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Comparison of Communication Algorithms on OTIS-HHC and OTIS-Ring Parallel Architectures

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Abstract: ***The OTIS (Optical Transpose Interconnection System) has recently attracted the attention of researchers and it has become very popular for solving real life computation and communication intensive applications. In this paper, we have presented a comparison of communication algorithms on OTIS-HHC and OTIS-Ring architectures. Gossiping is a common process for solving some of the problems like polynomial interpolation, matrix multiplication, prefix computation and enumeration sorting. The proposed algorithm is based on some predefined data routing functions. To analyze the time complexity of the proposed communication algorithms, we have considered the data movements on electronic link and optical link. The time complexity of both the proposed algorithms is O(n) OTIS moves and $O(n^2)$ electronic moves.***

Keywords: **OTIS-HHC, OTIS-Ring, interconnection network, parallel algorithm, communication algorithm, gossiping, time complexity**

1. Introduction

Optical Transpose Interconnection System (OTIS) has become one of the most popular parallel architectures for developing parallel algorithms for solving communication and computation intensive problems. An OTIS is a hybrid architecture that exploits electronic and optical links to provide interconnectivity among the processors [1], [2], [3]. The electronic links are used to connect the processors that are in a few millimeter range and these nodes can be fabricated within a chip. The free space optical links connect the processing nodes of one group to that of other groups. In an OTIS model, the processors are organized in groups. Each group contains equal number of processing nodes and the number of groups within the architecture may or may not be equal to the processing nodes within each group. If, the number of processing nodes within the group is equal to the number of group within the architecture, then the bandwidth of the OTIS system can be maximized and the power consumption can be minimized [4], [5]. Any OTIS model is characterized by the interconnection pattern of each group within the overall architecture. If the interconnection pattern G is implemented to connect processing nodes within each group then the overall architecture is named as OTIS-G. In the recent years, many researchers have exploited OTIS parallel architectures to propose various parallel algorithms for solving several scientific and engineering problems. A rich literature on OTIS models and optical network is also available such as basic operations [6], matrix multiplication [7], [8], BPC permutation [9], sorting [10], [11], [12], [13], [14], [15], [16] routing [10], [12], [16], image processing [16], conflict graph construction [17], load balancing [18], [19], polynomial interpolation [21], polynomial root finding [20], [21], prefix computation [22], gossiping [23], [24], [25].

In this paper, we have presented a comparison of proposed communication algorithms for OTIS-HHC and OTIS-Ring architectures. OTIS-HHC is a relatively parallel architecture proposed in [26]. To analyze the time complexity of the proposed algorithms, we count the data movements through electronic links (electronic moves) and through optical links (OTIS moves). The time complexity of the proposed algorithms on both the architectures is $O(n)$ OTIS moves and $O(n^2)$ electronic moves.

The paper is organized as follows: the topology of OTIS-HHC is presented in section 2. In section 3, we have presented the proposed algorithms followed by conclusion in section 4.

2. Topology of OTIS-HHC and OTIS-Ring

The OTIS-HHC topology combines the attractive properties of both OTIS and hyper hexa-cell (HHC) topologies, where HHC is based on the properties of hypercube. The hypercube is one of the most versatile and efficient networks discovered so far for parallel computation. The topological structure and properties of an OTIS-HHC is based on that of hypercube, hyper hexa-cell (HHC) and OTIS topologies [26]. The topology of each group in an OTIS-HHC is a hyper hexa-cell. A d_h-dimensional HHC constitutes a hypercube of dimension d_h+1. Various topological properties have been in discussed in detail [26]. The diameter of OTIS-HHC is $(2d_h+3)$. The maximum and minimum degrees are (d_h+3) and (d_h+2) respectively. In an OTIS-HHC, the number of groups can be equal to the number of processors within each group or the number of groups can be half the number of processors within each group. The network size is $(6\times2^{d-1})^2$ for G=P and $((6\times2^{d-1})/2)^2$ for G=P/2. The bisection width of an OTIS-HHC is $((6\times2^{d-1})/2)^2$ for G=P and $((6\times2^{d-1})/4)^2$ for G=P/2. The OTIS-HHC is better in terms of diameter, minimum node degree, bisection width and optical cost than that of OTIS-Mesh. The topology of one-dimensional OTIS-HHC is shown in Fig. 1. The topology of OTIS-Ring is given Fig. 2. The thin solid lines represent the electronic links connecting intra-group processing nodes. The dashed thick lines represent free space optical links representing inter-group processing nodes.

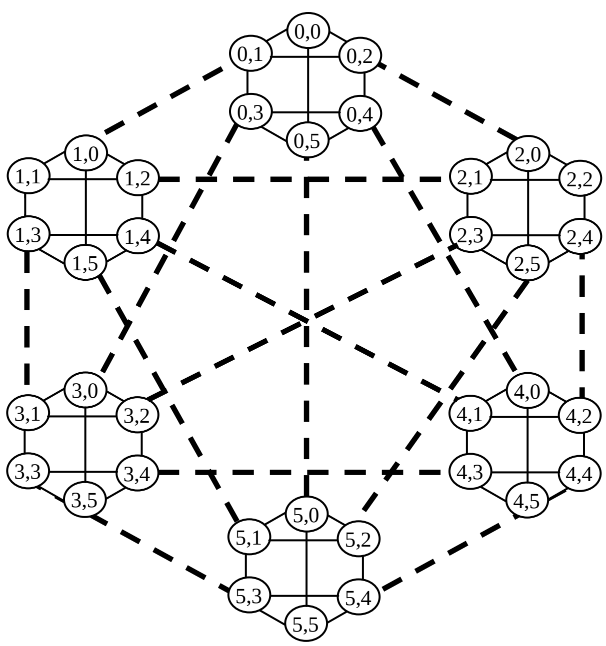

Figure 1: Topology of one-dimensional OTIS-HHC

In an OTIS-Ring architecture, the interconnection pattern of each group is a ring and hence called OTIS-Ring. As we intend to compare the time complexity of the algorithms, we have shown the OTIS-Ring architecture in Fig. 2 of the same size as that of OTIS-HHC network.

3. Proposed Algorithms

In the proposed algorithm, first we need to realize that there are two triangles and electronic links connect the counterparts. A ring can be easily embedded in each of the triangle within each HHC and a ring can also be embedded in HHC (group). To present a comparison between the time complexities of the algorithms proposed for these two architectures, we consider the network size to same for both. Let the network size be n^2, i.e. each group contains n processing nodes.

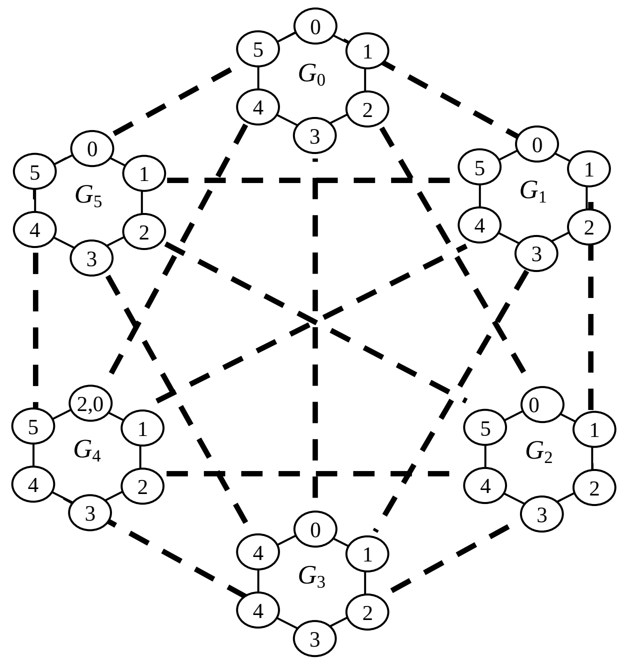

Figure 2: Topology of OTIS-Ring

The proposed gossiping algorithm is based on some basic data routing functions. For the sake of simplicity, we consider each processing node to have two Registers *A* and *B* containing different data values. The *Group Move* procedure actually moves the data of group to another and which can be given as follows:

Algorithm Gossiping-OTIS-HHC

Step 1: Initialize the Registers A and B

Step 2: /* For each group, do in parallel */

/* For each ring in each group, do in parallel */

For t=1 to (n/2) - 1, do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

Step 3: /* For all the groups, do in parallel */

Exchange the data between the triangles

Step 4: /* For each group, do in parallel */

/* For each ring in each group, do in parallel */

For *t*=1 to (*n*/2) - 1, do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

Step 5: /* For all the groups, do in parallel */

For *t*=1 to (*n*/2) - 1, do in parallel

{

Call Group Move

/* For each group, do in parallel */

/* For each ring in each group, do in parallel */

For *t*=1 to (*n*/2) - 1, do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

/* For all the groups, do in parallel */

Exchange the data between the triangles

/* For each group, do in parallel */

/* For each ring in each group, do in parallel */

For *t*=1 to (*n*/2) - 1, do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

}

Time complexity: Step 1 requires constant time for data initialization. Steps 2 and 4, each requires (0.5*n*-1) electronic moves. Only one electronic move is needed for Step 3. Step 5 needs ($0.5n^2$-*n*) electronic moves and (*n*-2) OTIS moves. Thus the time complexity of the algorithm *Gossiping-OTIS-HHC* is (*n*-2) OTIS moves and ($0.5n^2$-1) electronic moves.

Algorithm Gossiping-OTIS-Ring

Step 1: Initialize the Registers A and B

Step 2: /* For each group, do in parallel */

/* For each ring in each group, do in parallel */

For *t*=1 to (*n* – 1), do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

Step 3: /* For all the groups, do in parallel */

For *t*=1 to (*n* –1), do in parallel

{

Call Group Move

/* For each ring, do in parallel */

For *t*=1 to (*n*-1), do in parallel

{

Clockwise rotation of Register *A*

Anticlockwise rotation of Register *B*

}

}

Time complexity: Step 1 requires constant time for data initialization. Step 2 requires (*n*-1) electronic moves. Step 3 needs *n*(*n*-1) electronic moves and 2(*n*-1) OTIS moves. Thus the time complexity of the algorithm *Gossiping-OTIS-Ring* is 2(*n*-1) OTIS moves and (n^2-1) electronic moves.

The comparative study between OTIS-HHC and OTIS-Ring architecture based on the data movements through electronic and OTIS links is given in Table 1.

Table 1: comparisontime complexity based on data movements

Processors/	OTIS-HHC		OTIS-Ring	
	OTIS Moves	Electronic Moves	OTIS Moves	Electronic Moves
n = 6	4	17	10	35
n = 12	10	71	22	143
n = 24	22	287	46	575
n = 48	46	1151	94	2303

It is obvious from Table 1that the OTIS-HHC needs lesser data movements because of its topological properties and seems to be preferable to OTIS-Ring architecture.

4. Conclusion

In this paper, we have presented the comparison of time complexities of proposed communication algorithms. The algorithm *Gossiping-OTIS-Ring* requires 2(n-1) OTIS moves and (n^2-1) electronic moves. The algorithm for OTIS-HHC, *Gossiping-OTIS-HHC* needs (n-2) OTIS moves and (0.5n^2-1) electronic moves. As it is clear, the OTIS-HHC requires lesser data movements through optical and electronic links.

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