



# Advanced Computer Architecture

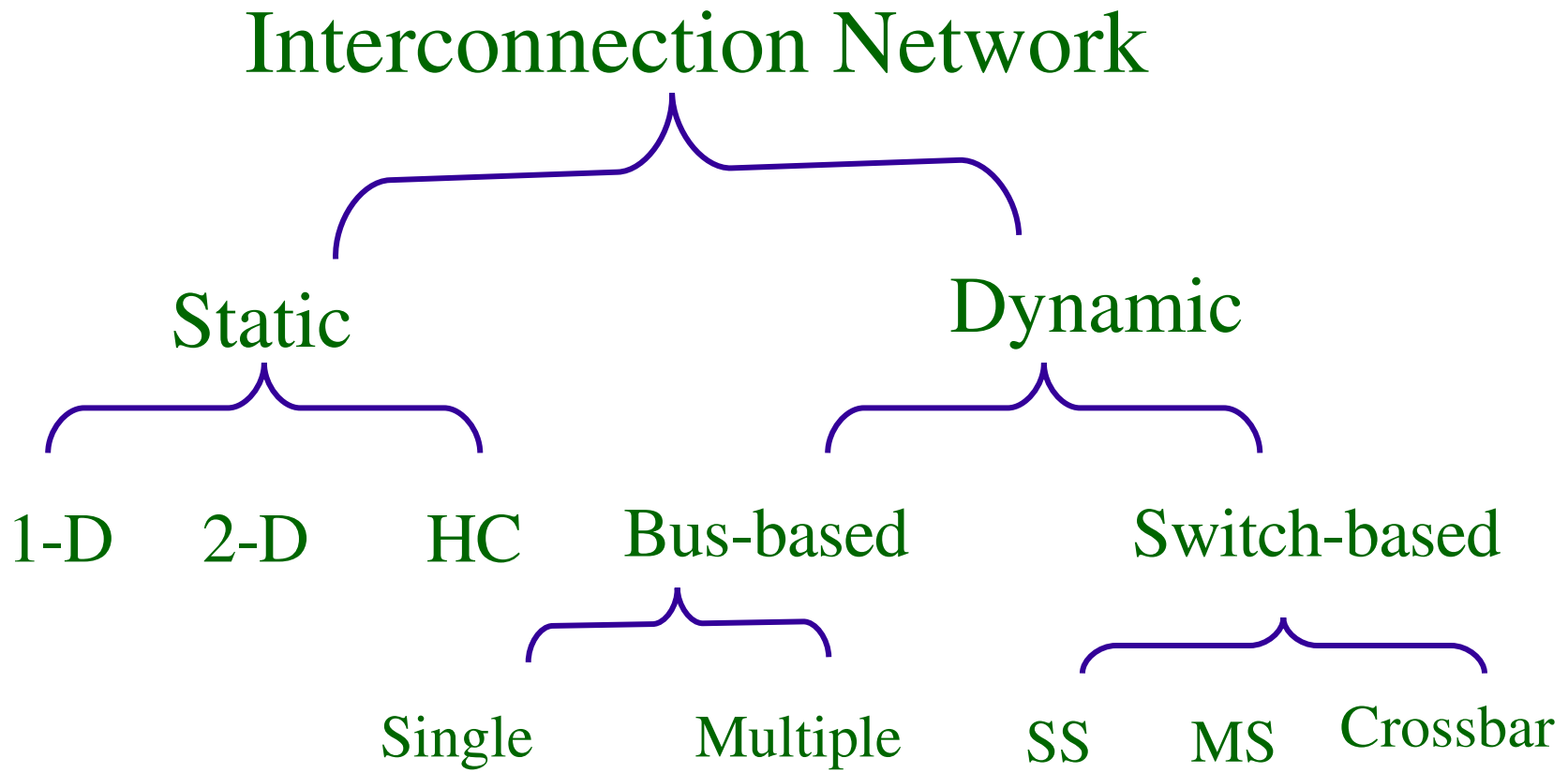


# Interconnection Network

- Mode of Operation (Synchronous vs. Asynchronous)
- Control Strategy (Centralized vs. Decentralized)
- Switching Techniques (Packet switching vs. Circuit switching)
- Topology (Static Vs. Dynamic)



# Interconnection Network Taxonomy





# Static IN

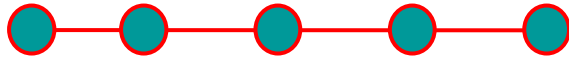


## Static Interconnection Networks

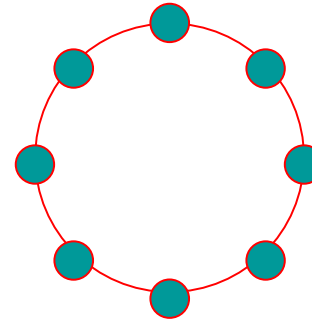
- Static (fixed) interconnection networks are characterized by having fixed paths, unidirectional or bi-directional, between processors.
- Completely connected networks (CCNs): Number of links:  $O(N^2)$ , delay complexity:  $O(1)$ .
- Limited connected network (LCNs)
  - *Linear arrays*
  - *Ring (Loop) networks*
  - *Two-dimensional arrays*
  - *Tree networks*
  - *Cube network*



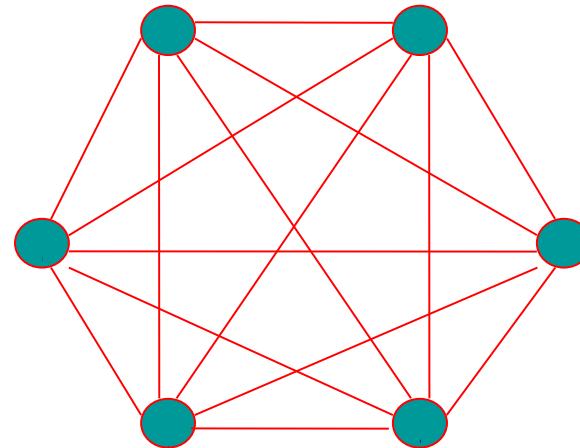
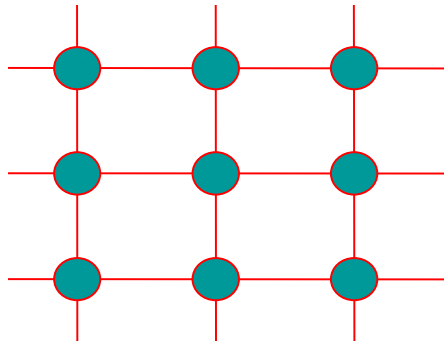
# Examples of Network Topology



Linear Array



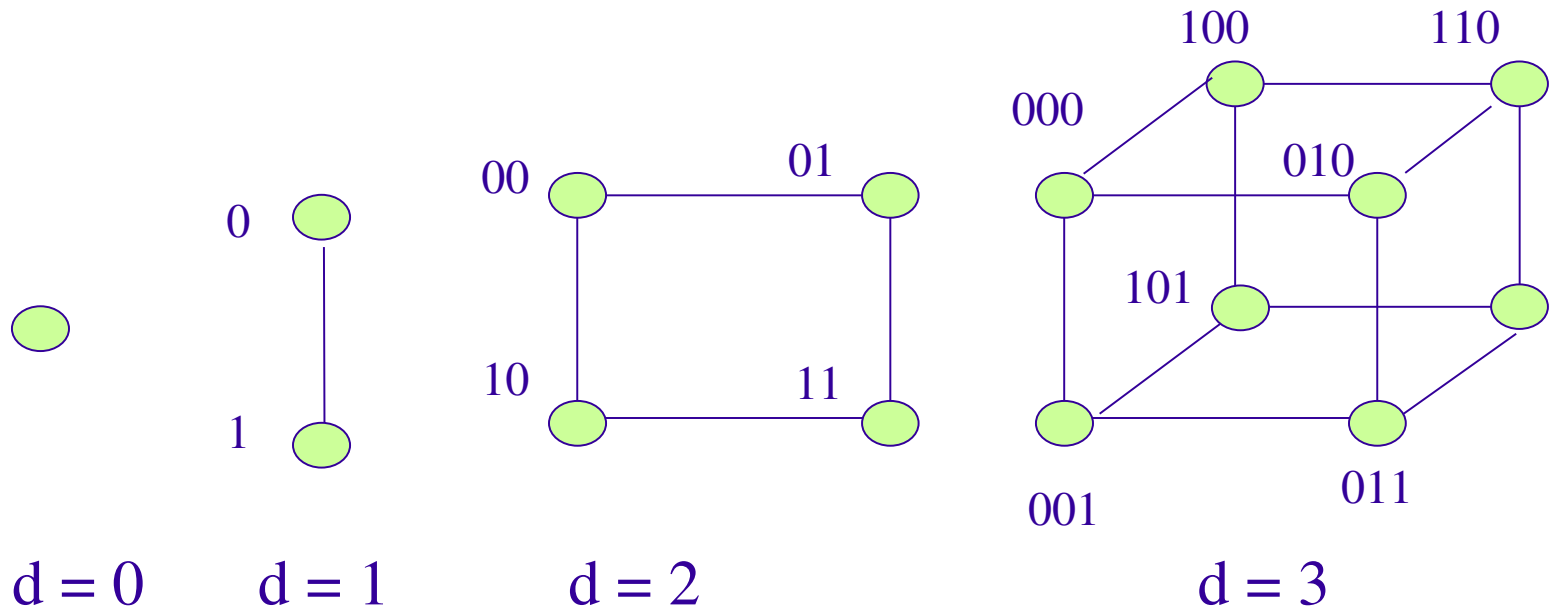
Ring



Complete Graph



# Hypercube





## Hypercube of dimension $d$

$$n = 2^d$$

$$d = \log n$$

**Node degree =  $d$**

**Number of bits to label a node =  $d$**

**Diameter =  $d$**

**Number of edges =  $n*d/2$**

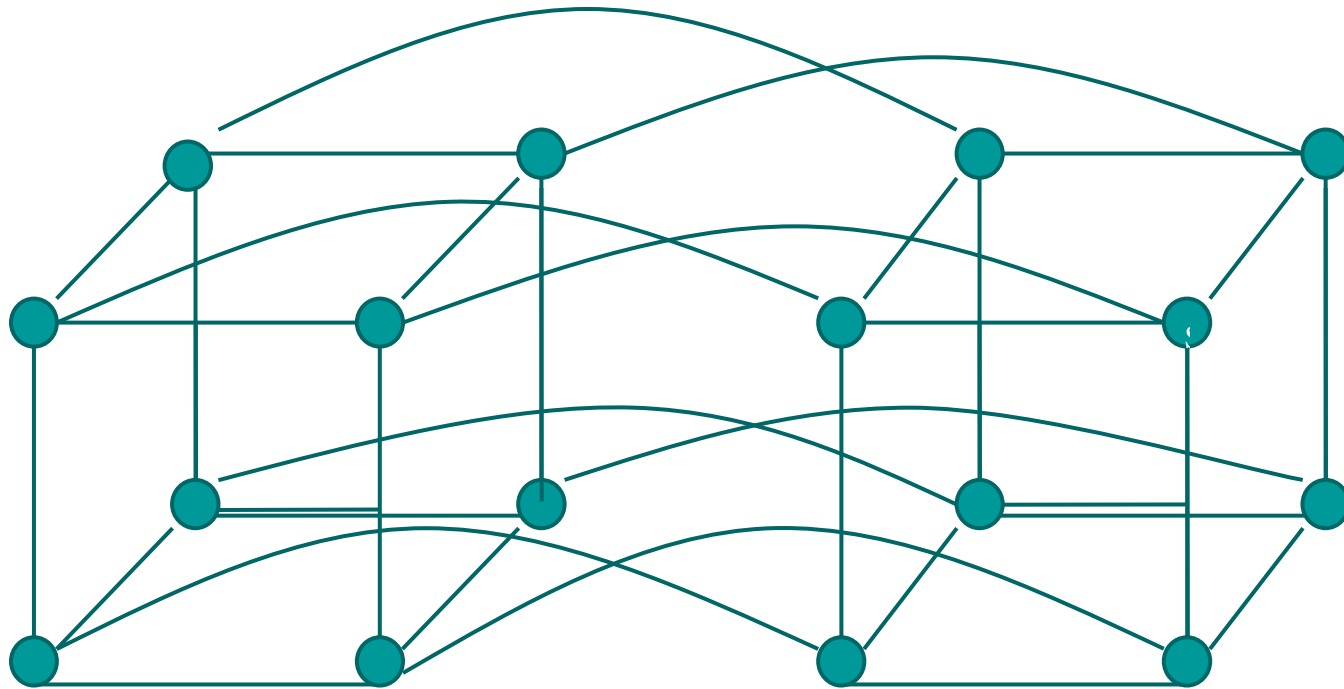
**Hamming distance!**

**Routing**





# Hypercubes



**d = 4**



# Analysis and performance metrics static networks

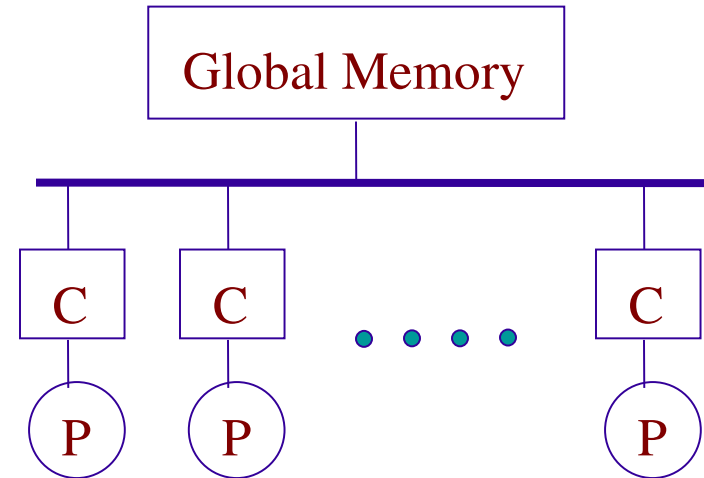
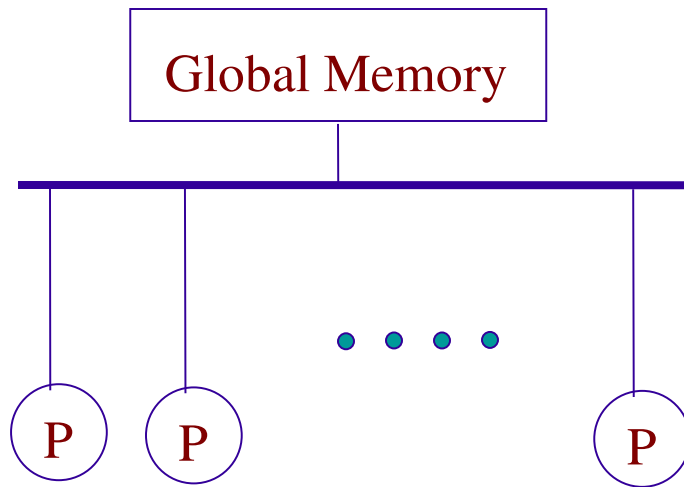
Network	Degree(d)	Diameter(D)	Cost	Symmetry	Worst delay
CCNs	$N-1$	1	$N(N-1)/2$	Yes	1
Linear Array	2	$N-1$	$N-1$	No	$N$
Binary Tree	3	$2(\lceil \log_2 N \rceil - 1)$	$N-1$	No	$\log_2 N$
n-cube	$\log_2 N$	$\log_2 N$	$nN/2$	Yes	$\log_2 N$
2D-Mesh	4	$2(n-1)$	$2(N-n)$	No	$\sqrt{N}$
K-ary n-cube	$2n$	$n \lfloor k/2 \rfloor$	$nN$	Yes	$K \times \log_2 N$



# Dynamic IN



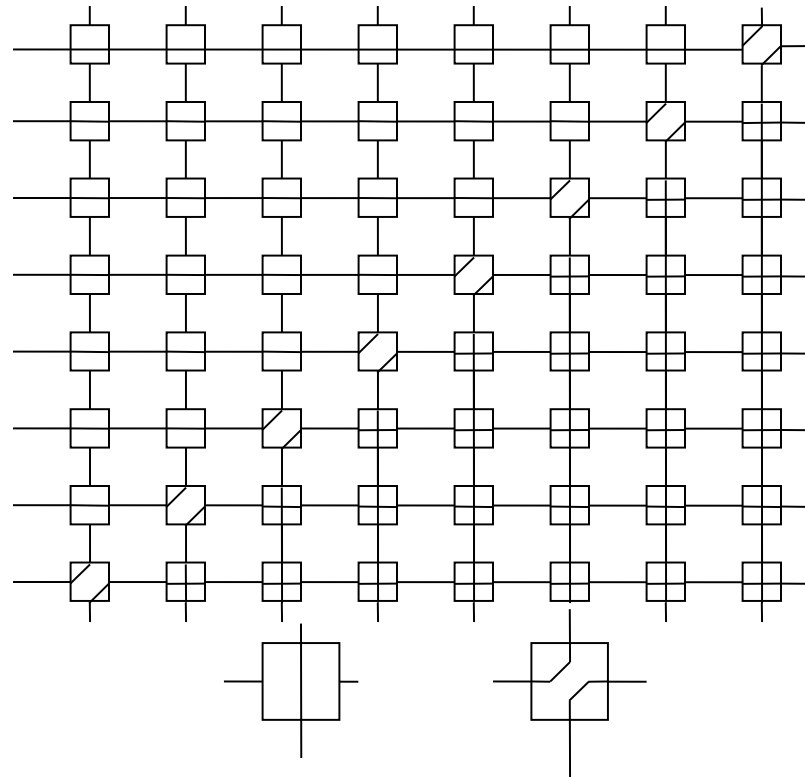
# Bus Based IN





# Dynamic Interconnection Network

## Crossbar network

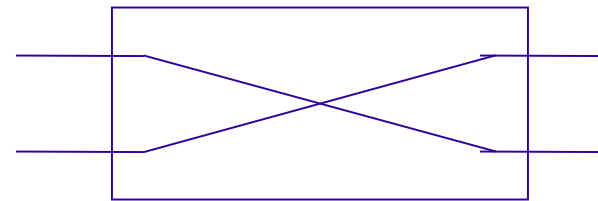




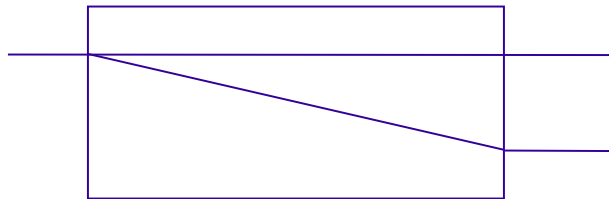
# Dynamic Networks



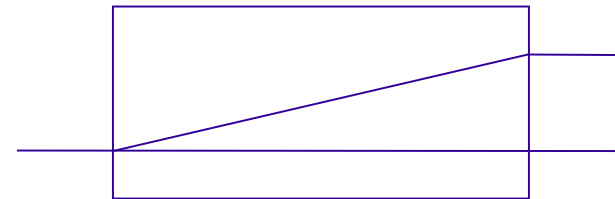
Straight



Exchange



Upper-  
broadcast

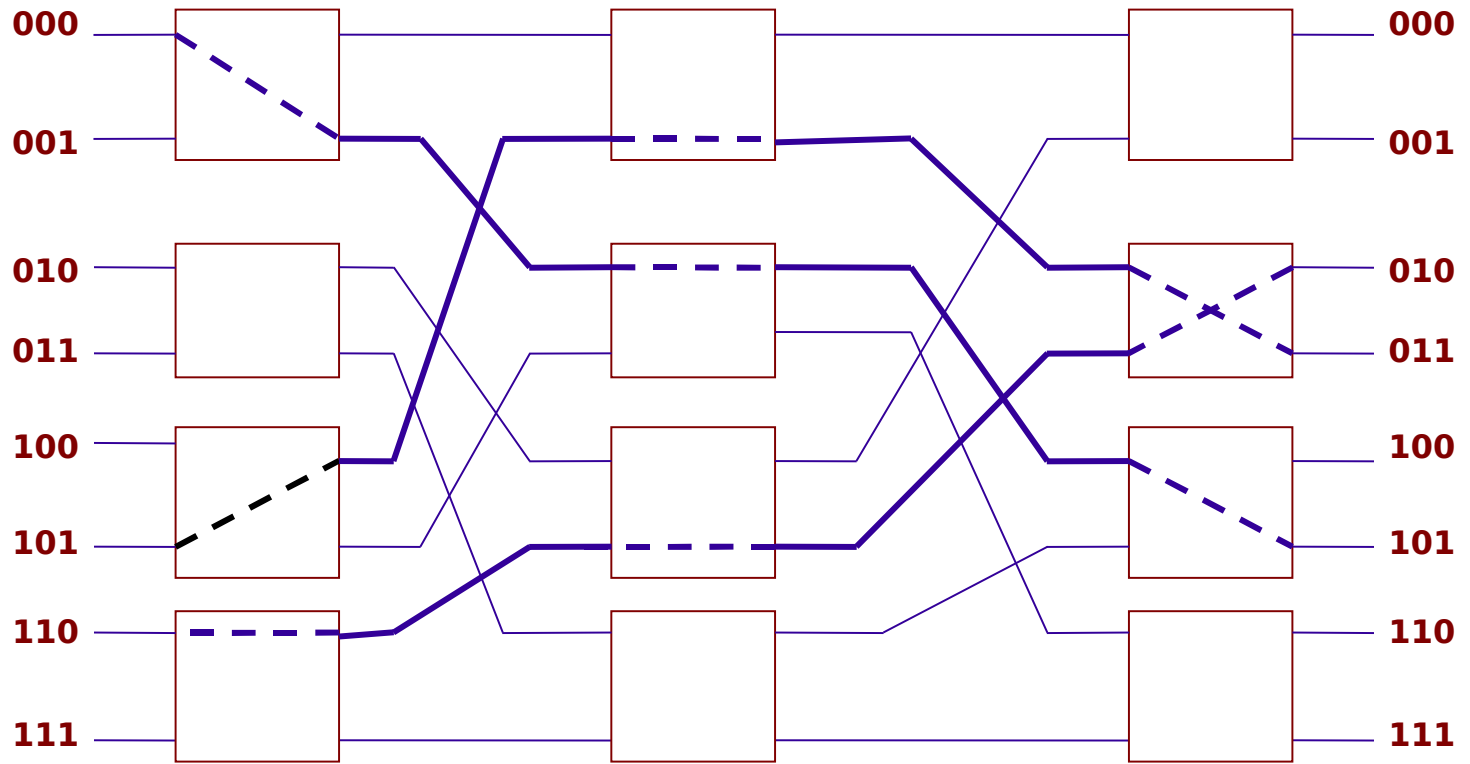


Lower-broadcast

The different setting of the 2X2 SE



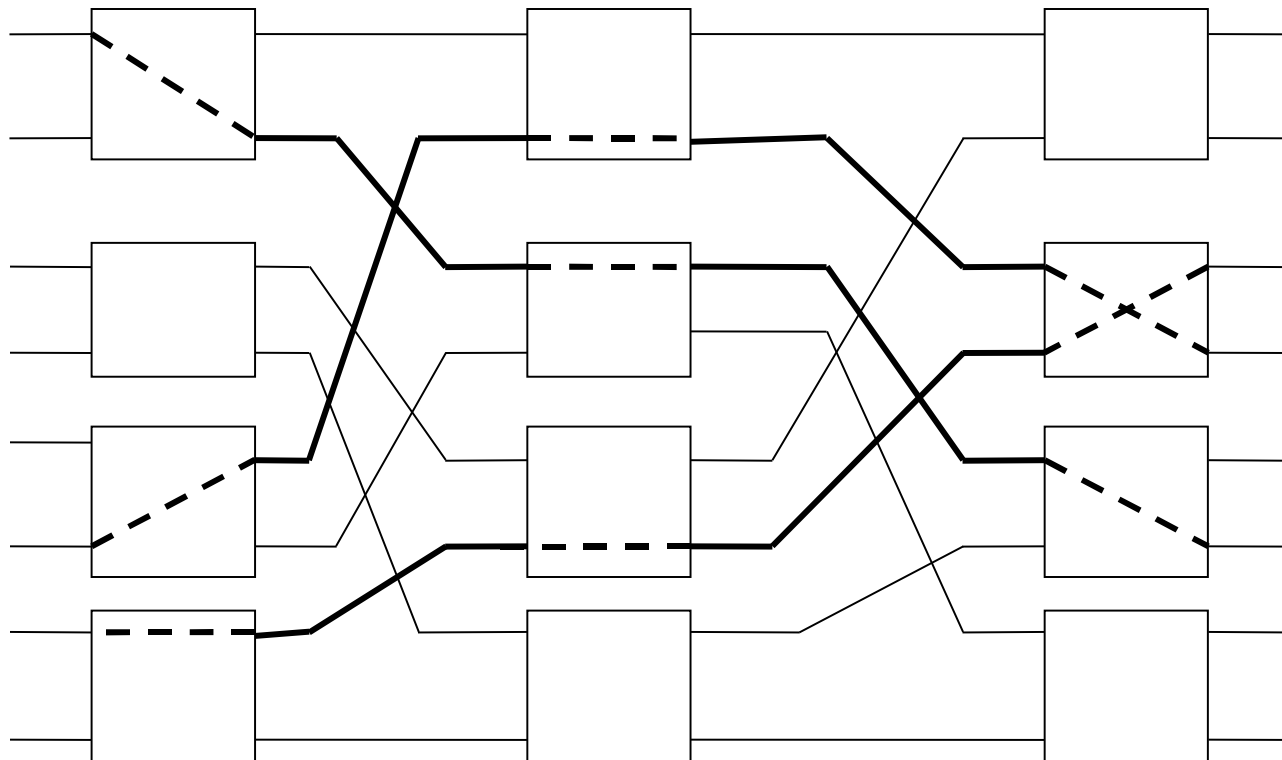
# Multi-stage network





# Dynamic Interconnection Network

## Multi-stage INs (MINs)

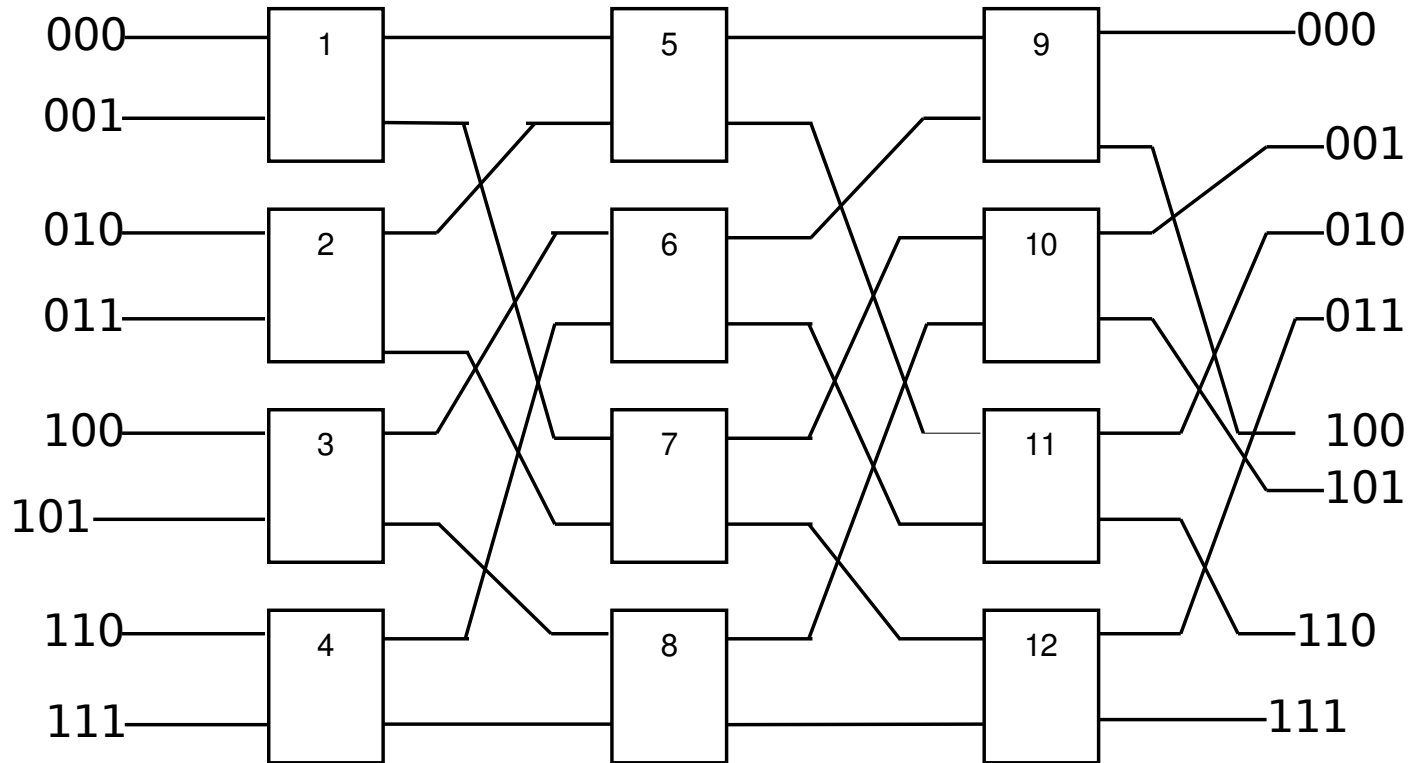






# Dynamic Interconnection Network

## Multi-stage INs (MINs) (cont.)





# Analysis and performance metrics dynamic networks

Networks	Delay	Cost	Blocking	Degree of FT
Bus	$O(N)$	$O(1)$	Yes	0
Multiple-bus	$O(mN)$	$O(m)$	Yes	$(m-1)$
MINs	$O(\log N)$	$O(N \log N)$	Yes	0
Crossbar	$O(1)$	$O(N^2)$	No	0