NAME: **Ibegbu Ejiamike Albert**

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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. Hypercube interconnection network is formed by connecting N nodes that can be expressed as a power of 2. This means if the network has n nodes it can be expressed as: N=2m

where m is the number of bits that are required to label the nodes in the network. So, if there are 4 nodes in the network, 2 bits are needed to represent all the nodes in the network. The network is constructed by connecting the nodes that just differ by one bit in their binary representation. This is commonly referred to as Binary labelling. A 3D hypercube internetwork would be a cube with 8 nodes and 12 edges. A 4D hypercube network can be created by duplicating two 3D networks, and adding a most significant bit. The new added bit should be ‘0’ for one 3D hypercube and ‘1’ for the other 3D hypercube. The corners of the respective one-bit changed MSBs are connected to create the higher hypercube network. This method can be used to construct any m-bit represented hypercube with (m-1)-bit represented hypercube.

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.

1. **FAT TREE CONNECTION:**

It is recommended that one should have basic knowledge of Tree topology.

Fat tree network topology looks like a tree topology like. In tree topology, we have same terminologies like Root, parent, child etc. This is mainly used to connect a large number of physical servers/ computers in a large data center. In the tree structure topology, leaf nodes are physical servers or computers. Rest other nodes are switches.

Switches are basically 3 types: Core switches, Aggregation switches, and Edge switches.

Servers can be heterogeneous in terms of their configurations.

Fat tree topology is based on the complete binary tree. Below is an example of 3 layer Fat tree topology. The top layer (level-0) of switches is called Core layer. The second layer of switches is called Aggregation layer. And the third layer of switches is called Edge layer. The number of ports in each switch is same.

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 thin(i.e. low bandwidth) . 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.

