

# Introduction to Interconnection Networks



## Outline

- **Design considerations**
- **Classifications of interconnection networks**
  - Direct vs Indirect Networks
  - Irregular vs MINs vs Fat Trees
- **Convergence of Direct and Indirect Networks**

## Design Considerations

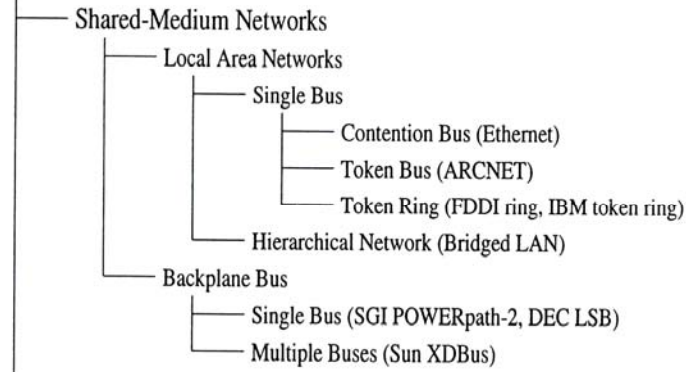
- **Performance Requirements (latency, throughput)**
- **Scalability**
- **Incremental expandability**
- **Partitionability**
- **Simplicity**
- **Distance Span (maximum clock rate, physical media)**
- **Physical constraints (packaging, wiring, and maintenance)**
- **Reliability and repairability**
- **Expected workloads**
- **Cost constraints**

## Classification of INs

- **Four major categories**
  - **shared-medium networks**
  - **direct networks (router-based)**
  - **indirect networks (switch-based)**
  - **hybrid networks**

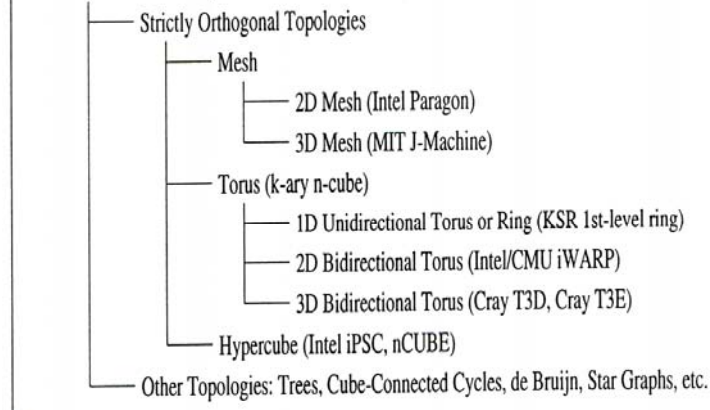
# Shared-Medium Networks

## Interconnection Networks



# Direct Networks (Router-based)

## Direct Networks (Router-Based Networks)



## Direct Networks

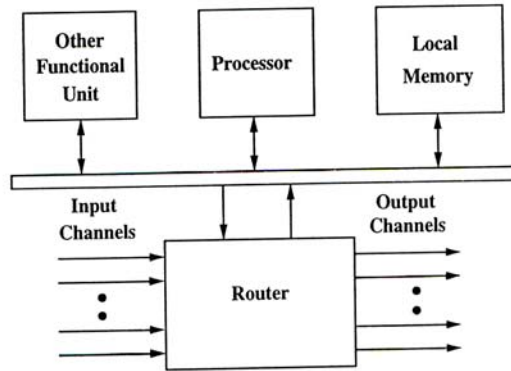


Figure 1.6: A generic node architecture

## Orthogonal Topologies

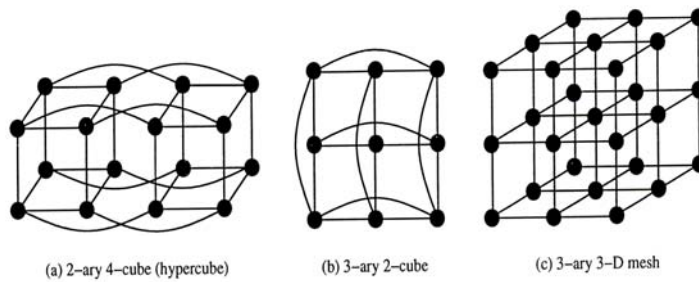
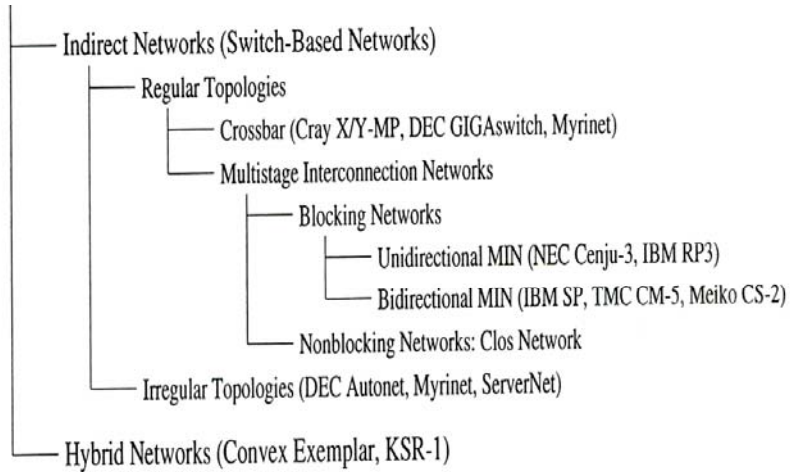


Figure 1.7: Strictly orthogonal direct network topologies

## Indirect Networks (Switch-based)



## Switch Architecture for MINs

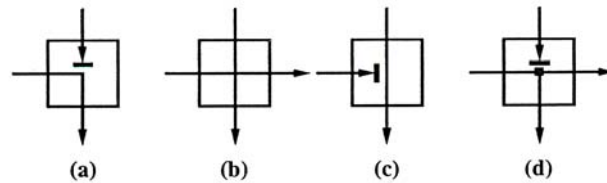


Figure 1.12: States of a switch point in a crossbar network

# Generalized MIN Arch.

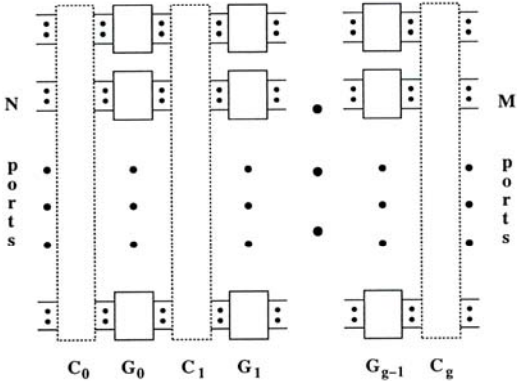
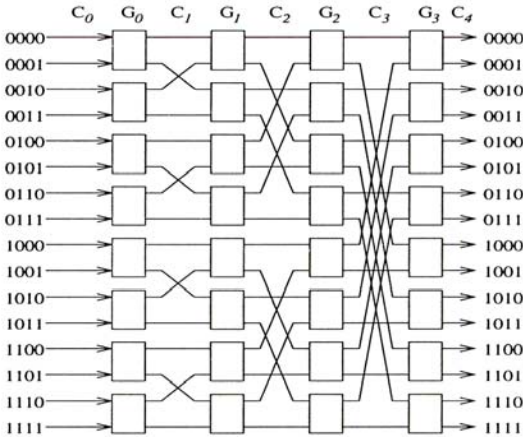


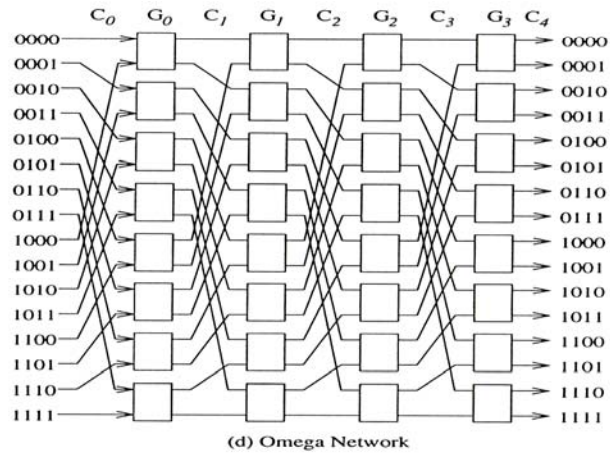
Figure 1.13: A generalized MIN with  $N$  inputs,  $M$  outputs, and  $g$  stages

# Butterfly MIN



(b) Multistage Butterfly Network

## Omega MIN



## Switch Architecture for Bidirectional-MIN (BiDi-MIN)

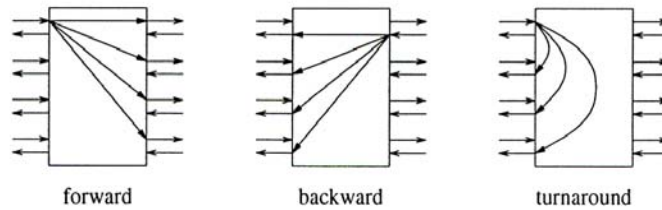


Figure 1.22: Connections in a bidirectional switch

## Buttefly BMIN

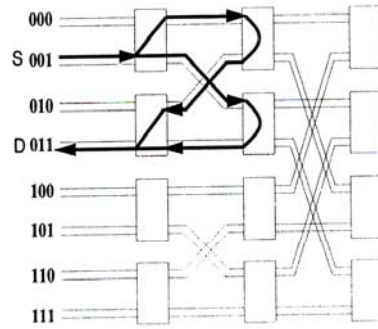
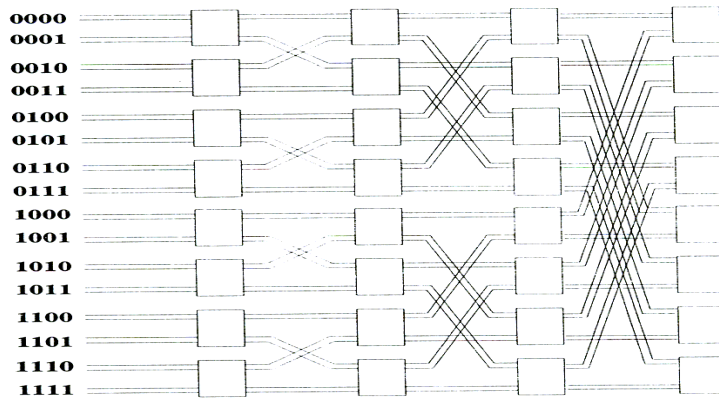


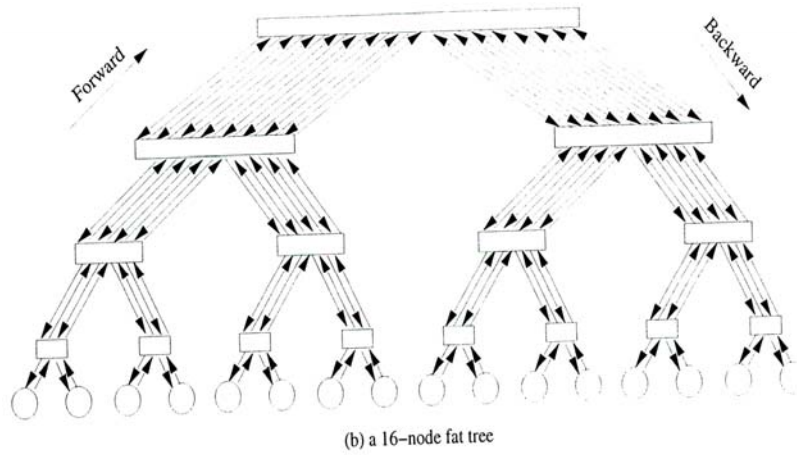
Figure 1.24: Alternative paths in an 8-node butterfly bidirectional MIN

## 16-node BMIN



(a) a 16-node butterfly BMIN built with 2x2 switches

## Fat-Tree



## Irregular Topology

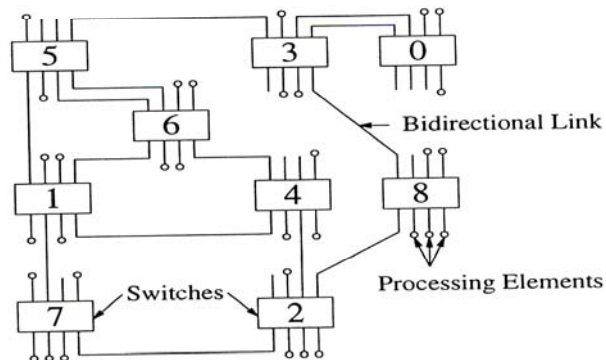


Figure 1.10: A switch-based network with irregular topology

## Hybrid Network and Convergence

- Hybrid/Hierarchical Networks
  - Cray T3D
    - two processors connected to each node
  - SGI origin
    - two processors connected to a Hub (a node)
    - multiple nodes connected to hypercube (up to 64 nodes)
    - fat hypercube architecture (intermediate routers do not have any node connected to them)
  - NUMA-Q
    - hierarchical ring
  - SMP clusters
    - bus within a node and regular/irregular across nodes
  - Multi-core clusters
    - QPI/HT inside a node
    - Commodity network (fat-tree, hypercube, combined fat-tree/hypercube outside)
- Direct Networks
  - a node connected to each router
- Indirect Networks
  - switches at the intermediate stages are not connected to nodes