Outline

- Classes of Shared memory systems
- Types of Interconnection Networks
- Metrics for Interconnection Networks

Recap

- Where there are N processors each with its own individual data stream i.e. SIMD. and MIMD ,
- it is usually necessary to communicate data / results between processors.
- This can be done in two main ways.
- Using a SHARED MEMORY and SHARED VARIABLES
- And using Interconnection Networks.

SHARED MEMORY and SHARED VARIABLES

- Depending on whether 2 or more processors can gain access to the same memory location simultaneously,
- we have 4 subclasses of shared memory computers

SHARED MEMORY and SHARED VARIABLES

- **Exclusive Read, Exclusive Write (EREW) SM Computers**
- Access to memory locations is exclusive i.e. no 2 processors are allowed to simultaneously read from or write into the same location.
- **Concurrent Read, Exclusive Write (CREW) SM Computers**
- Multiple processors are allowed to read from the same location but write is still exclusive. .i.e. no 2 processors are allowed to write into the same location simultaneously

SHARED MEMORY and SHARED VARIABLES

- **Exclusive Read, Concurrent Write (ERCW) SM Computers**
- Multiple processors are allowed to write into the same memory location but read access remains exclusive.
- **Concurrent Read, Concurrent Write (CRCW) SM Computers**
- Both multiple read and multiple write privileges are allowed.

SHARED MEMORY and SHARED VARIABLES

- Allowing concurrent read access to the same address should pose no problems (except perhaps to the result of a calculation)
- Conceptually, each of the several processors reading from that location makes a copy of its contents and stores it in its own register (RAM)

SHARED MEMORY and SHARED VARIABLES

- Problems arise however, with concurrent write access.
- If several processors are trying to simultaneously store (potentially different) data at the same address, which of them should succeed ?
- i.e. we need a deterministic way of specifying the contents of a memory location after a concurrent write operation.

SHARED MEMORY and SHARED VARIABLES

- Some ways of resolving **write conflicts** include :-
  - Assign priorities to the processors and accept value from highest priority processor
  - All the processors are allowed to write, provided that the quantities they are attempting to store are equal, otherwise access is denied to ALL processors.

SHARED MEMORY and SHARED VARIABLES

- It is only feasible to allow P processors to access P memory locations simultaneously for relatively small P (< 30)
- Usually because of the cost of the communication.

Interconnection Networks

- We have seen that one way for processors to communicate data is to use a shared memory and shared variables.
- However this is unrealistic for large numbers of processors.
- A more realistic assumption is that each processor has its own private memory and data communication takes place using message passing via an INTERCONNECTION NETWORK.

Interconnection Networks

- The interconnection network plays a central role in determining the overall performance of a multicomputer system.
- If the network cannot provide adequate performance, for a particular application, nodes will frequently be forced to wait for data to arrive.
- Some of the more important networks include

Interconnection Networks

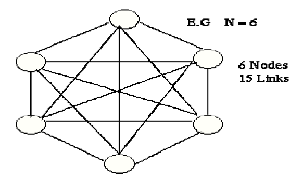
- Fully connected or all-to-all
- Mesh
- Rings
- Hypercube
- X - Tree
- Shuffle Exchange
- Butterfly
- Cube Connected Cycles

Interconnection Networks -dynamic

- Multi – Stage Interconnection network
- Cross – Bar Interconnection Network

Fully connected or all-to-all

- This is the most powerful interconnection network (topology): each node is directly connected to ALL other nodes.



Fully connected or all-to-all

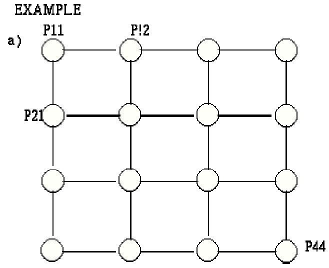
- Each node has N-1 connections (N-1 nearest neighbours)
- giving a total of N(N-1) / 2 connections for the network.
- Even though this is the best network to have,
- the high number of connections per node mean this network can only be implemented for small values of N.

Mesh (Torus)

- In a mesh network, the nodes are arranged in a **k dimensional lattice** of width w, giving a total of w^k nodes.
- Usually k=1 (linear array) or k=2 (2D array) e.g. ICL DAP.
- Communication is allowed only between neighbouring nodes.
- All interior nodes are connected to 2k other nodes.

Mesh (Torus)

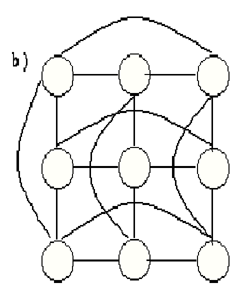
EXAMPLE



2D mesh of width 4 with no wraparound connections on edge or corner nodes

corner nodes have degree 2
edge nodes have degree 3

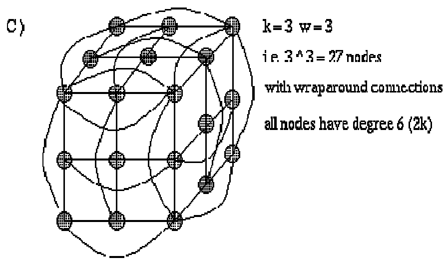
Mesh (Torus)



2D mesh of width 3 with wraparound connections between nodes on same row or column

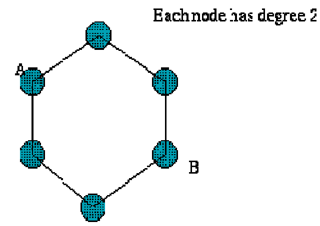
Edge and corner nodes have degree 4

Mesh (Torus)



Rings

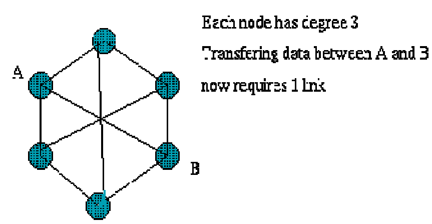
- A **simple ring** is just a linear array with the end nodes linked.



Rings

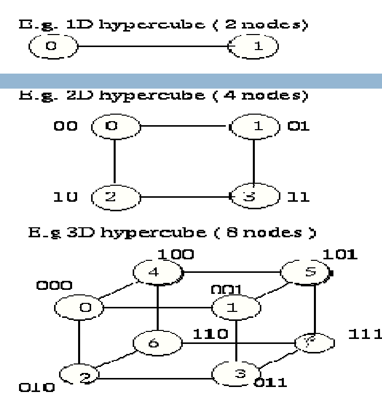
- It is equivalent to a 1D mesh with wraparound connections.
- One drawback to this network is that some data transfers may require N/2 links to be traversed e.g. A and B above (3).
- This can be reduced by using a **chordal ring**
- This is a simple ring with cross or chordal links between nodes on opposite sides

Rings

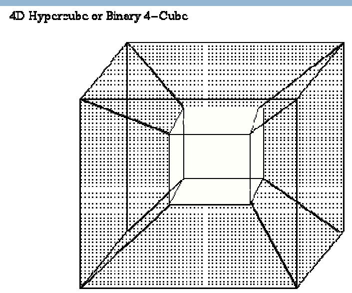


Hypercube Connection (Binary n-Cube)

- Hypercube networks consist of N = 2^k nodes
- arranged in a k dimensional hypercube.
- The nodes are numbered 0 , 1, ...2^k -1
- and two nodes are connected if their binary labels differ by exactly one bit



Hypercube Connection (Binary n-Cube)



Hypercube Connection (Binary n-Cube)

- K dimensional hypercube is formed by combining two k-1 dimensional hypercubes and connecting corresponding nodes i.e. hypercubes are recursive.
- each node is connected to k other nodes i.e. each is of degree k

Metrics for Interconnection Networks

- Metrics provide a framework to compare and evaluate interconnection networks.
- The main metrics are:
  - Network connectivity
  - Network diameter
  - Narrowness
  - Network expansion increments

Network Connectivity

- Network nodes and communication links sometimes fail and must be removed from service for repair.
- When components do fail the network should continue to function with reduced capacity.
- Network connectivity measures the resiliency of a network and
- its ability to continue operation despite disabled components

Network Connectivity

- i.e. connectivity is the minimum number of nodes or links that must fail to partition the network into two or more **disjoint networks**
- The larger the connectivity for a network the better the network is able to cope with failures.

Network Diameter

- The diameter of a network is the maximum internode distance
- i.e. it is the maximum number of links that must be traversed to send a message to any node along a shortest path.
- The lower the diameter of a network the shorter the time to send a message from one node to the node farthest away from it.

Narrowness

- This is a measure of congestion in a network and is calculated as follows:
- Partition the network into two groups of processors A and B
- where the number of processors in each group is Na and Nb and assume Nb < = Na.
- Now count the number of interconnections between A and B call this I.

Narrowness

- Find the maximum value of Nb / I for all partitionings of the network.
- This is the narrowness of the network.
- The idea is that if the narrowness is high (Nb > I) then if the group B processors want to send messages to group A, congestion in the network will be high (since there are fewer links than processors)

Network Expansion Increments

- A network should be expandable i.e.
- it should be possible to create larger and more powerful multicomputer systems by simply adding more nodes to the network.
- For reasons of cost, it is better to have the option of small increments since this allows you to upgrade your network to the size you require (i.e. flexibility) within a particular budget.

Network Expansion Increments

- E.g. an 8 node linear array can be expanded in increments of 1 node but a 3 dimensional hypercube can be expanded only by adding another 3D hypercube. (i.e. 8 nodes)

Other metrics

- Bisection bandwidth
  - the speed with which data from two halves of the network can be transposed across an arbitrary cut
- Cost
  - Proportional to the number of communication links