Module-2
CSEN 3104
Lecture 17

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Interconnection Networks

Shuffle-Exchange and Omega Networks

- Based on two routing functions --- Shuffle (S) and Exchange (E)
- Let A = a_{n-1} …. a_1a_0 be the address of a Processing Element (PE)
- The Shuffle function is given by

  $S(a_{n-1} \ldots a_1a_0) = a_{n-2} \ldots a_1a_0\, a_{n-1}$ where $0 \le A \le (N-1)$ and $n = \log_2 N$
- Corresponds to cyclic shifting of the bits in A to the left for 1 bit position
- Show figure for perfect shuffle
- This action corresponds to perfect shuffling a deck of N cards
- The inverse perfect shuffle does the opposite to restore ordering (Show figure)
- Corresponds to cyclic shifting of the bits in A to the right for 1 bit position
- The Exchange function is given by

  $E(a_{n-1} \ldots a_1a_0) = a_{n-1} \ldots a_1a_0'$
- The Exchange function exchanges the data between two PEs with adjacent addresses
- It is to be noted that $E(A) = C_0(A)$, where C_0 was the cube routing function

Shuffle-Exchange and Omega Networks

- The Shuffle-Exchange function can be implemented as
  - Single stage network
  - Multistage network
- Single Stage recirculating shuffle-exchange network (Show figure)
- Dashed lines -> Shuffle Solid lines -> Exchange
- A number of parallel algorithms can be effectively implemented by using Shuffle-Exchange function. Examples:
  - Fast Fourier Transform (FFT)
  - Polynomial Evaluation
  - Sorting
  - Matrix Transposition etc…

Multistage Omega Networks

- To implement Shuffle-Exchange functions (Show figure)
- An N X N Omega network consists of n (= $\log_2 N$) identical stages
- Perfect shuffle interconnection between two adjacent stages
- Each stage has N/2 numbers of 4-function (straight, exchange, upper broadcast and lower broadcast) switch boxes under independent box control
- The switch boxes can be repositioned without violating the perfect shuffle interconnection between stages (Show figure)
- The n-cube network has the same interconnection topology as the repositioned Omega
- However, they are different in the following two points:
  - Cube NW uses 2-function switch boxes, whereas Omega NW uses 4-function ones
  - The dataflow directions in the two NWs are opposite to each other i.e. the roles of the input-output lines are exchanged in the two networks

Routing Algorithm for Omega Network

- A source *S* (with address $s_{n-1}\ s_{n-2}\ \ldots\ s_0$) has to be connected to a certain destination *D* (with address $d_{n-1}\ d_{n-2}\ \ldots\ d_0$)
- Starting at input *S*, connect the input of the first switch [in the $(n\text{-}1)^{th}$ stage] that is connected to *S* to
  - the upper output of the switch when $d_{n-1}= 0$
  - otherwise, to the lower output
- In the same way, bit d_{n-2} determines the output of the switch located on the next stage
- This process continues until a path is established between *S* and *D*
- In general, the input of the switch on the i^{th} stage is connected to the upper output when $d_i = 0$; Otherwise, the switch is connected to the lower output
- Example: Source 2 (i.e., *S* = 010) and destination 6 (i.e., *D* =110) (Show Figure)
- In addition to one-to-one connections, the omega network also supports broadcasting
- Show Figure to explain the paths between source 2 and destinations 4,5,6 and 7

Thank you