
Chapter 11

Parallel Structures

SISD Architecture

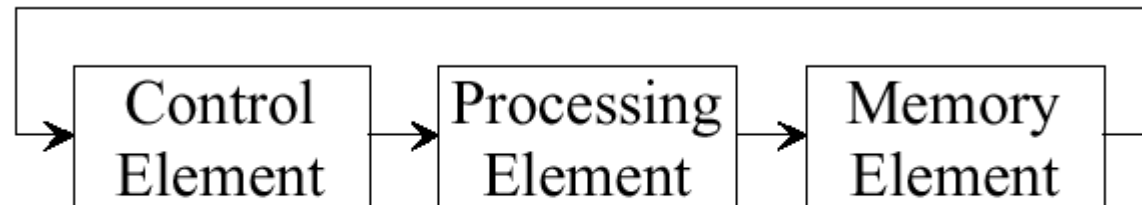


Fig. 11.1 Conceptual view of an SISD architecture.

Parallel Architecture

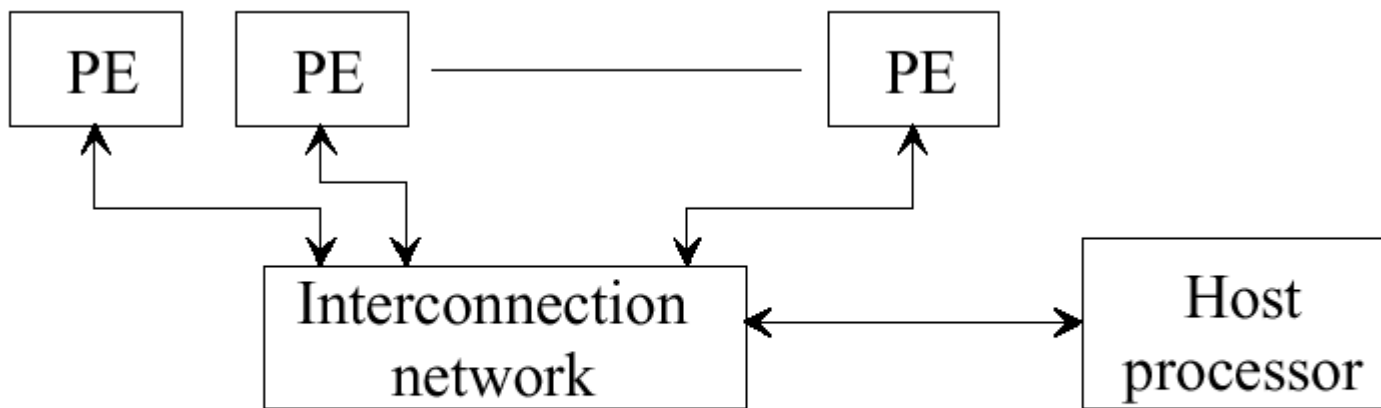


Fig. 11.2 Conceptual view of a parallel architecture.

Fully-Connected Network

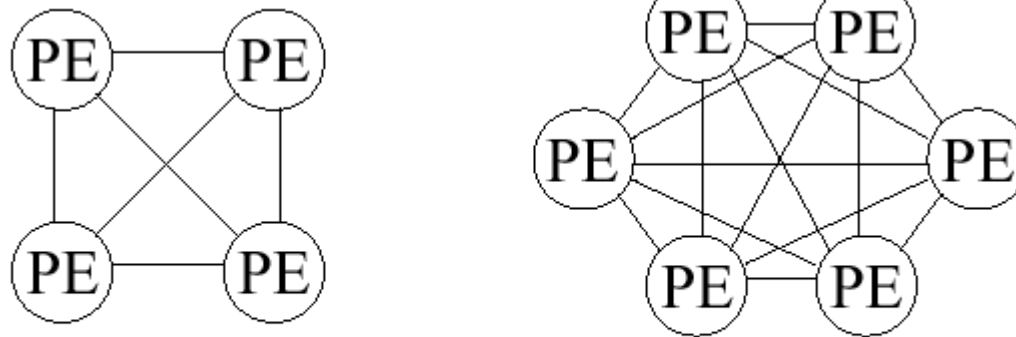


Fig. 11.3 Fully-connected parallel structures.

Fully-Connected Network

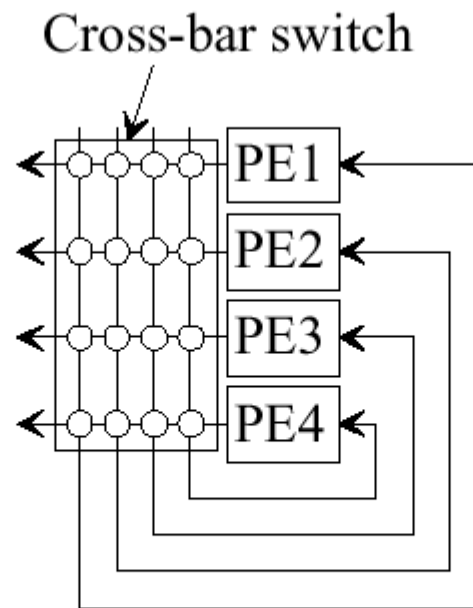


Fig. 11.4 Cross-bar switch implementing a fully-connected interconnection network.

Linear Interconnection Network

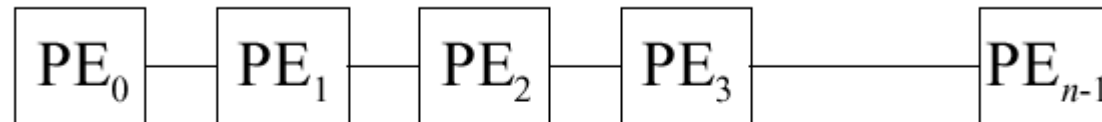


Fig. 11.5 Linear interconnection network with n PEs.

Ring Interconnection Network

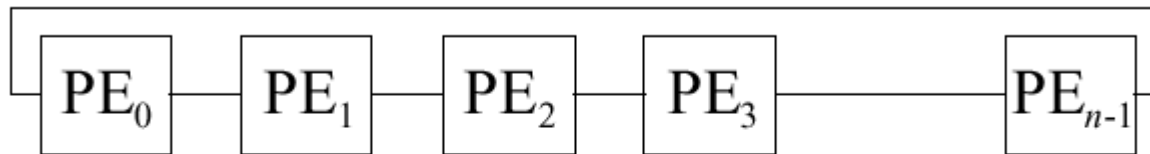


Fig. 11.6 Ring interconnection network with n PEs.

Shuffle

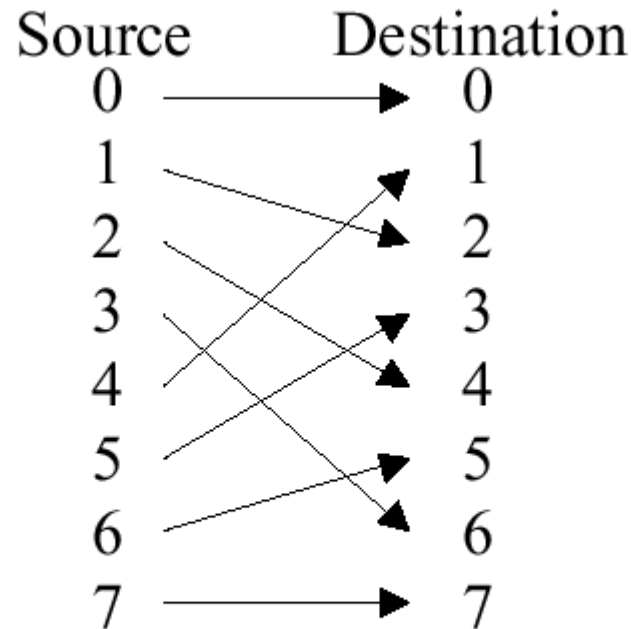


Fig. 11.7 Shuffle operations of 8 PEs.

Exchange

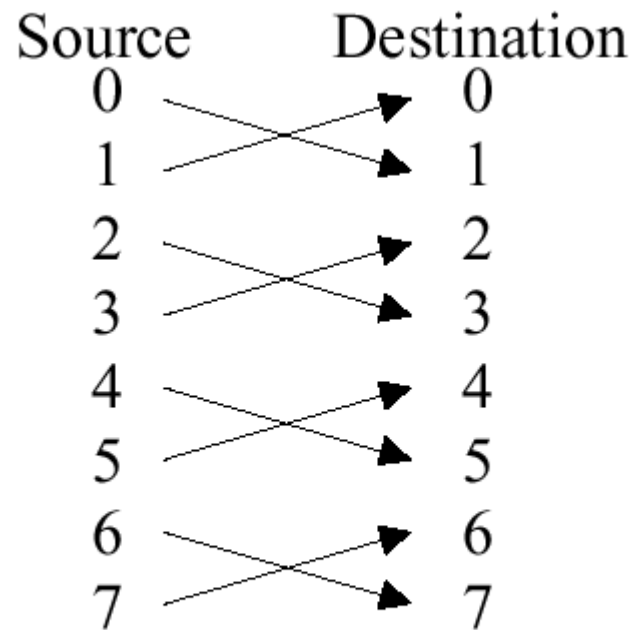


Fig. 11.8 Exchange operations.

Shuffle-Unshuffle-Exchange Network

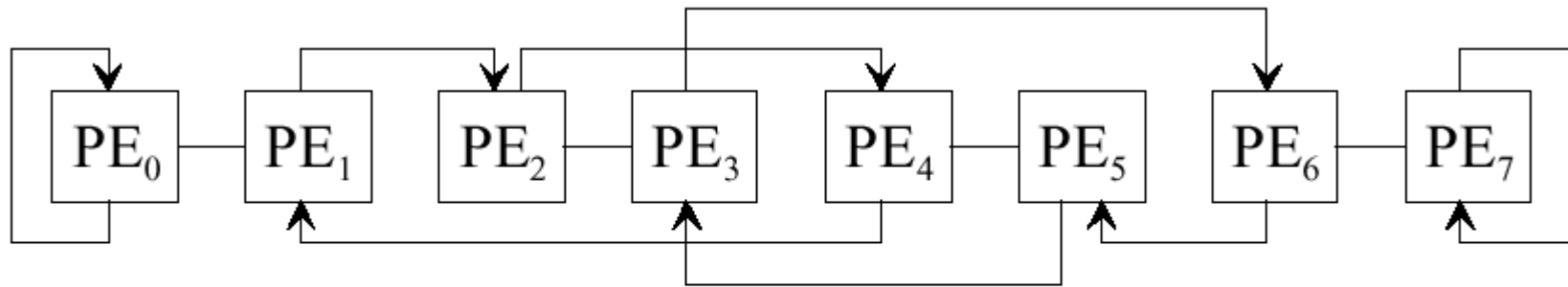


Fig. 11.9 Shuffle-exchange interconnection network with 8 PEs.

Shuffle-Unshuffle-Exchange Network

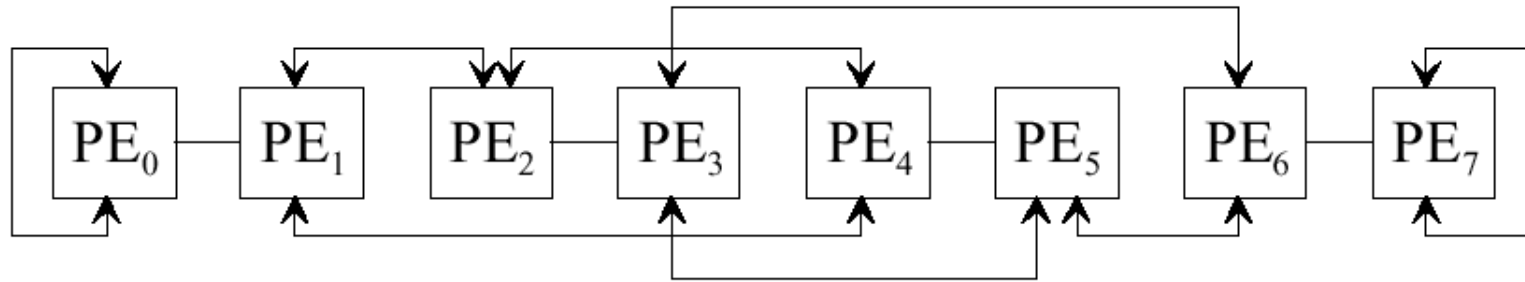


Fig. 11.10 Shuffle-unshuffle-exchange interconnection network with 8 PEs.

Mesh Interconnection Network

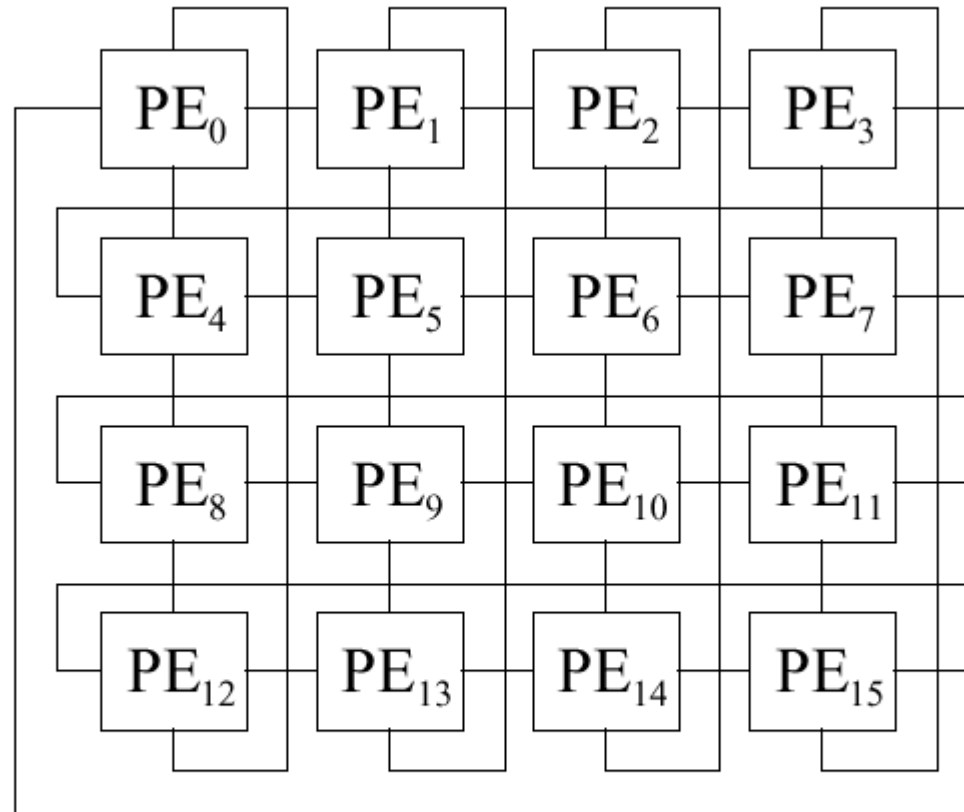


Fig. 11.11 Mesh interconnection network with 16 PEs.

Hypercube Interconnection Network

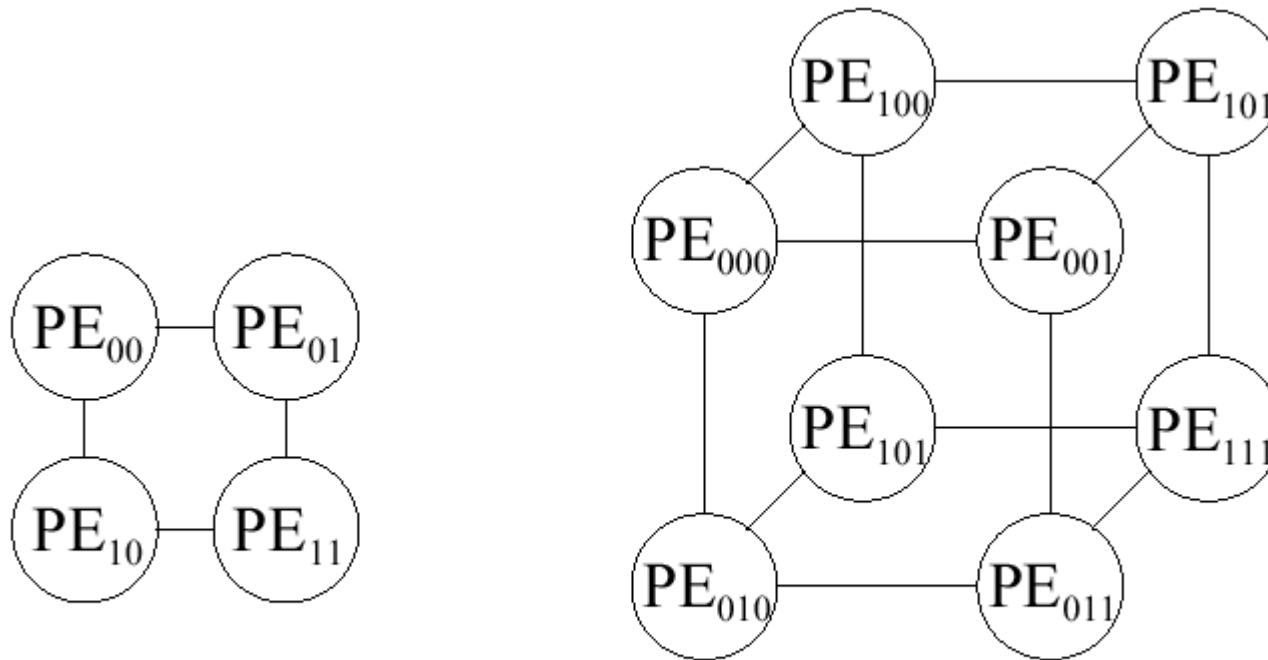


Fig. 11.12 Hypercube interconnection networks.

Hypercube Interconnection Network

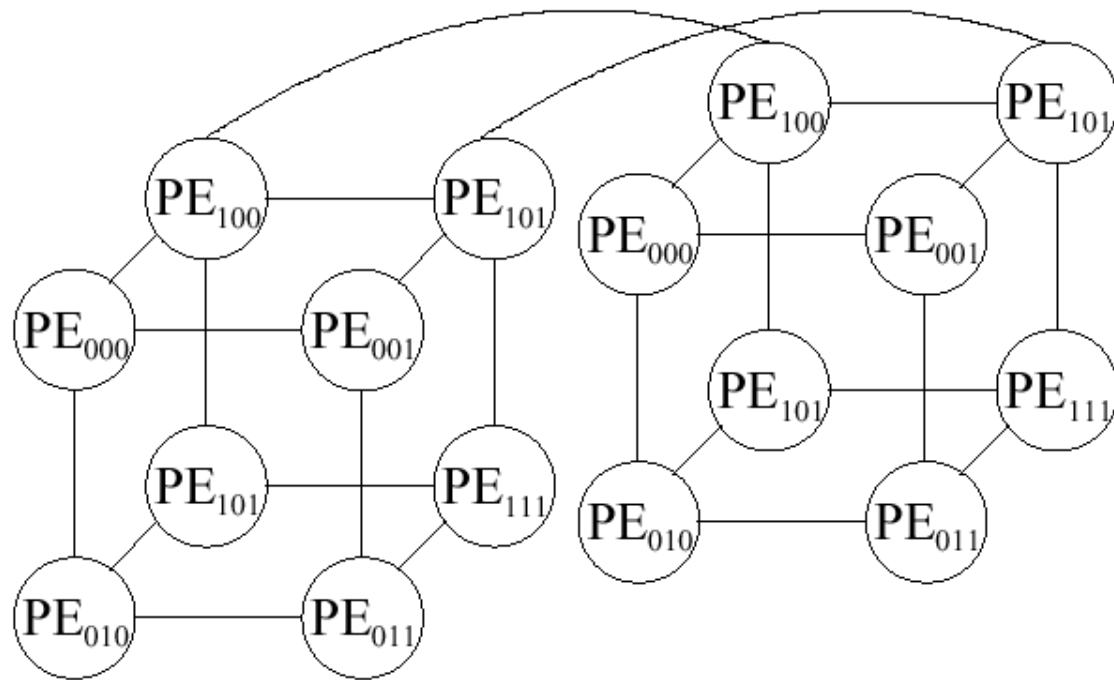


Fig. 11.13 Procedure of forming a 4-dimensional hypercube interconnection network by connecting two 3-dimensional hypercubes (not all connections shown).

Binary Tree

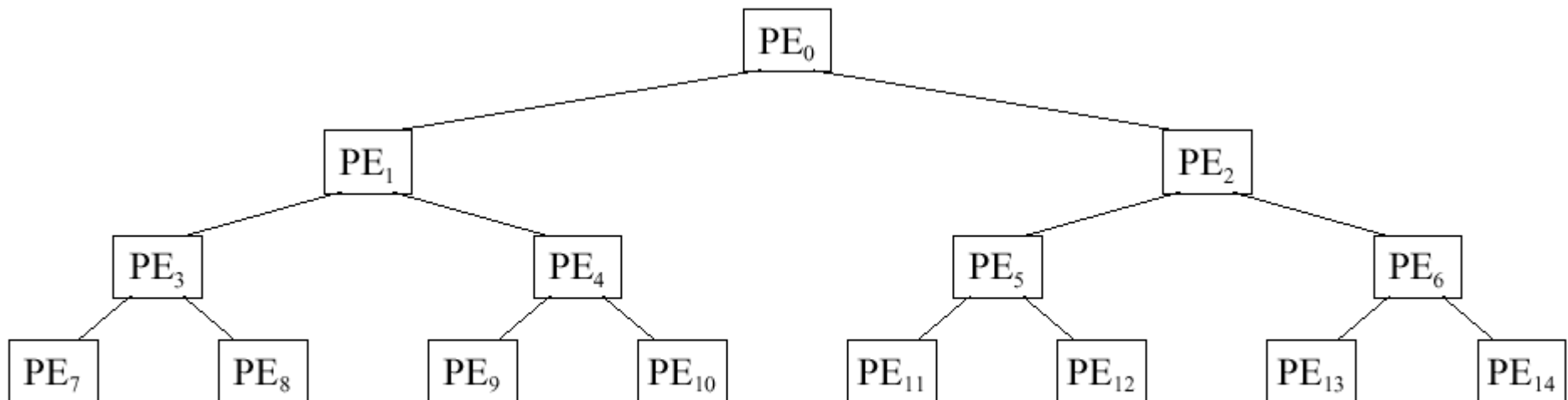


Fig. 11.14 Binary tree interconnection network with 15 PEs.

Switch Boxes

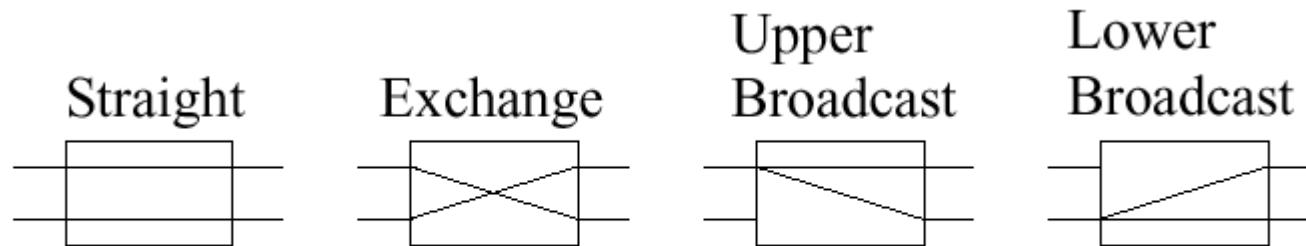


Fig. 11.15 Operating modes of switch boxes for the omega network.

Interconnection Network

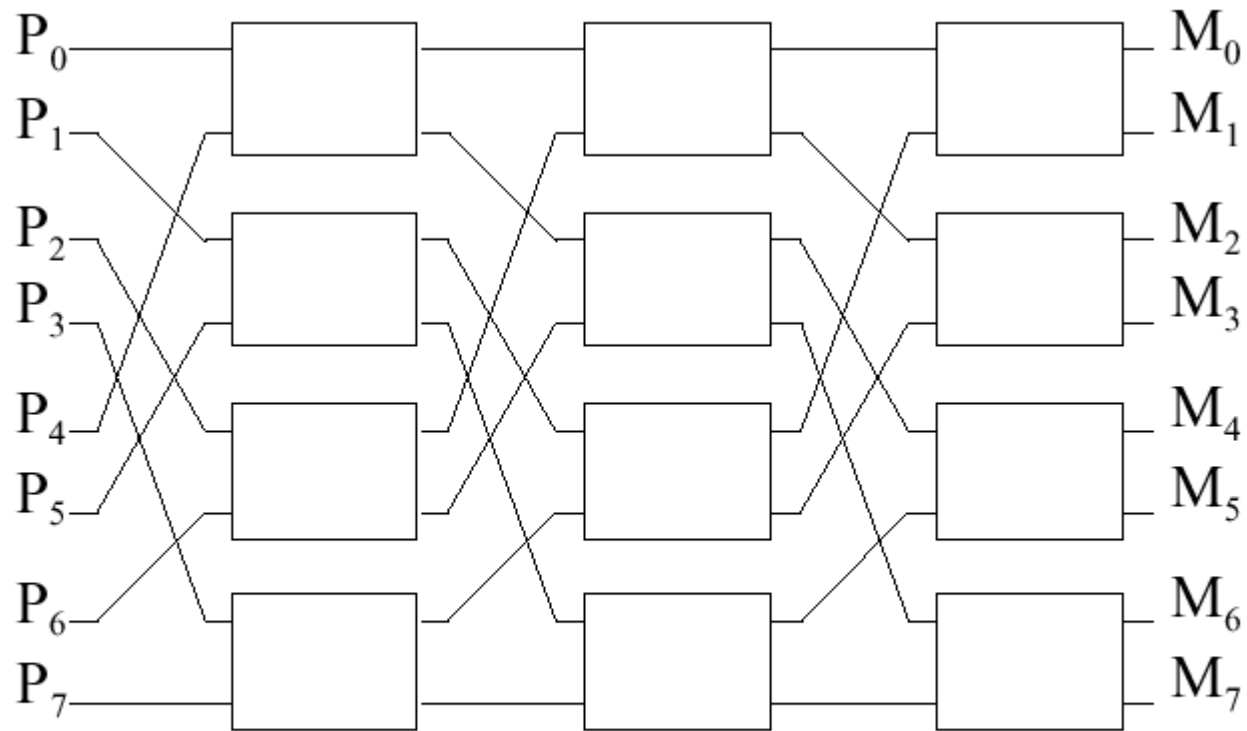


Fig. 11.16 Omega interconnection network with 8 inputs.

Interconnection Network

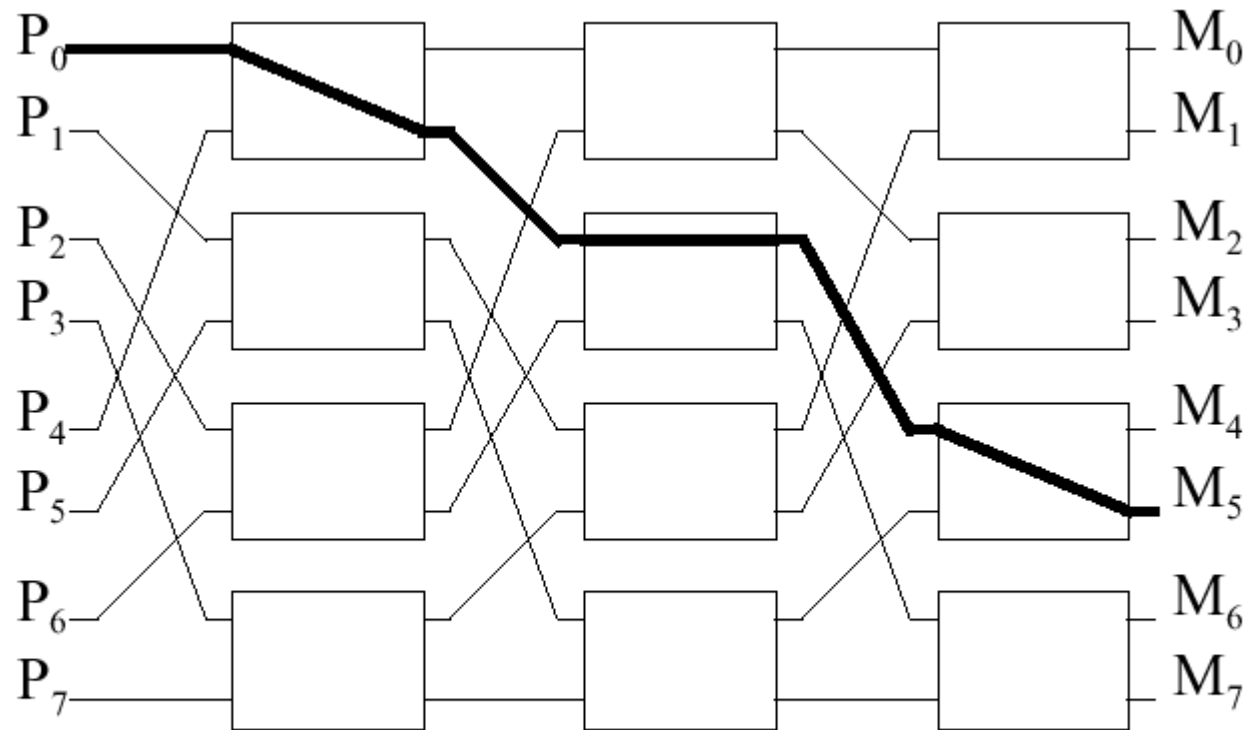


Fig. 11.17 Message routing in an omega interconnection network.

Task Stream

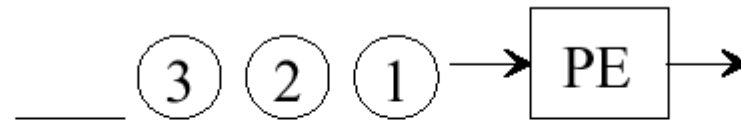


Fig. 11.18 Continuous stream of tasks processed by a single PE.

Spatial Parallelism

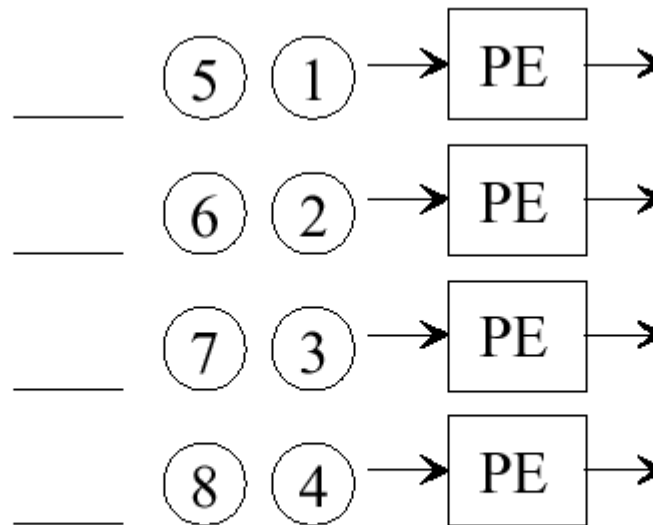


Fig. 11.19 Exploring spatial parallelism between tasks by replicating PEs.

Pipelined PE

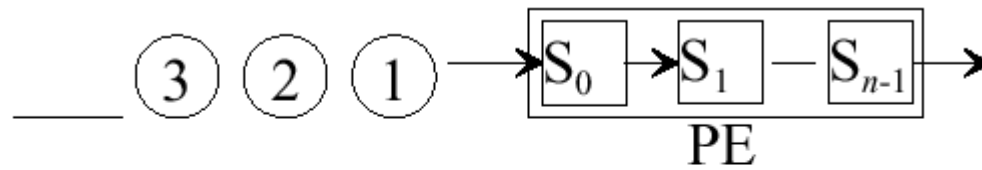


Fig. 11.20 Linearly pipelined PE.

Four-Phase CPU

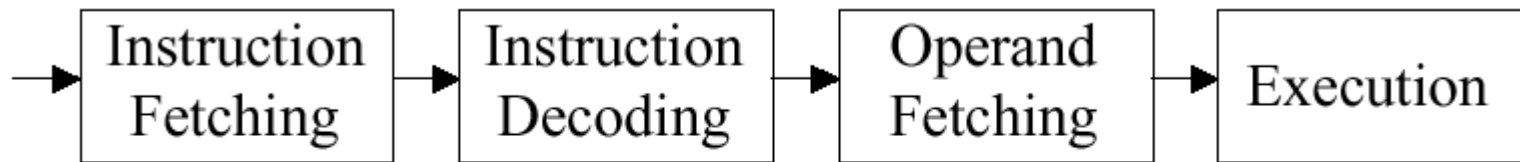


Fig. 11.21 Four-phase CPU.

Space-Time Diagram

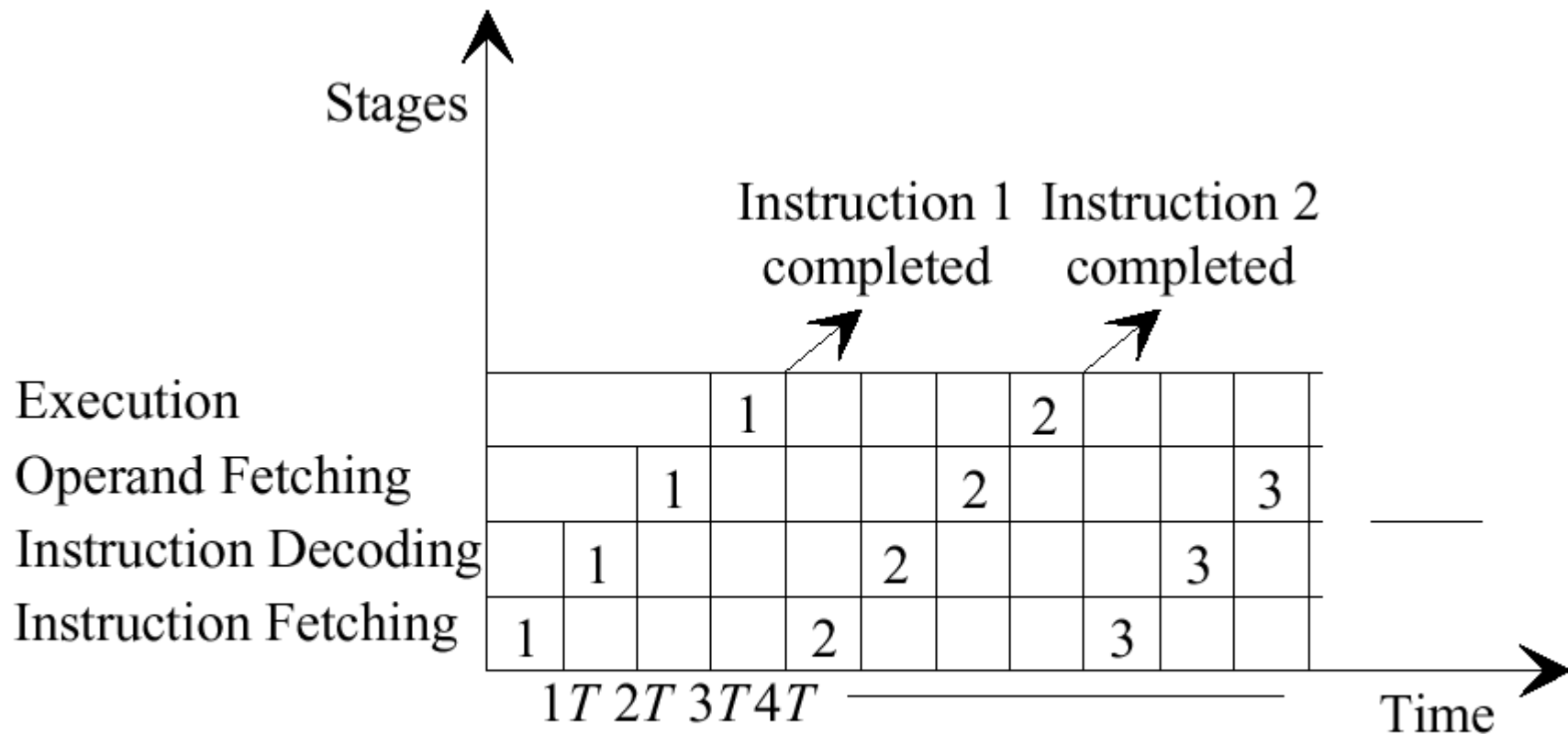


Fig. 11.22 Space-time diagram of non-pipelined CPU.

Space-Time Diagram

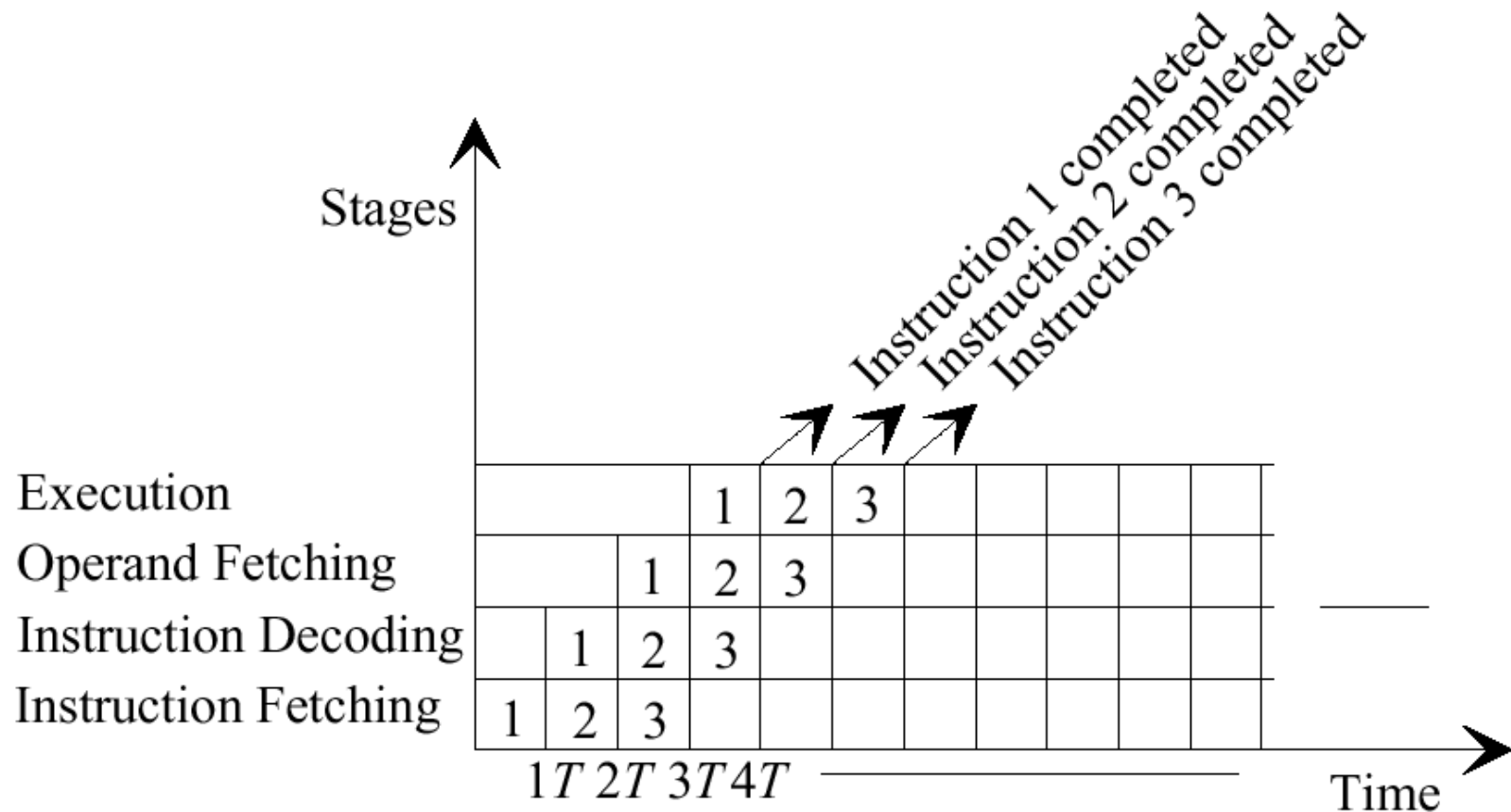


Fig. 11.23 Space-time diagram of pipelined CPU.

Non-Linear Pipeline

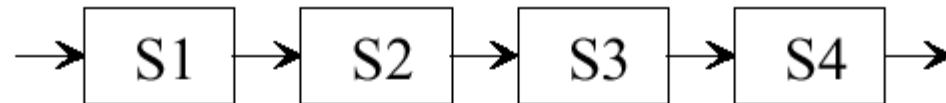


Fig. 11.24 Four-stage pipeline.

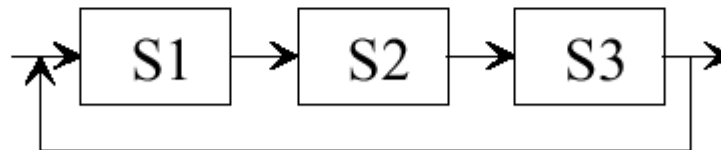


Fig. 11.25 Non-linear implementation of the pipeline in Fig. 11.24.

Reservation Table

		X	
	X		
X			X

Fig. 11.26 Reservation table of the non-linear pipeline in Fig. 11.25.

Task Scheduling

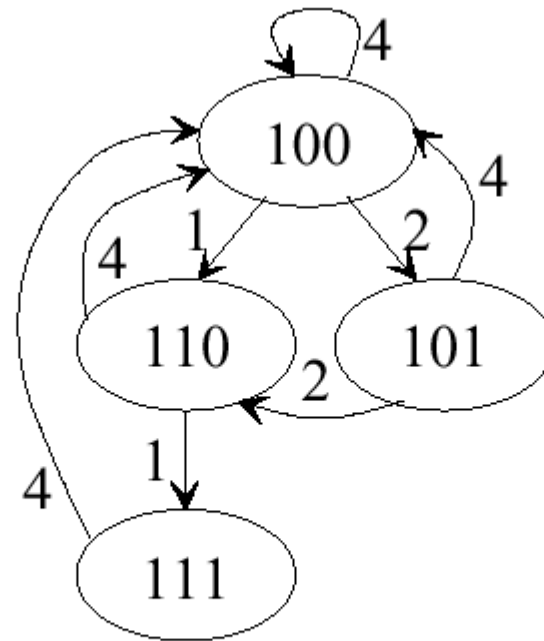


Fig. 11.27 Task scheduling diagram for the reservation table in Fig. 11.26.

Data Distribution

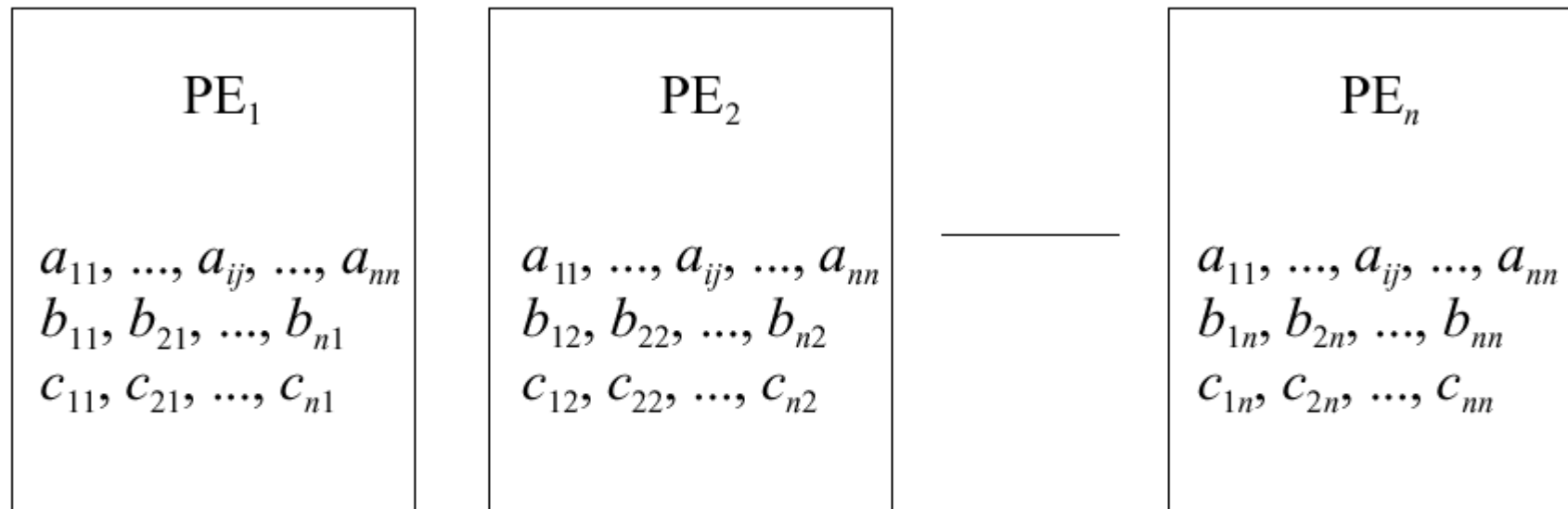


Fig. 11.28 Initial data distribution for matrix multiplication.

Hypercube

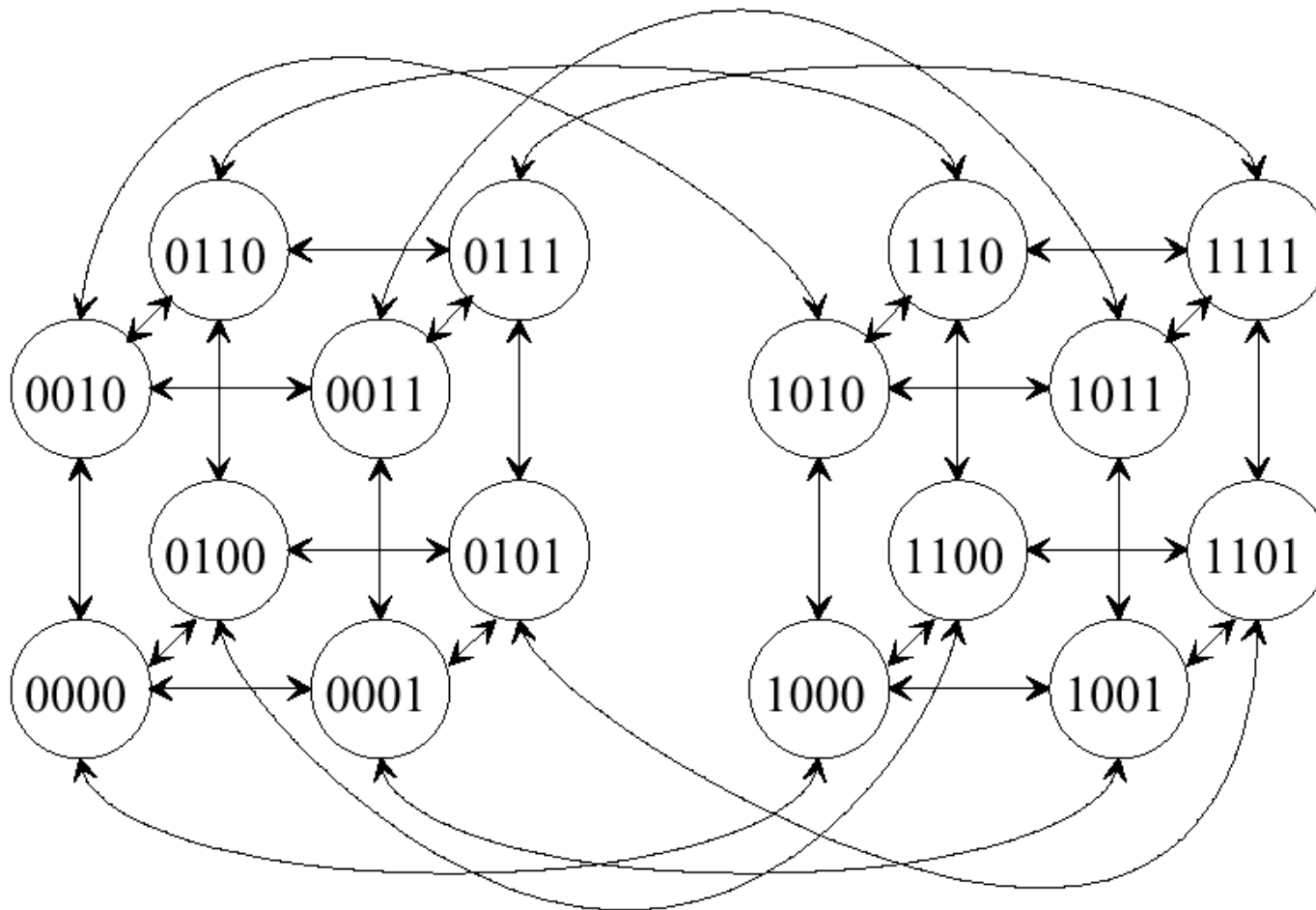


Fig. 11.29 A hypercube interconnection of 16 PEs.

Data Distribution

Matrix Elements	PE
Row 1 of $[A]$: $a_{11}, a_{12}, a_{13}, a_{14}$	0000
Row 2 of $[A]$: $a_{21}, a_{22}, a_{23}, a_{24}$	0101
Row 3 of $[A]$: $a_{31}, a_{32}, a_{33}, a_{34}$	1010
Row 4 of $[A]$: $a_{41}, a_{42}, a_{43}, a_{44}$	1111
Column 1 of $[B]$: $b_{11}, b_{21}, b_{31}, b_{41}$	0000
Column 2 of $[B]$: $b_{12}, b_{22}, b_{32}, b_{42}$	0100
Column 3 of $[B]$: $b_{13}, b_{23}, b_{33}, b_{43}$	1000
Column 4 of $[B]$: $b_{14}, b_{24}, b_{34}, b_{44}$	1100

Fig. 11.30 The distribution of matrix elements in a hypercube architecture.

Data Distribution

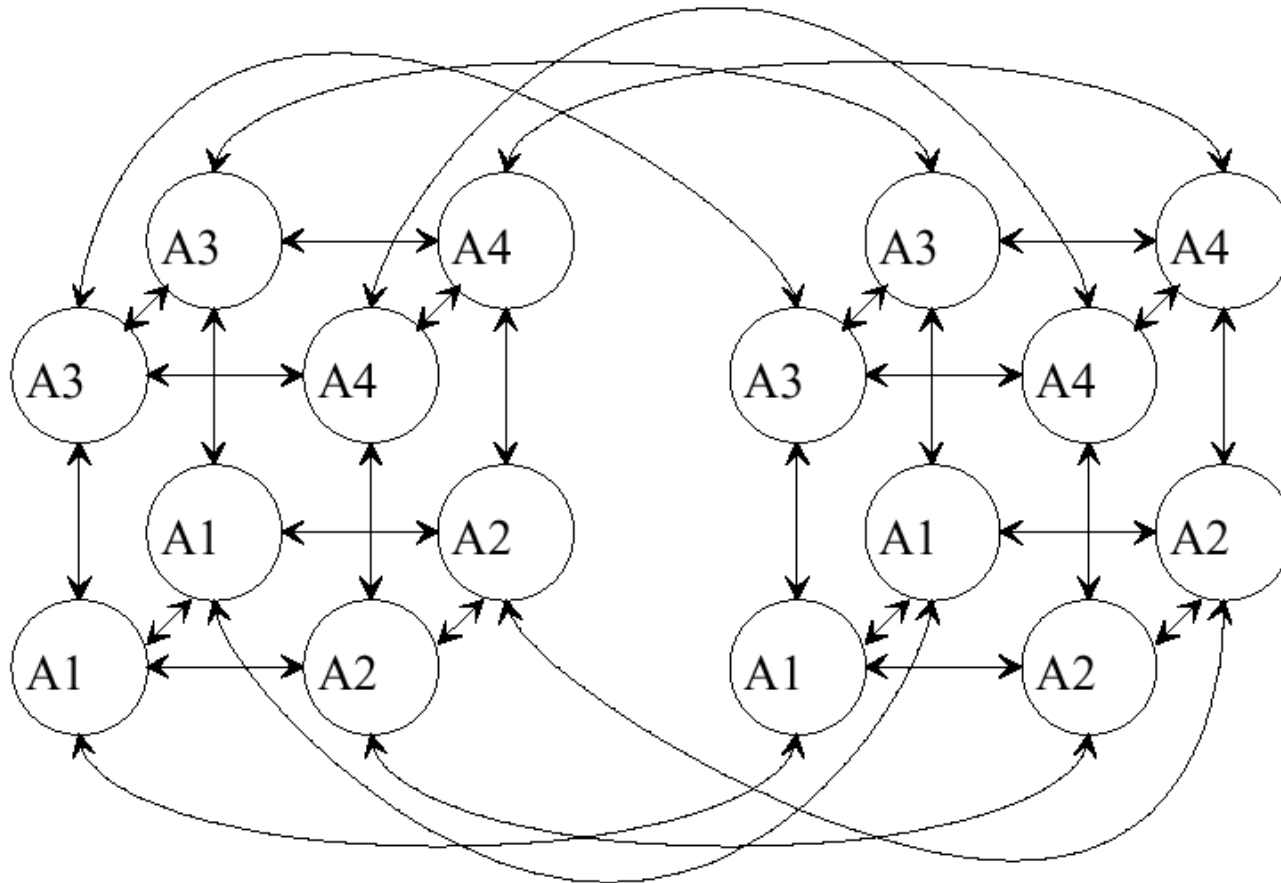


Fig. 11.31 The final distribution of the rows of A . A1, A2, A3, and A4 are the first, second, third, and fourth rows of A , respectively.

Data Distribution

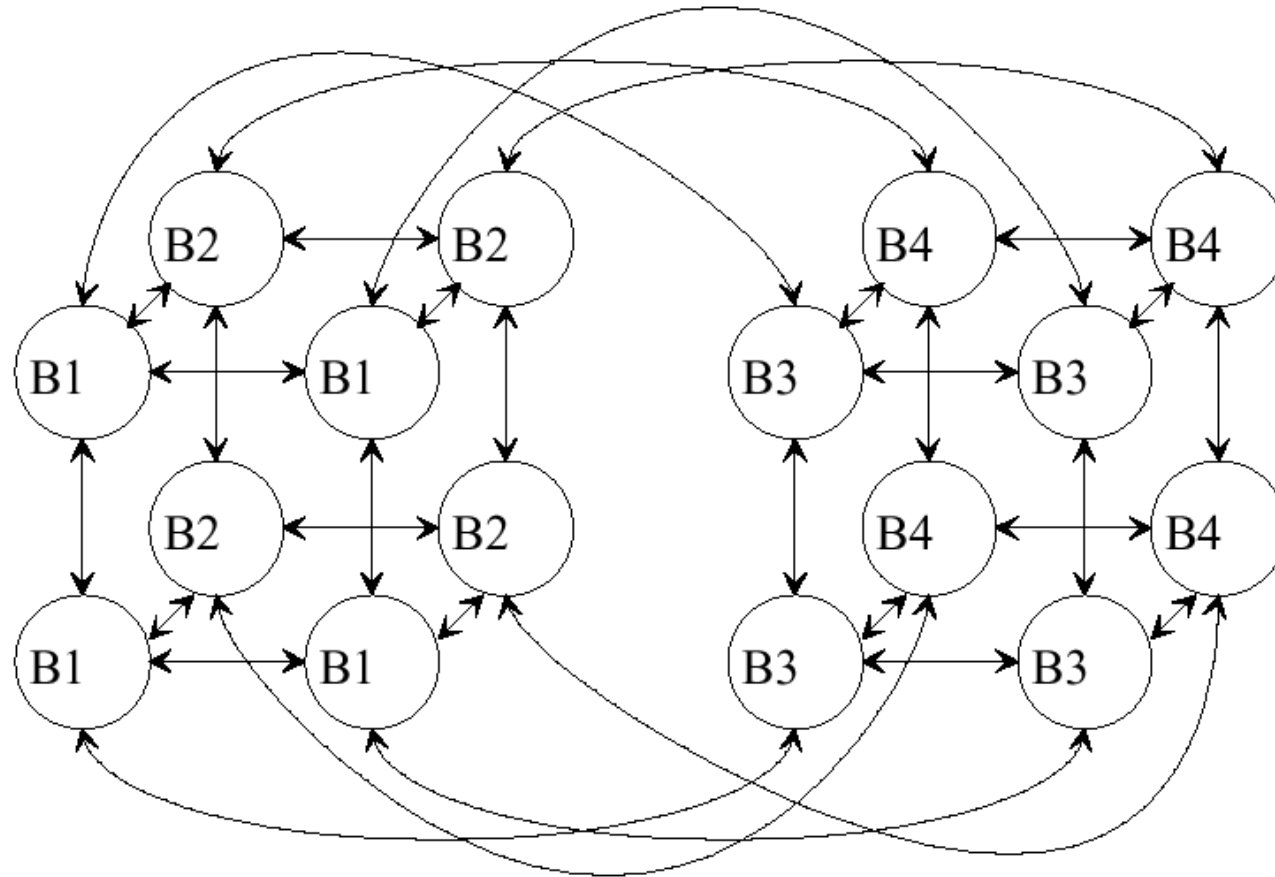


Fig. 11.32 The final distribution of the rows of $[B]$. B1, B2, B3, and B4 are the first, second, third, and fourth columns of $[B]$, respectively.

Linear Array

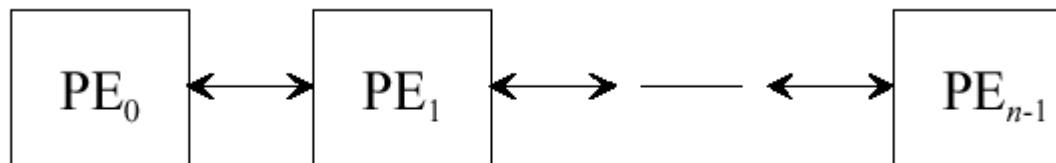


Fig. 11.33 A linear array of n PEs for the parallel sorting algorithm.

Array Sorting

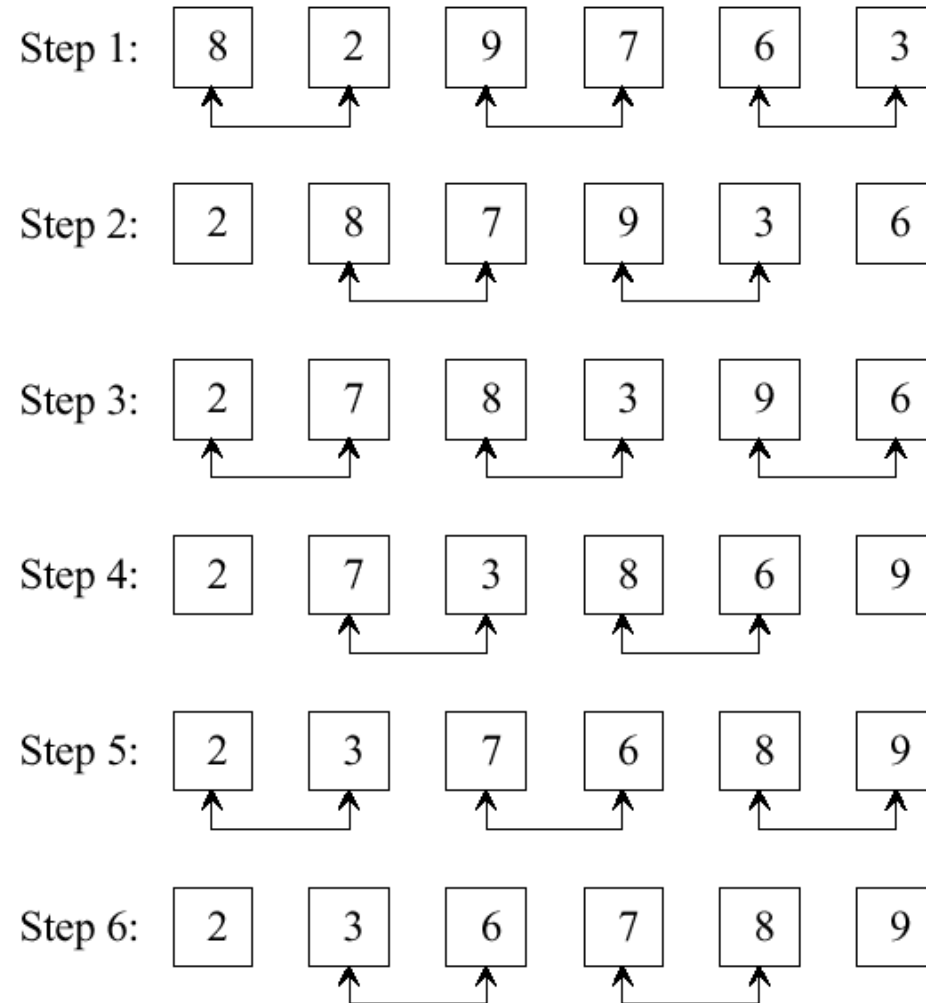


Fig. 11.34 Snapshots of sorting 6 numbers into an ascending order in a linear array.

Problem 11.13

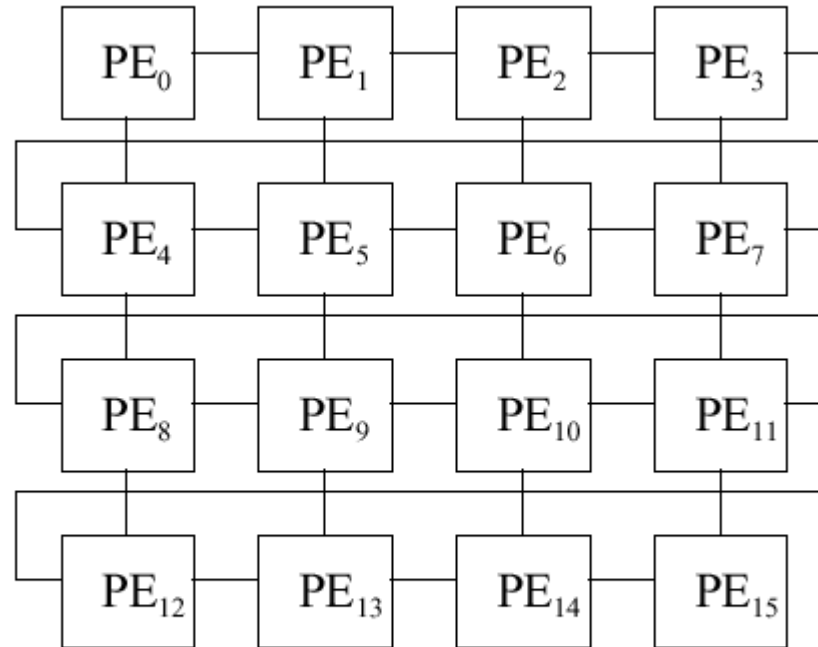


Fig. 11.35 16 PEs connected in a mesh.