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Multiprocessor Packaging

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1 Introduction

This note describes a simple scheme for packaging large multiprocessors assuming the existence of a four input four output switching module. Given such a module it describes a packaging scheme for building a 4N processor system where N is a power of sixteen. The scheme uses the popular banyan, delta, omega, butterfly interconnection network and is an extension of the work described in David S. Wise's paper "Compact Layouts of Banyan/FFT Networks" published in the proceedings of the "CMU Conference on VLSI Systems and Computations" held in October of 1981.

In the discussion below we will use the following notation. For any integers i and j, we use rem(i j) to represent the remainder that results when i is divided by j. For any real numbers a and b, we use a**b to represent a raised to the b power.

2 Description

The system is composed of 4(N**(1/2)) identical printed circuit boards. If n is such that 4**n is equal to N then each board contains N**(1/2) processors and ((N**(1/2))/4)(n + 1) switching modules.

The system contains a single backplane. 2(N**(1/2)) boards are attached to each side of the backplane. The orientation of the boards attached to one side of the backplane differs by 90 degrees from the orientation of boards attached to the other side. This is shown in Figure 1.

The boards attached to a given side of the backplane are divided into 2 groups with N**(1/2) boards in each group. The groups are interleaved across the backplane as shown in Figure 2.

The switching modules on a board are arranged into a stage of (N**(1/2))/4 modules and two butterfly networks as shown in Figure 3. Each of the butterfly networks have N**(1/2) inputs and N**(1/2) outputs.

The outputs of the transmitting butterfly networks of the boards in a given group on a given side of the backplane are connected to the inputs of the receiving networks of the boards in the same group on the other side of the backplane. In particular if the boards of the given group on the given side of the backplane are numbered from 0 to N**(1/2) - 1 and if the boards in the same group on the other side of the backplane are numbered similarly then for any integers i and j such that $0 \leq i \leq$ N**(1/2) - 1 and $0 \leq j \leq$ N**(1/2) - 1, the i output of the transmitting network of the j board on the given side of the backplane is connected to the j input of the receiving network

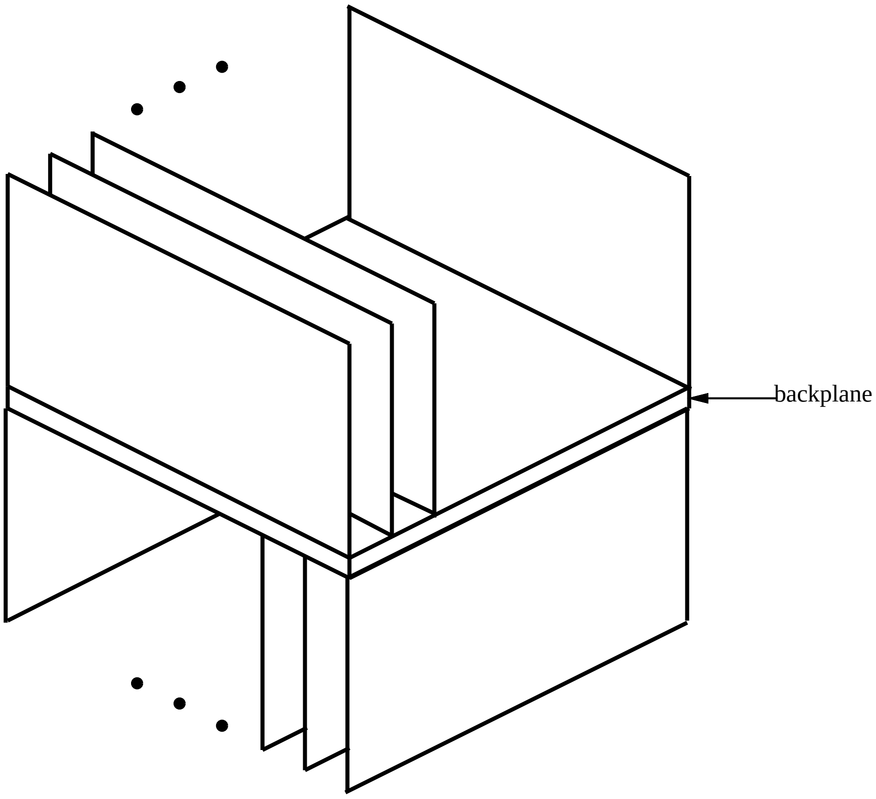

Figure 1: System Backplane

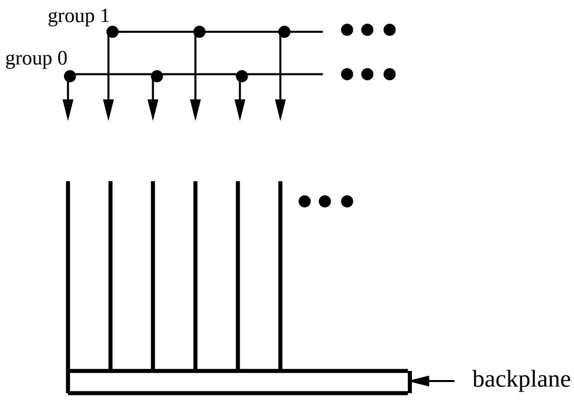

Figure 2: Board Groups

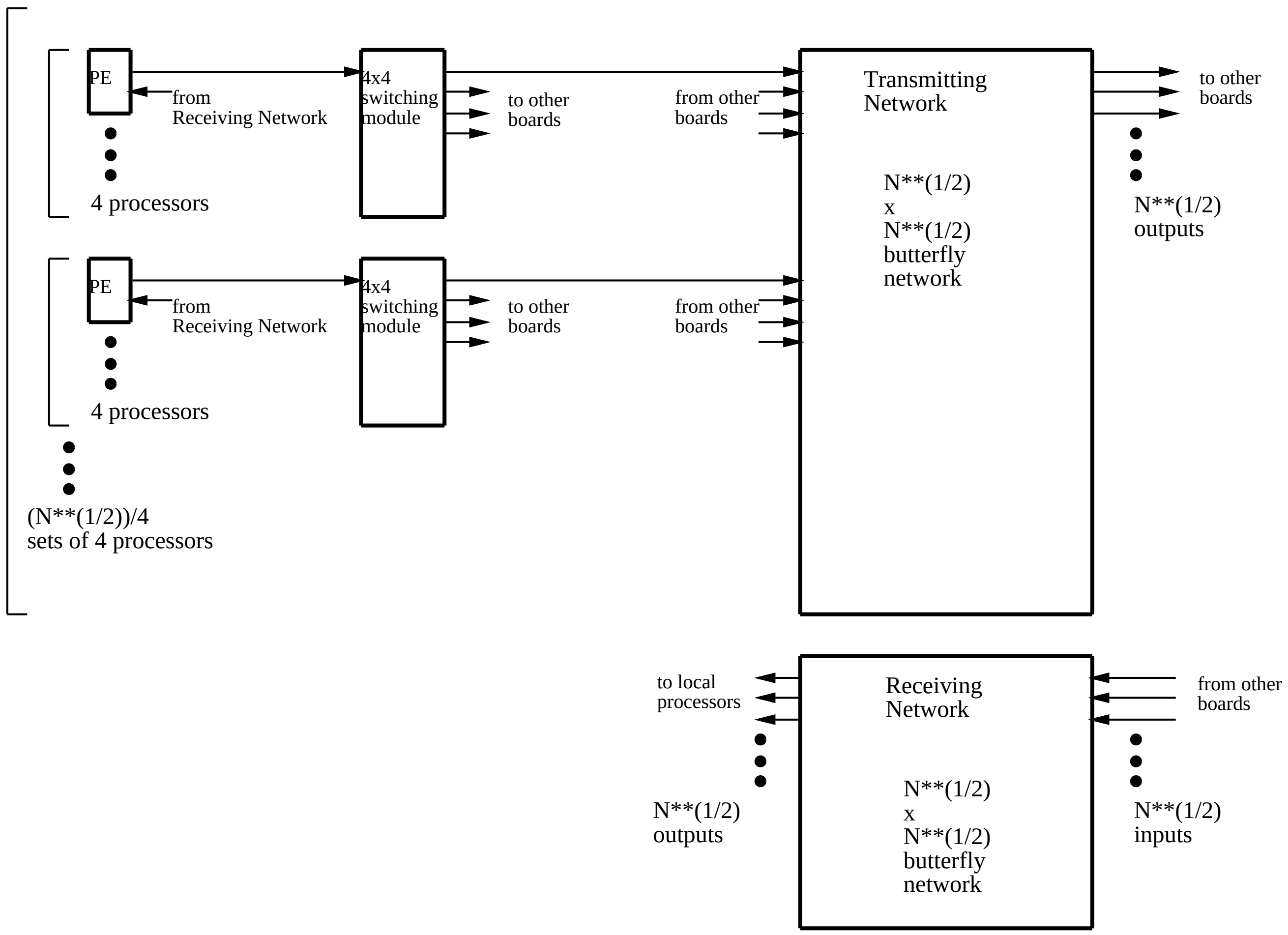

Figure 3: Board Components

of the i board on the other side of the backplane. This in effect creates a N x N butterfly network from the boards of the given group on the given side to the boards of the same group on the other side. The wiring of the connectors on the boards is such that only wires that go straight through the backplane are required to make the interconnects described above.

As is shown in Figure 3, only one output of a given switching module in the first stage (the stage prior to the transmitting network) of a given board is attached directly to the transmitting network of the board. The other three outputs of the module are connected to the transmitting networks of other boards. Similarly the transmitting network on the given board is connected to outputs from first stage modules on other boards.

In particular if the first stage modules on each board are numbered from 0 to (N**(1/2))/4 - 1, if the outputs of each module are numbered from 0 to 3, and if the inputs of each transmitting network are numbered from 0 to N**(1/2) - 1 then for any integers i and j such that $0 \leq i \leq$ (N**(1/2))/4 - 1 and $0 \leq j \leq$ N**(1/2) - 1, the outputs of the i module on the j board of a given group on a given side of the backplane are connected as follows. The 0 output is connected to the 4i input of the transmitting network on the same board. The 1 output is connected to the 4i + 1 input of the transmitting network of the j board of the other group on the same backplane side. The 2 output is connected to the j - (rem(j 4)) + 2 input of the transmitting network of the 4i + (rem(j 4)) board of the same group on the other backplane side. The 3 output is connected to the j - (rem(j 4)) + 3 input of the transmitting network of the 4i + (rem(j 4)) board of the other group on the other backplane side.

While these connections can not be accomplished by straight through backplane wires, they can be accomplished using fairly short backplane wires. As is shown in Figure 4, the backplane can be broken up into a (N**(1/2))/4 x (N**(1/2))/4 grid. Each square of the grid has eight boards connected to it on one side and eight on the other as is shown in Figure 5. The above connections can be implemented using wires that are local to each square of the grid. All of the squares can be wired using the same pattern. One possible pattern of tracts for the wires required for these connections is shown in white in Figure 6. It should be noted that slightly more complicated patterns that result in shorter wires are possible.

If the rows of the backplane grid are numbered from 0 to (N**(1/2))/4 - 1 and if the columns are numbered in a similar fashion then for any integers i and j such that $0 \leq i \leq$ (N**(1/2))/4 - 1 and $0 \leq j \leq$ (N**(1/2))/4 - 1, the wires in backplane grid square i, j are responsible for connecting the number j first stage modules of the eight boards on one side of the backplane to the 4i + 1 through 4i + 3 inputs of the transmitting networks of the eight boards on the other side of the backplane. Similarly the wires in backplane grid square i, j are responsible for connecting the number i first stage modules of the eight boards of the second backplane side to the 4j + 1 through 4j + 3 inputs of the transmitting networks of the eight boards on the first backplane side. Given the definition of the interconnection pattern (given two paragraphs above), the grid square wires only connect a given board to three other boards as is shown in Figure 6.

3 Butterfly Network

For any M that is greater than four and is a positive power of four, a M input M output butterfly network can be constructed using M/4 switching modules with four inputs and four outputs, and four butterfly networks with M/4 inputs and M/4 outputs as is shown in Figure 7. Of course a four input four output network is simply one switching module.

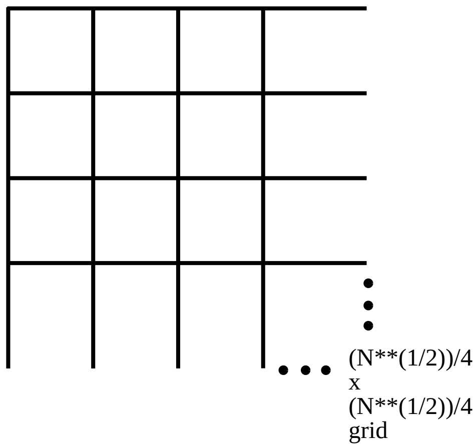

Figure 4: Backplane Grid

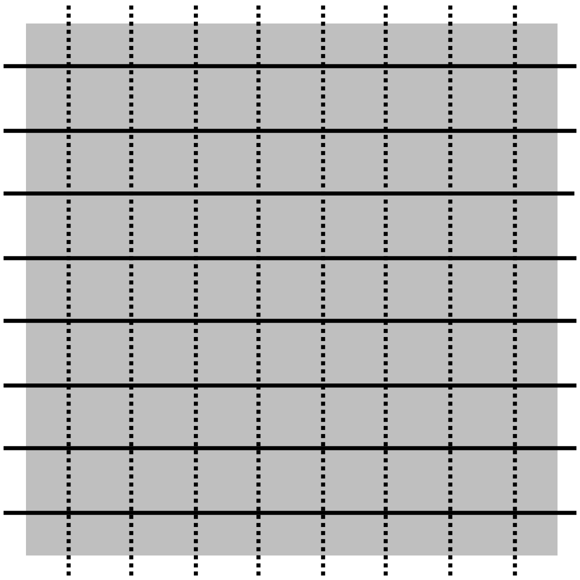

Figure 5: Grid Square of the Backplane

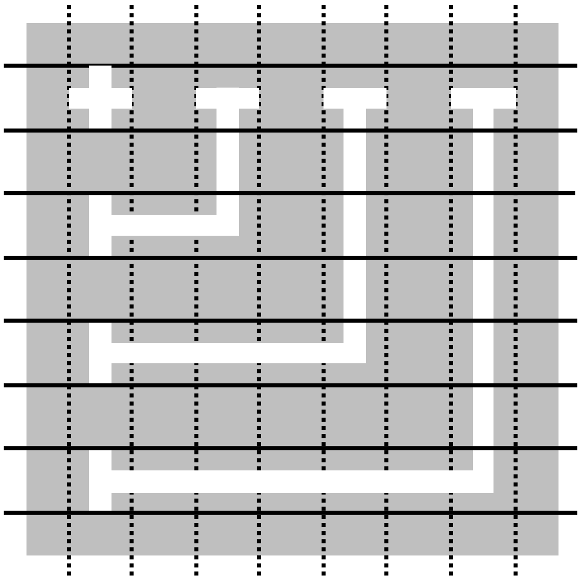

Figure 6: Wiring Tracts in a Backplane Grid Square

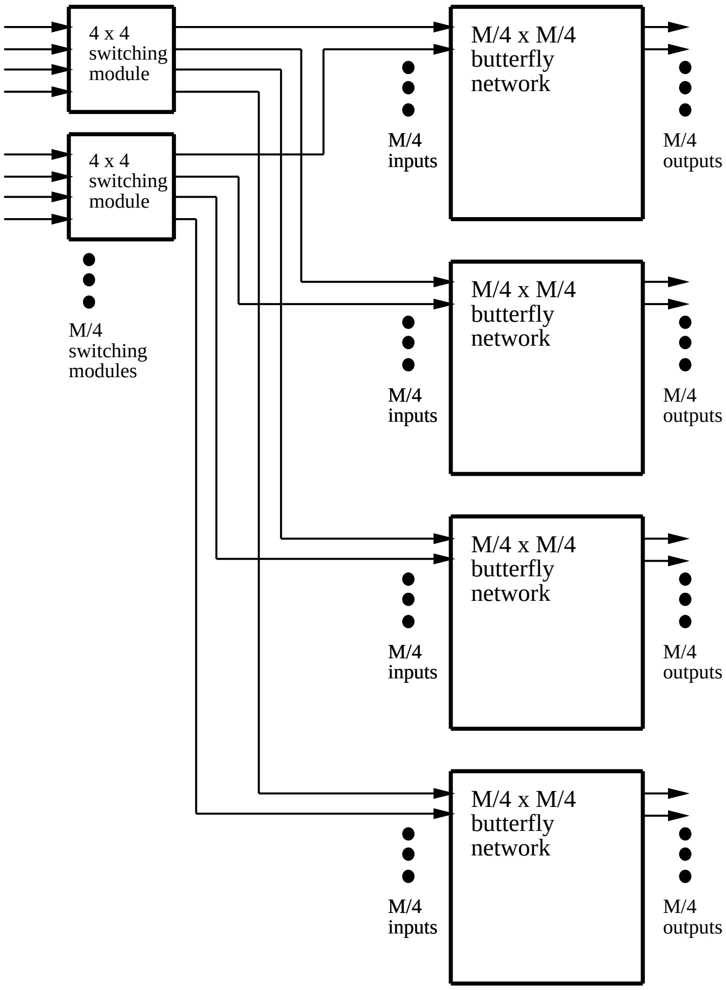

Figure 7: M x M Butterfly Network