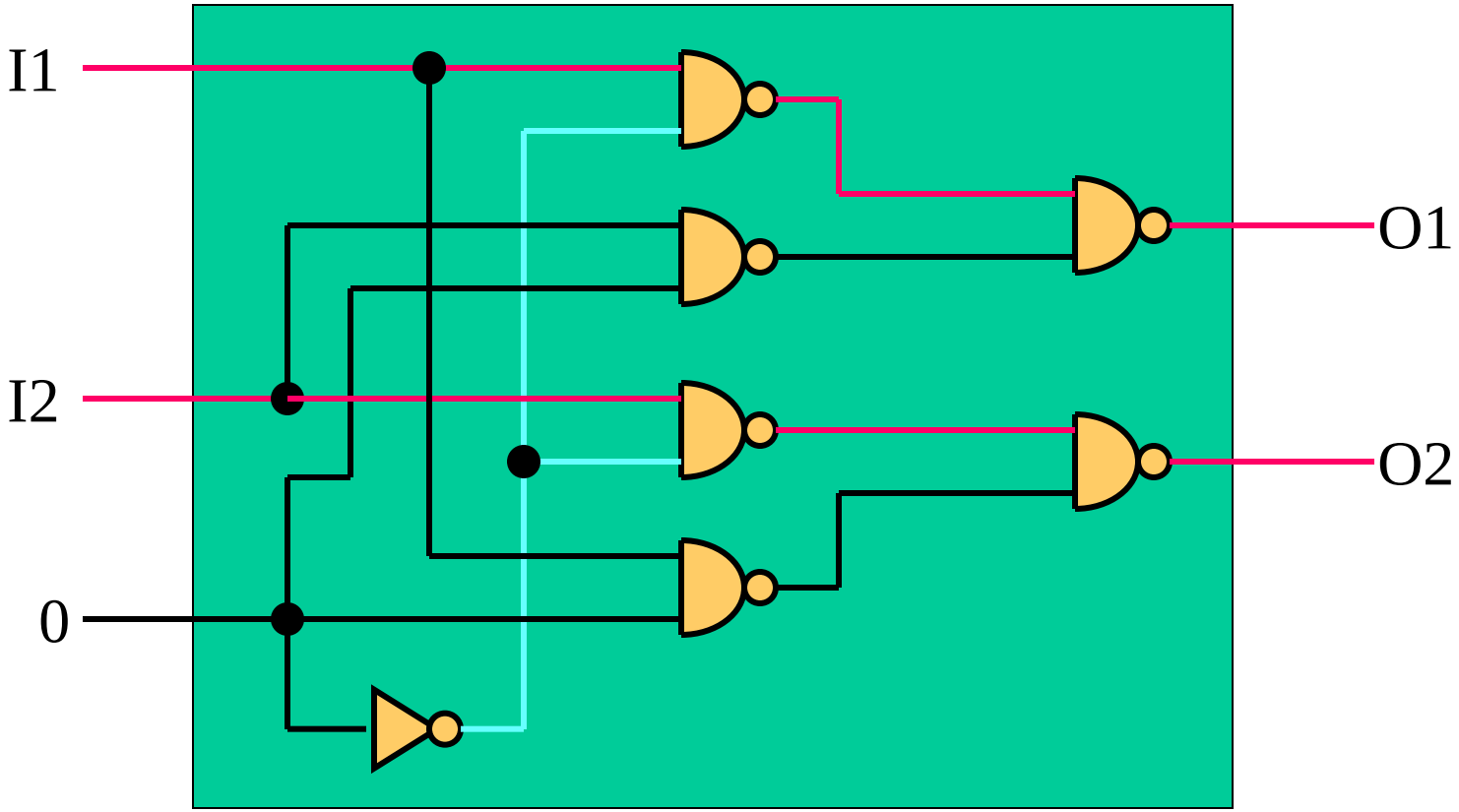
OMEGA NETWORK: SWITCH



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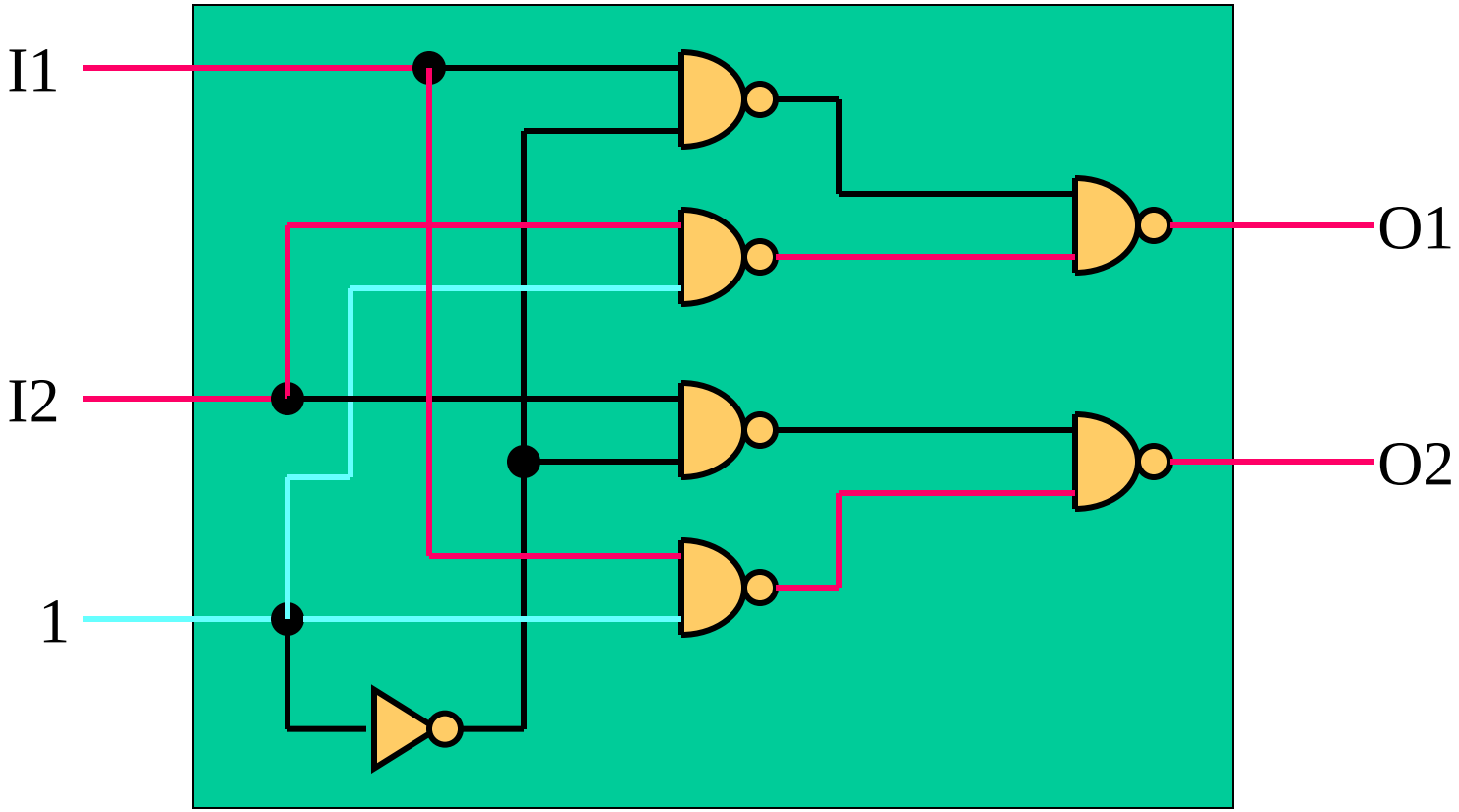
OMEGA NETWORK: SWITCH



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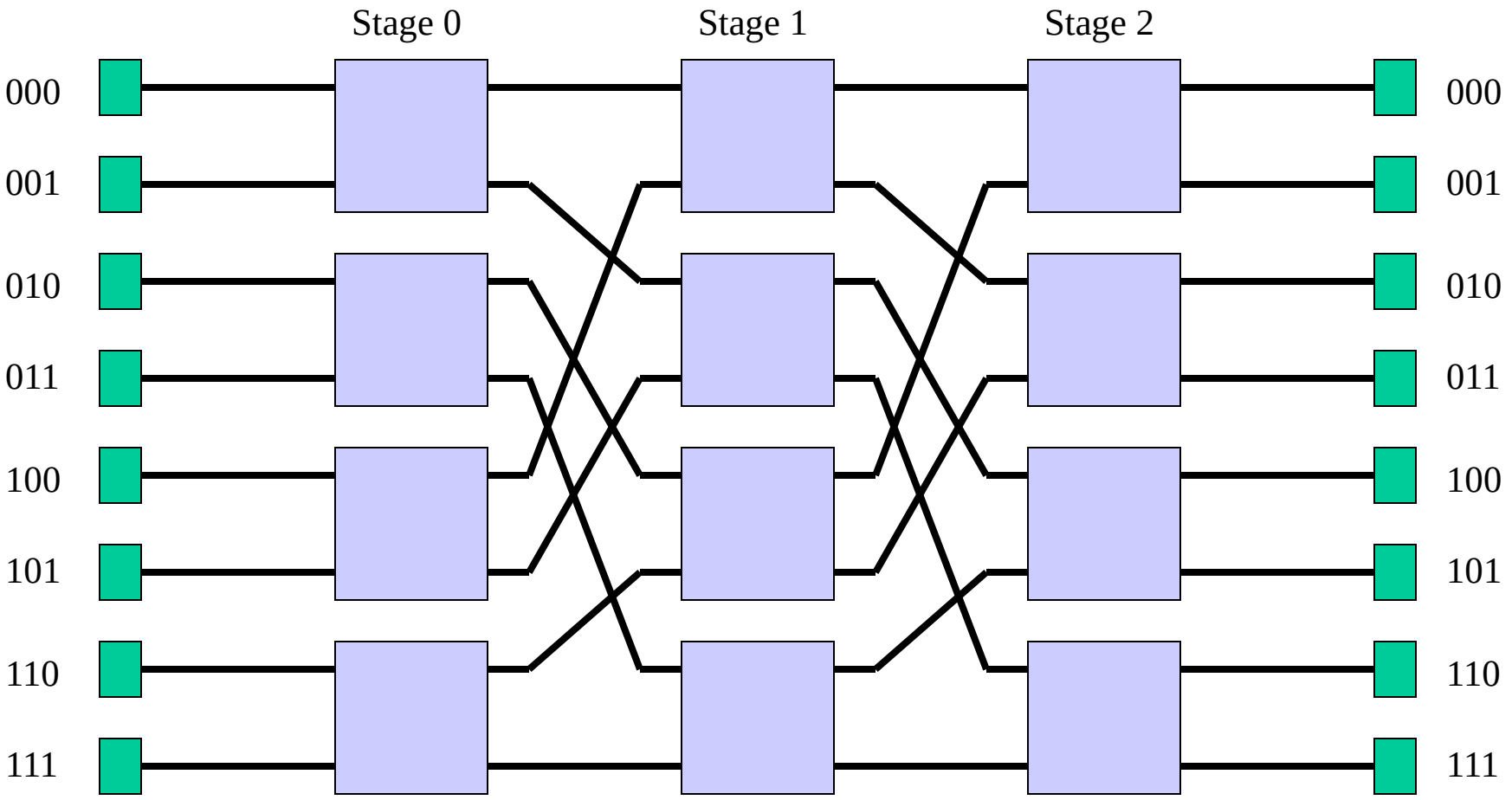
OMEGA NETWORK: ROUTING



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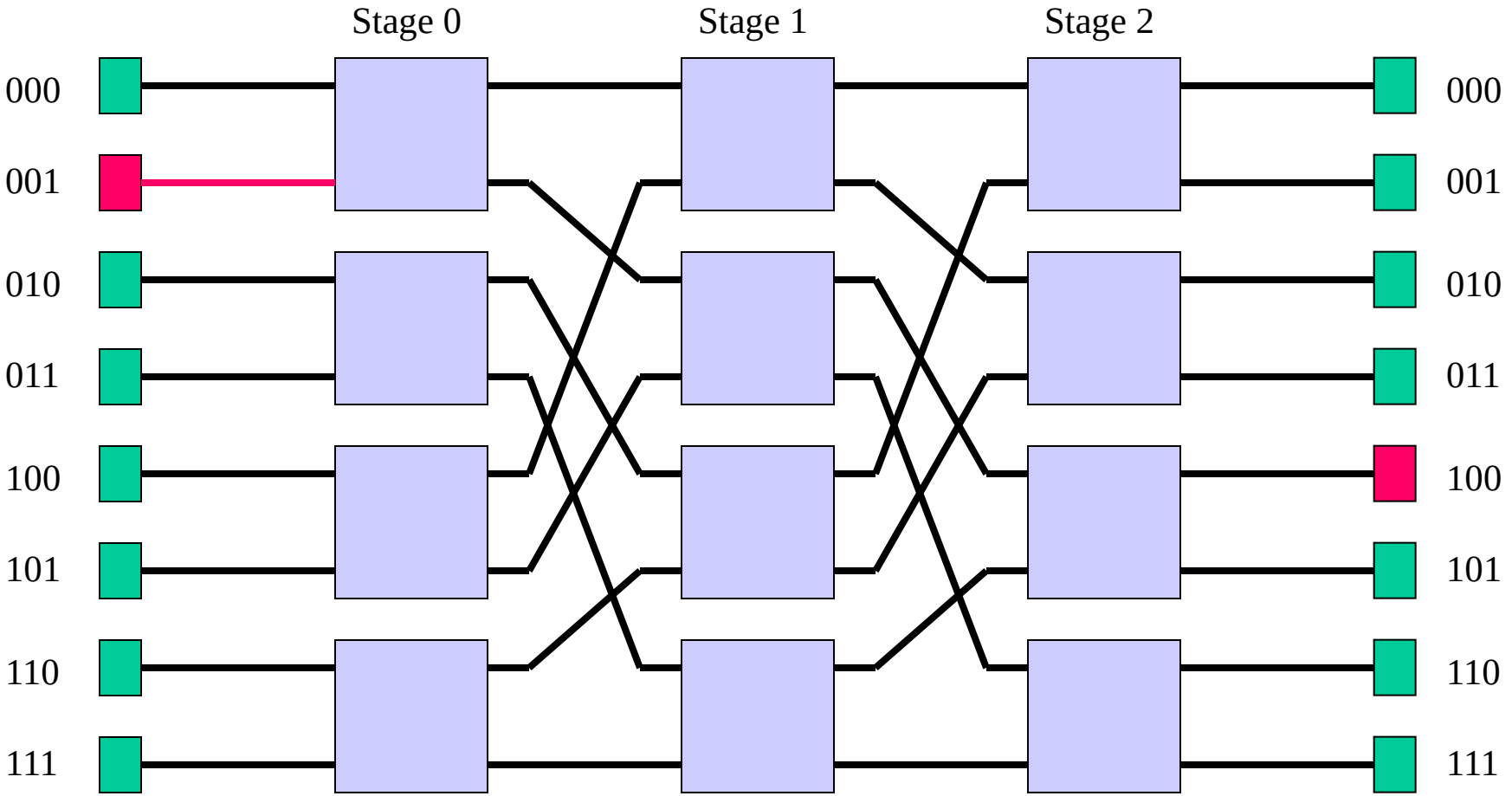
OMEGA NETWORK: ROUTING



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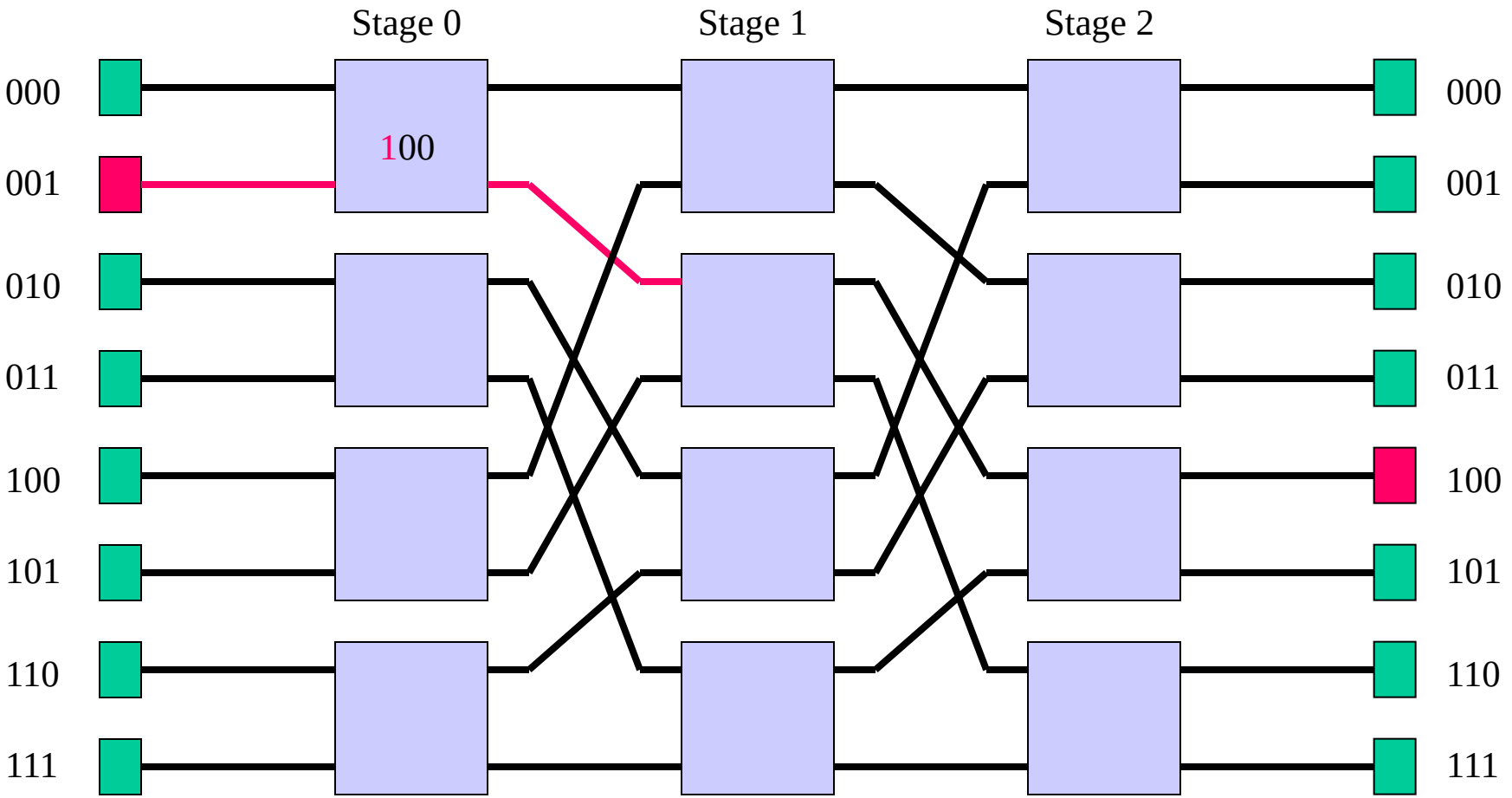
OMEGA NETWORK: ROUTING



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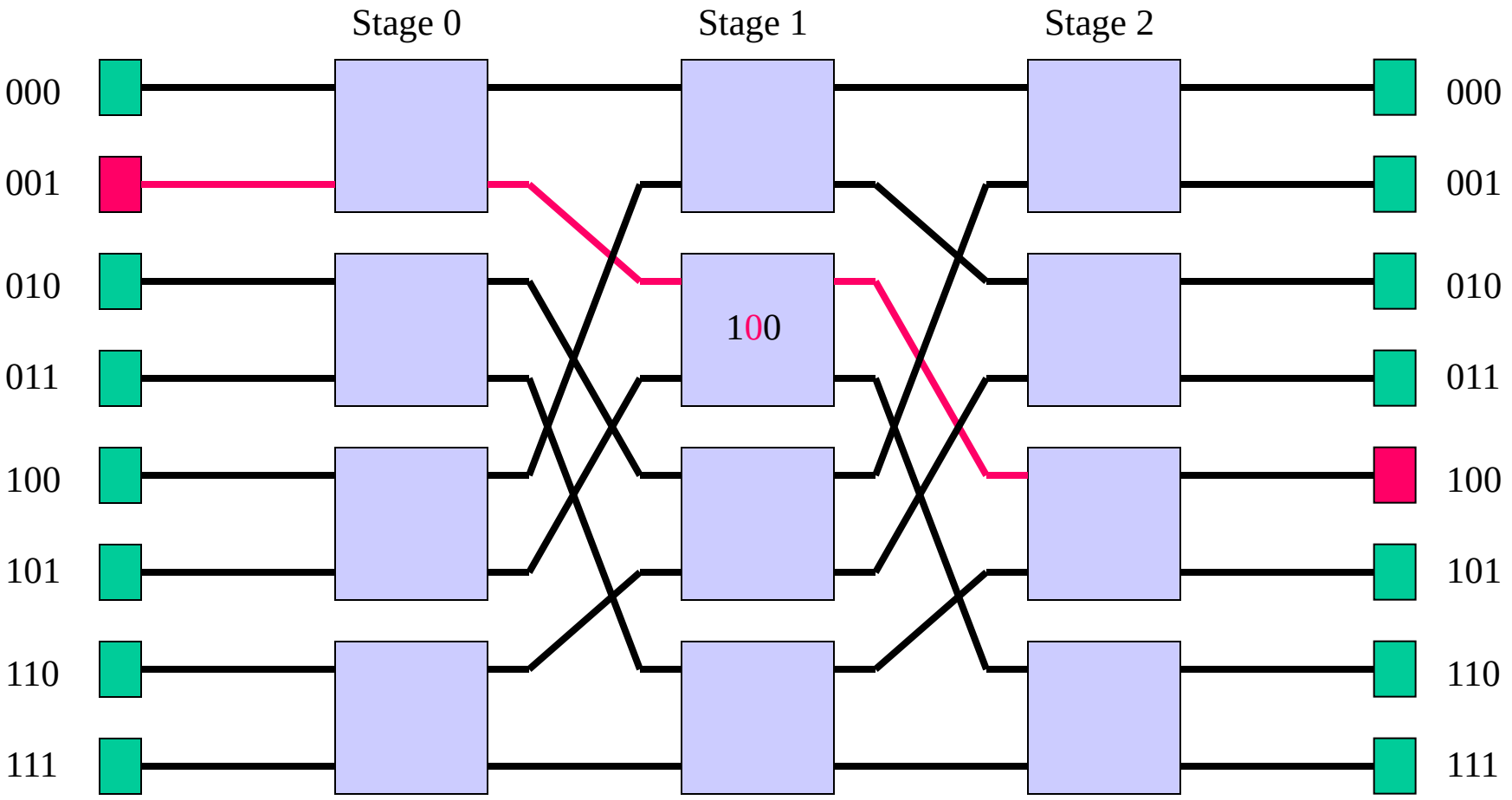
OMEGA NETWORK: ROUTING



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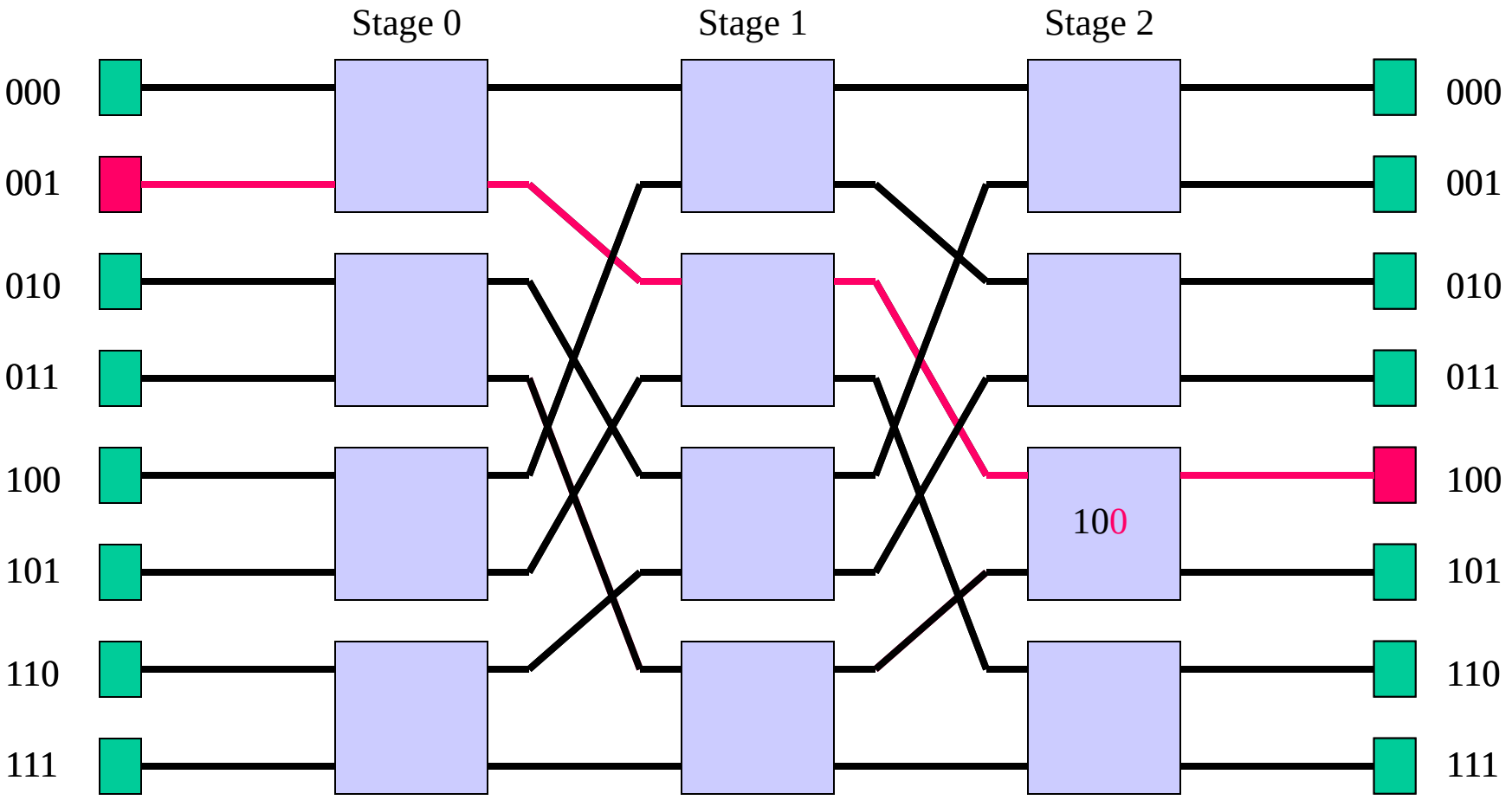
OMEGA NETWORK: ROUTING



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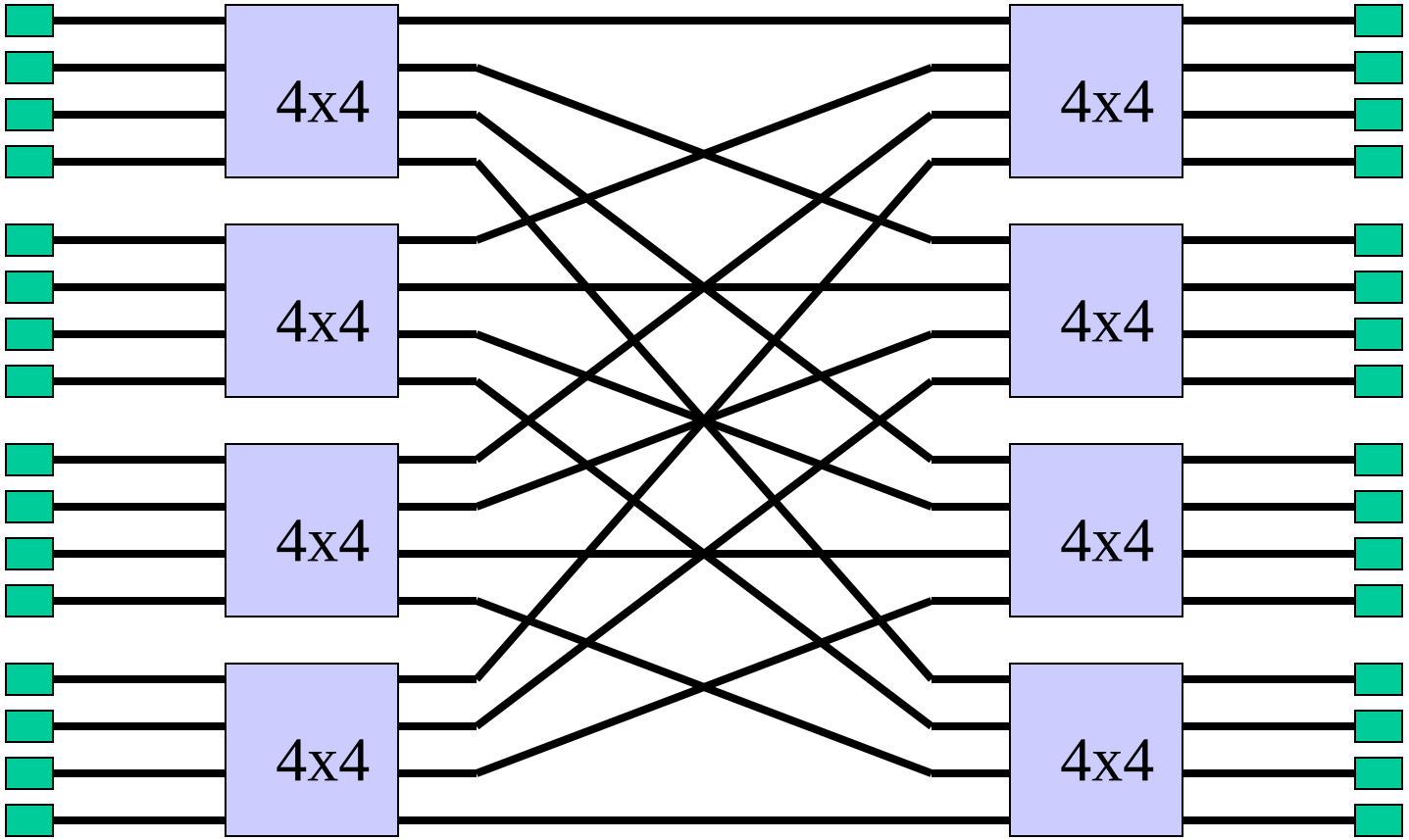
DYNAMIC (indirect) TOPOLOGIES

Butterfly



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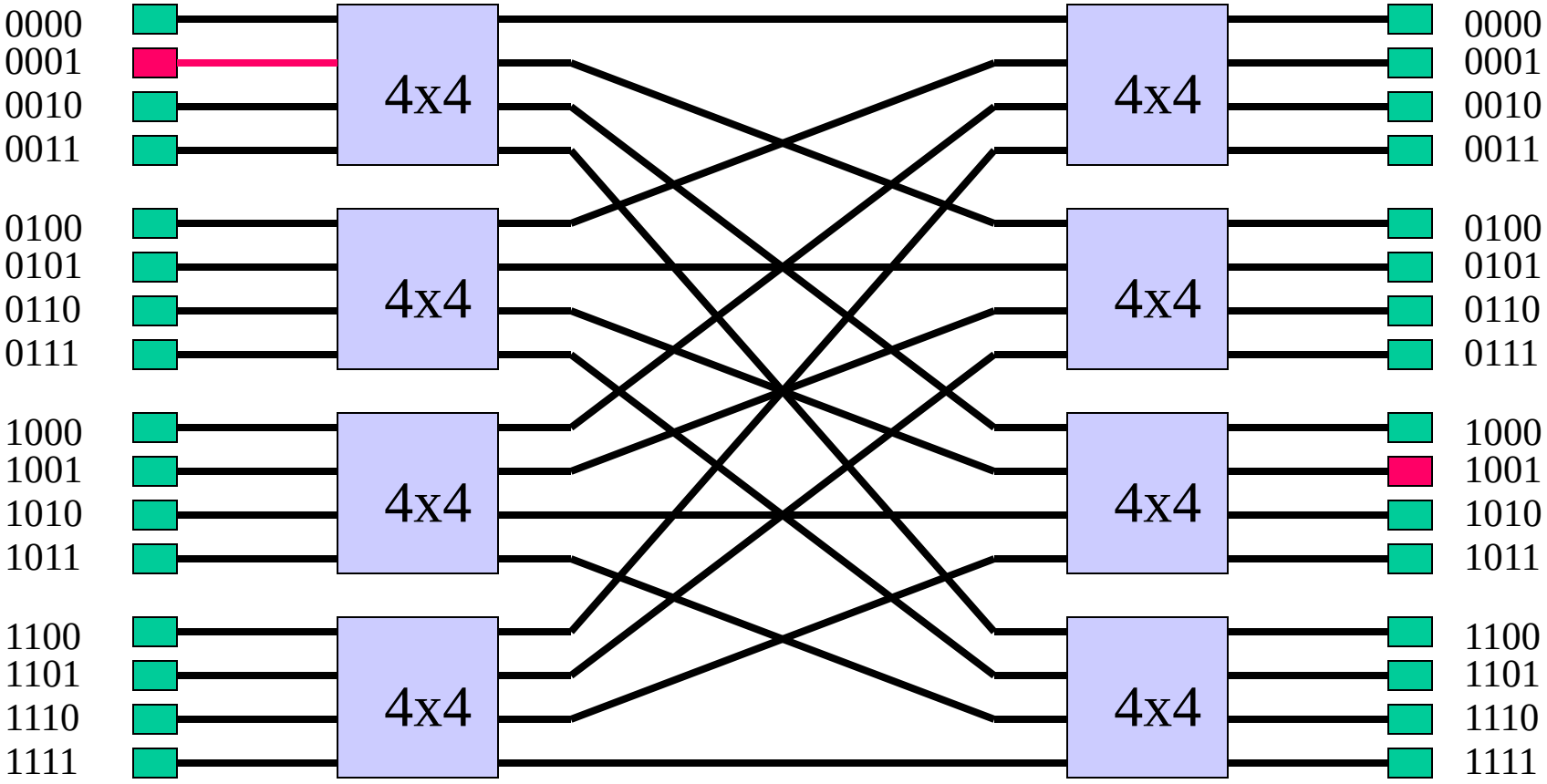
BUTTERFLY: ROUTING



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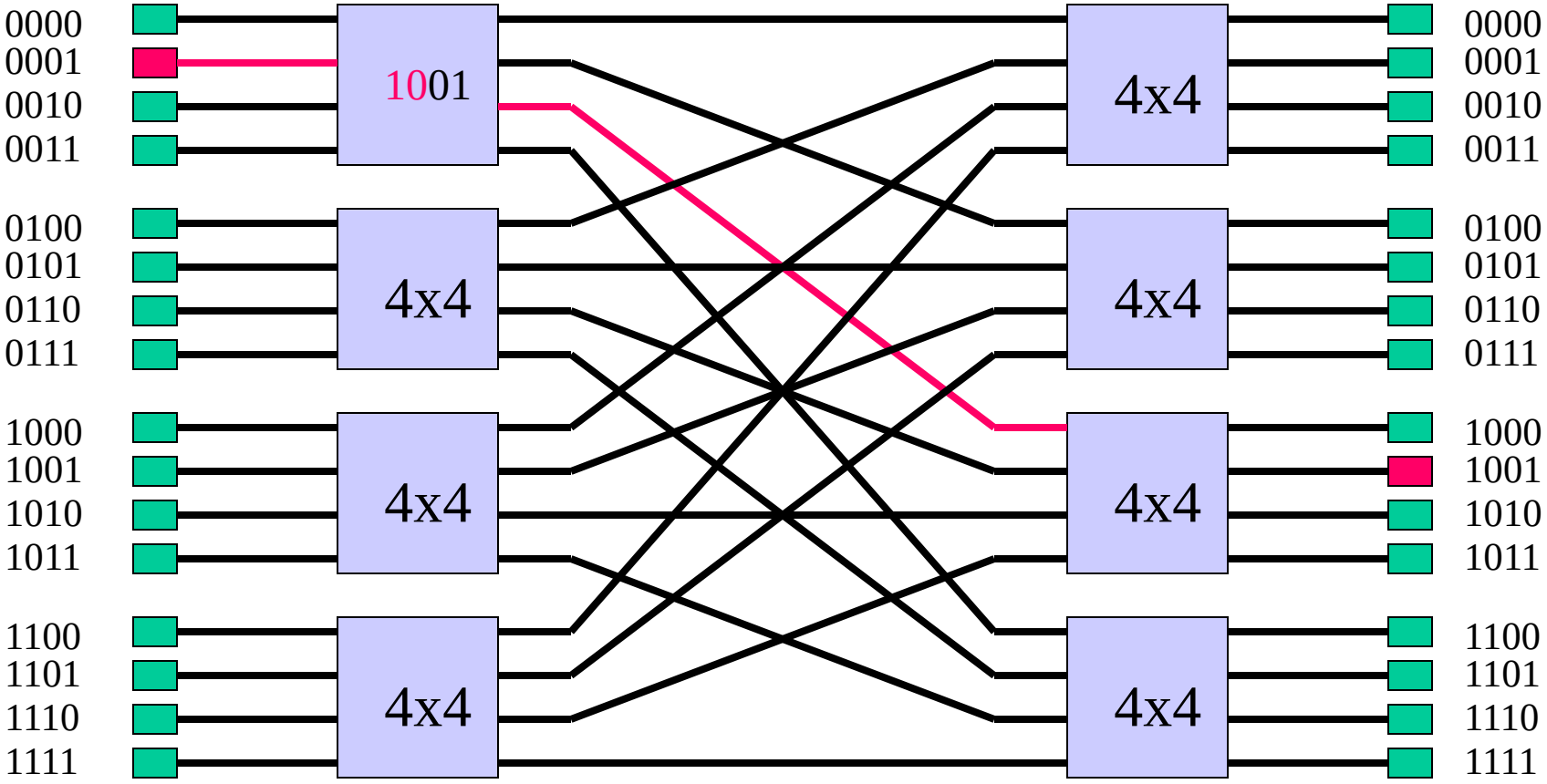
BUTTERFLY: ROUTING



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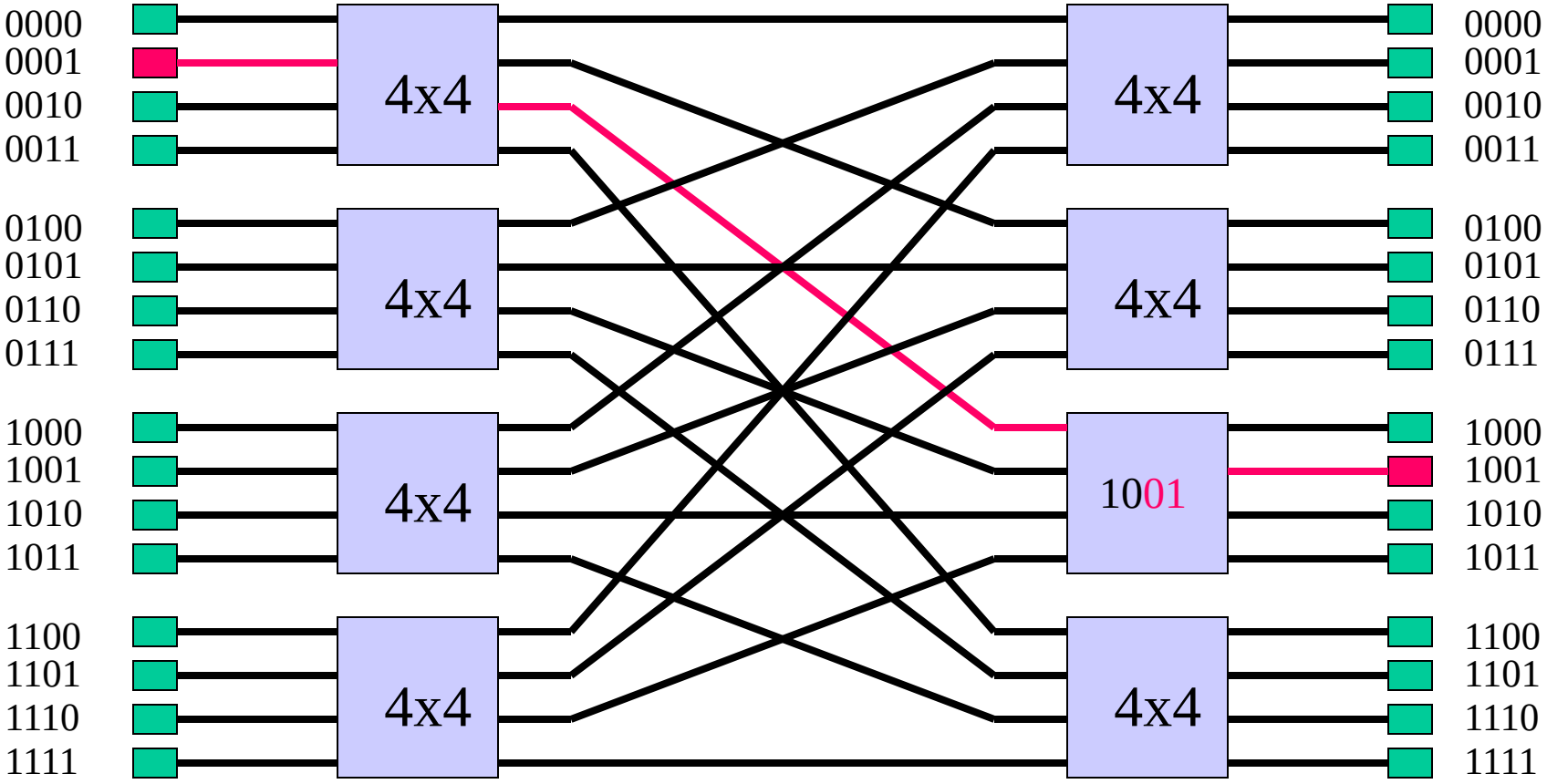
BUTTERFLY: ROUTING



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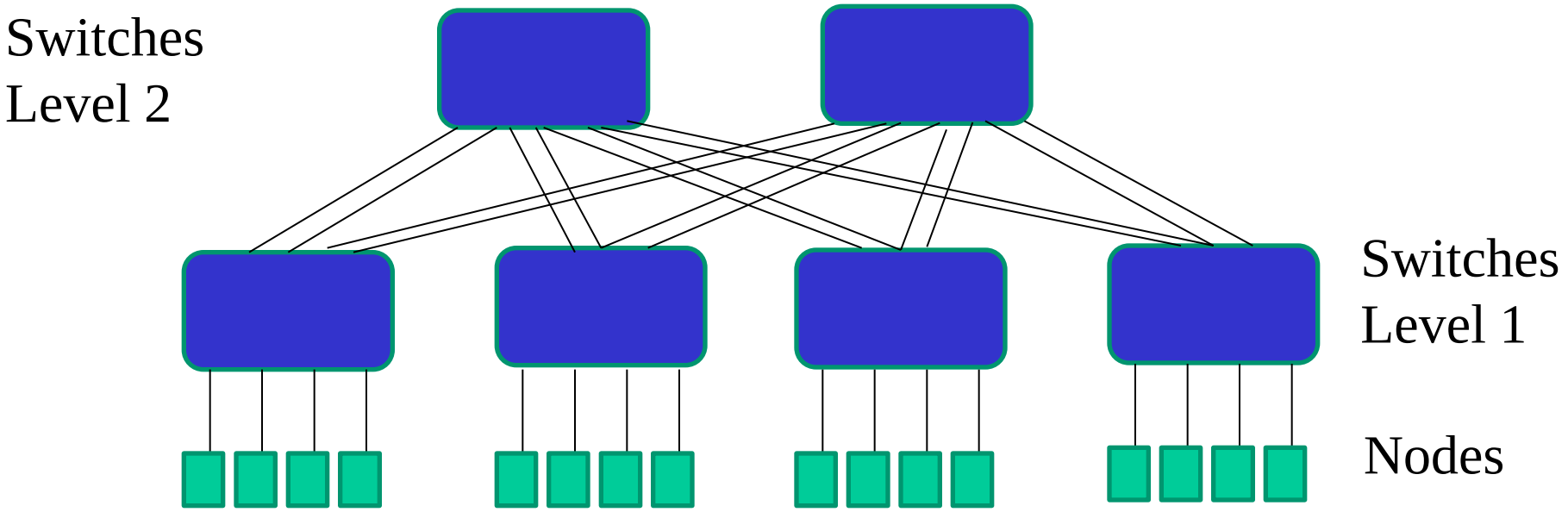
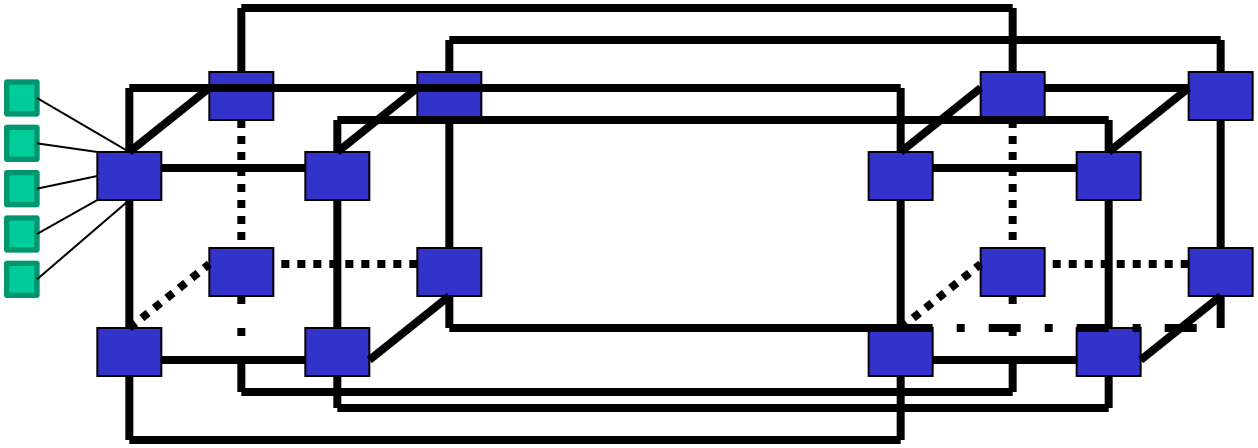
Switched fat tree



Switched hypercube



Modern routers

- Main structures:
  - Buffering queues:
    - Inyection: to allow the local node to put packets into the network.
    - Transit: store packets travellin across the local node.
    - Consumption: deliver packets to the local node.
  - Interconnect (asymetric crossbar).
  - Arbiter: makes routing and conflict resolution decissions.

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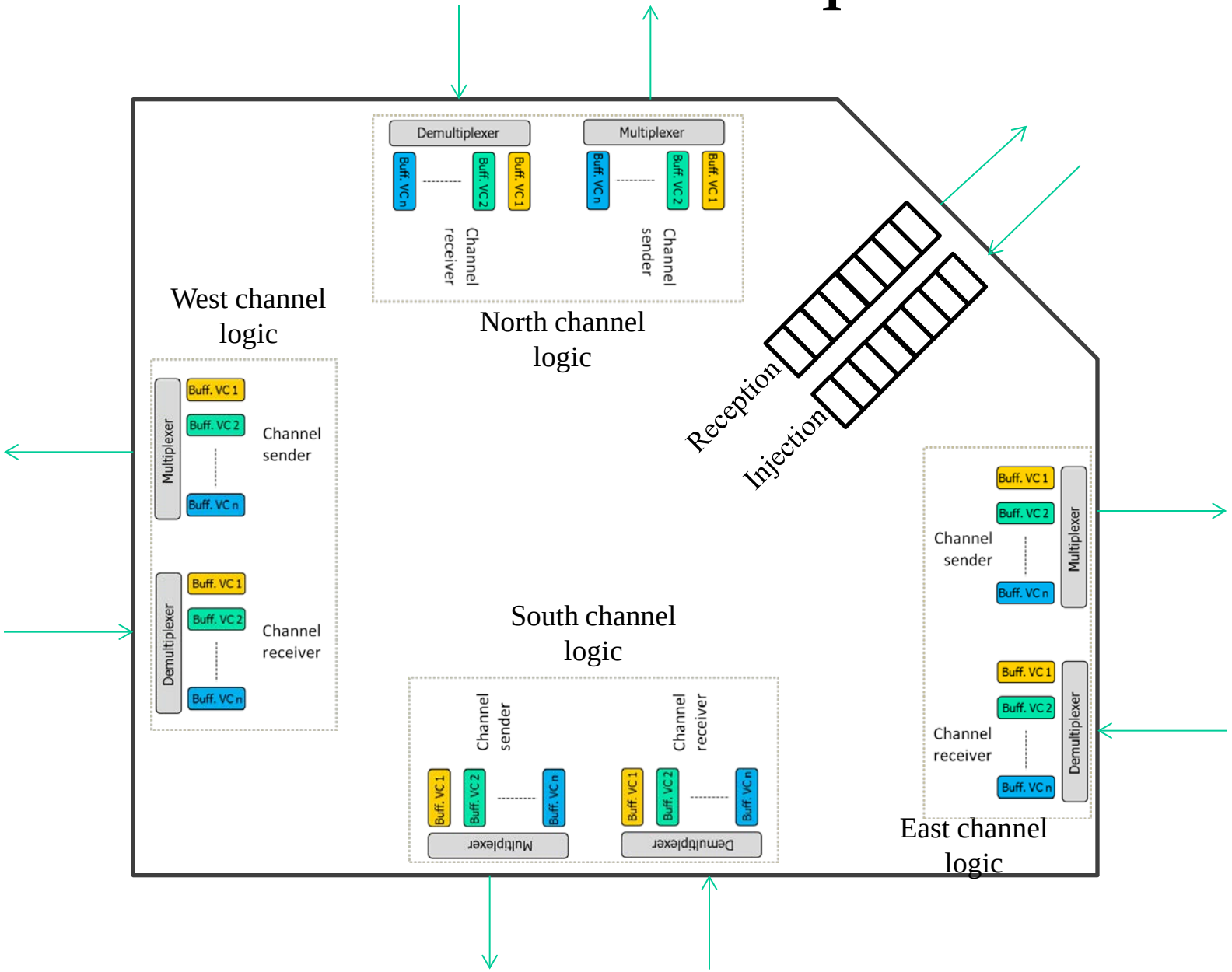
Modern routers - queues



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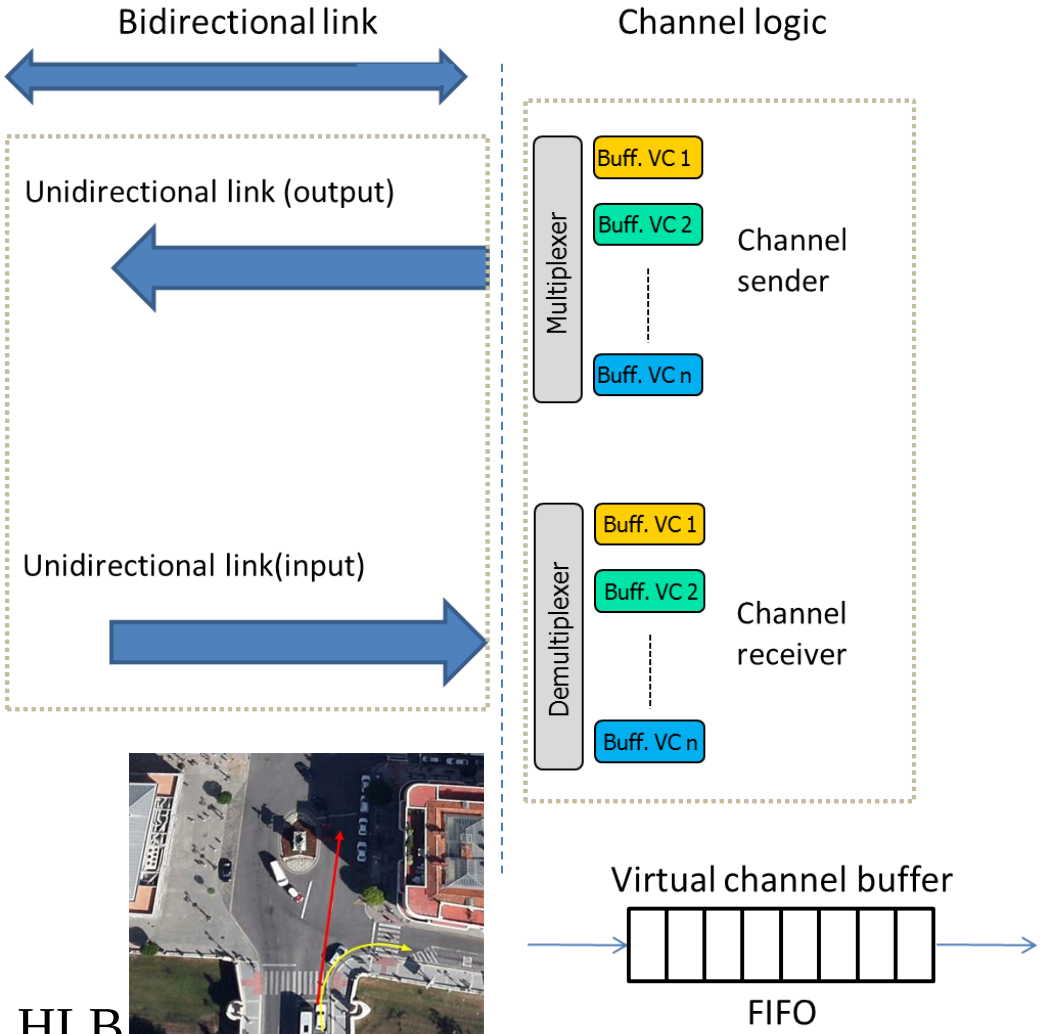
Modern routers - queues

Their structure depends on the flow control mechanism:

- Store & forward: packets.
- Wormhole: flits.
- Virtual cut through: packets.

Typically FIFO -> Head of Line Blocking (HLB). If the first packet on the queue is not delivered the following are stalled.

There are as many transit queues per link as virtual channels.



HLB

The red car can't turn right because the white one is stopped.
The white car can't move straight because the light is red.

Google Earth

Modern routers - arbitrage

- Selection: the arbiter has to assign an output port to an input packet among those who comply with the routing algorithm. For deterministic routing algorithms no selection policy is applicable.
- Arbitrage: when several input packets request the same output port, the arbiter has to select one of them.
- Goal: maximize efficiency avoiding fatal circumstances; typically starvation.

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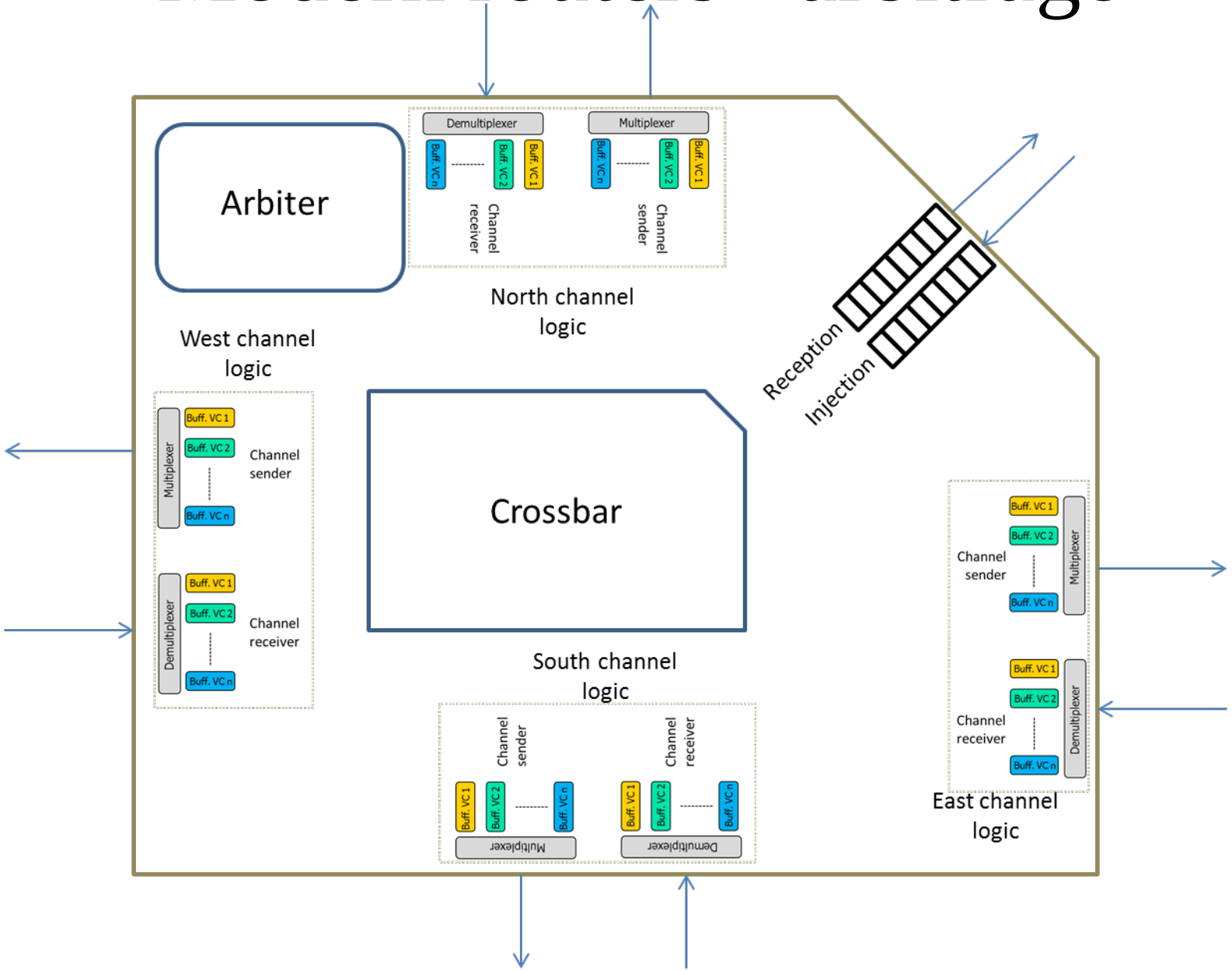
Modern routers - arbitrage



Modern routers – arbitrage – selection policies

- Random: output port is assigned randomly.
- Shortest queue: output port heading to the shortest input queue at the next node is chosen.
- Smart: it involves a series of attempts. It makes sense only for adaptive routing algorithms. The first option is to continue on the same channel. If not available, another direction is tried.

Modern routers – arbitrage – arbitration policies

- Random: the winning input queue is selected randomly.
- Round robin: assignment is alternatively granted to all competitors.
- Oldest: the oldest awaiting queue is selected.
- Longest queue: priority is given to the longest input queue.

References

- W. J. Dally & B. Towles. Principles and Practices of Interconnection Networks. Morgan Kaufmann, 2004.
- José Miguel Alonso. Redes de interconexión para sistemas masivamente paralelos. Informe de investigación EHU-KAT-IK-05-04.