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**ASSIGNMENT ANSWER:**

1. **THE CROSSBAR NETWORK:**

Crossbar networks allow any processor in the system to connect to any other processor or memory unit so that many processors can communicate simultaneously without contention. A new connection can be established at any time as long as the requested input and output ports are free. Crossbar networks are used in the design of high-performance small-scale [multiprocessors](https://www.sciencedirect.com/topics/computer-science/multiprocessors), in the design of routers for direct networks, and as basic components in the design of large-scale indirect networks. A crossbar can be defined as a switching network with N inputs and M outputs, which allows up to min{N, M} one-to-one [interconnections](https://www.sciencedirect.com/topics/computer-science/interconnection) without contention. Crossbar networks have been traditionally used in small-scale [shared-memory multiprocessors](https://www.sciencedirect.com/topics/computer-science/shared-memory-multiprocessor), where all processors are allowed to access memories simultaneously as long as each processor reads from, or writes to, a different memory. When two or more processors contend for the same memory module, arbitration lets one processor proceed while the others wait. The arbiter in a crossbar is distributed among all the switch points connected to the same output. However, the arbitration scheme can be less complex than the one for a bus because conflicts in crossbar are the exception rather than the rule, and therefore easier to resolve.

1. **CUBE INTERCONNECTION NETWORK:**

An n-cube network, also called hypercube, consists of N=2n nodes; n is called the dimension of the n-cube network. When the node addresses are considered as the corners of an n-dimensional cube, the network connects each node to its n neighbors. In an n-cube, individual nodes are uniquely identified by n-bit addresses ranging from 0 to N-1. Given a node with binary address d, this node is connected to all nodes whose binary addresses differ from d in exactly 1 bit. For example, in a 3-cube, in which there are eight nodes, node 7 (111) is connected to nodes 6 (110), 5 (101), and 3 (011). The figure below demonstrates all the connections between the nodes.

 Figure 1: A three-dimensional cube.

1. **FAT TREE CONNECTION:**

The fat tree network is a universal [network](https://en.wikipedia.org/wiki/Network_theory) for provably efficient communication. In a [tree](https://en.wikipedia.org/wiki/Tree_%28data_structure%29) [data structure](https://en.wikipedia.org/wiki/Data_structure), every branch has the same thickness, regardless of their place in the hierarchy—they are all "skinny" (*skinny* in this context means low-[bandwidth](https://en.wikipedia.org/wiki/Bandwidth_%28computing%29)). In a fat tree, branches nearer the top of the hierarchy are "fatter" (thicker) than branches further down the hierarchy. In a [telecommunications network](https://en.wikipedia.org/wiki/Telecommunications_network), the branches are [data links](https://en.wikipedia.org/wiki/Data_link); the varied thickness (bandwidth) of the data links allows for more efficient and technology-specific use. Fat-trees are optimal interconnects for large-scale clusters and, by extension, for WSCs. When using a fat-tree interconnect servers are placed at the leafs of the tree, while switches populate the root and the internal nodes of the tree. Fat-trees have additional links to increase the bandwidth near the root of the tree. Some set of paths in a fat-tree will saturate all bandwidth available to the end hosts for arbitrary communication patterns. A fat-tree communication architecture can be built with cheap commodity parts as all switching elements of a fat-tree are identical.