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Parallel Prefix Algorithm for OTIS-HHC Architecture

Abdul Hannan Akhtar[1], Keny Thomas Lucas[2]

[1]Department of Electronics and Communication Engineering,
Government Polytechnic, Ranchi, Jharkhand, India
abdulhannan.akhtar@gmail.com

[2]Principal, Xavier Institute of Polytechnic and Technology,
Ranchi, Jharkhand, India
kenny.lucas@gmail.com

Abstract: ***The OTIS (Optical Transpose Interconnection System) has become one of the popular models for developing parallel algorithms solving various computation and communication intensive problems. Various real life problems including job scheduling, knapsack, loop optimization, evaluation of polynomials, solutions of linear equations, and polynomial interpolation depend on the time complexity of prefix computation for the efficiency for their respective solutions. In this paper, we have proposed an algorithm for parallel prefix computation on OTIS-Hyper Hexa-cell. In this architecture, the time complexity of the algorithm for n^2 data elements is O(n) electronic moves and O(n) OTIS moves.***

Keywords: Interconnection network, OTIS-HHC, time complexity, parallel algorithm, prefix.

1. Introduction

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The OTIS (Optical transpose Interconnection System) [1], [2], [3] is a hybrid system that exploits the best features of electronic links as well as optical links for developing parallel architectures. The optical links are superior to electronic links in terms of power, speed and crosstalk properties if the connect distance between processors is more than a few millimeters. The electronic links are preferred to optical links for smaller distance between processors. The total number of processors in the network is divided into groups and each group can be assumed to be a microchip in an OTIS model. All the processors within a group are connected through the electronic links whereas the processors of one group are connected to the processors of different groups through the optical links. The number of groups in an OTIS network can be equal to the number of processors in each group for maximized bandwidth and minimized power consumption [4], [5]. The interconnection pattern of processors within each group determines the overall model of such system, i.e. an OTIS-G has G interconnection pattern for all of its groups. Some of the OTIS models are OTIS-Ring, OTIS-Mesh, OTIS-Hypercube, OTIS-Torus, OTIS-Mesh of trees. The OTIS-HHC is a newly proposed architecture of OTIS family [6].

In the recent years, researchers have proposed many parallel algorithms for various OTIS models that includes basic operations [7], matrix multiplication [8], [9], BPC permutation [10], sorting [11], [12], [13], [14], [15], [16], [17], routing [11], [13], [17], image processing [18], construction of conflict graph [19], load balancing [20], [21], polynomial root finding [22], [23], polynomial interpolation [22], [24], prefix computation [25], [26], [27], [28], [29], [30], gossiping [31], [32], [33].

Many real-life problems, such as job scheduling, knapsack, loop optimization, evaluation of polynomials, solutions of linear equations, and polynomial interpolation depend on the efficiency of prefix computation for their solutions. For a given set of data elements, i.e. x_1, x_2, x_3, $\cdots$, x_N belonging to a domain $\Re$, the prefix computation can be given as $P_i = x_1 \oplus x_2 \oplus x_3 \ldots \oplus x_i$, $1 \le i \le N$, where $\oplus$ is an associative operator over the domain $\Re$. The algorithm proposed in for extended multi-mesh network requires $O(N_{1/4})$ on N processors. The algorithm proposed for optical multi-trees requires $O(\log n)$ electronic moves + 4 optical moves for n^3 data elements on n^3-n^2 processors. In this paper we propose a parallel algorithm for prefix computation on a newly proposed OTIS model called OTIS-HHC [6]. Our proposed algorithm requires $(3.5n+2)$ electronic moves and $2(n-1)$ OTIS moves.

The rest of the paper is organized as follows. Section 2 describes the topology of the OTIS-HHC. Our proposed algorithm is discussed in section 3 followed by conclusion in section 4.

2. Topology of OTIS-HHC

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 [6]. 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 [6]. 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 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.

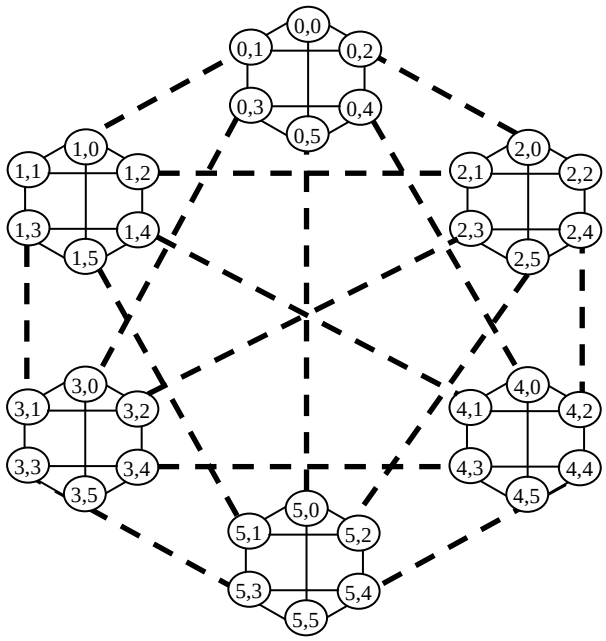

Figure 1: Topology of one-dimensional OTIS-HHC

In this architecture, the processing nodes of a hexa-cell are connected to processing nodes of other hexa-cells through the optical links using transpose rule. The processing elements represented by two indices. The first represents the group's number in the overall architecture and the second indicates the processor's number. Let any processing node be represented by (g,p), then g indicates the position of group in the architecture in which processor p is located. The processor (g,p) is connected to the processor (p,g) through optical link as shown in Fig. 1.

3. Proposed Algorithm

The local prefix computation (within the group) is illustrated below through Table 1.

Table 1: Illustration of Prefix computation within the group

Step	P_0	P_1	P_2	P_3	P_4	P_5
1	A_0	A_1	A_2	A_3	A_4	A_5
2		A_0	A_1		A_3	A_4
3			A_0			A_3
4	A_{pp}	A_{pp}	A_{pp}			
5	A_{pr}	A_{pr}	A_{pr}	A_{pr}	A_{pr}	A_{pr}
6						A_{pg}

It is obvious from the illustration presented in Table 1 that in step 1, all the processing nodes within each group are initialized with the data elements. It is also clearly seen that each group has two triangles and to exploit parallelism, we intend to compute partial prefix within the two rings in parallel. The content of the last processor of the upper triangle obtained in step 3 is broadcasted locally and then sent to the concerned connected processors of the lower ring in step 5. The final prefix computation is achieved in step 6 as shown in Table 1. This procedure is named as *LocalPrefix.* In our proposed algorithm, we will be using this procedure.

Algorithm Prefix-HHC

Step 1: For all the groups, do in parallel
    LocalPrefix
Step 2: For all the groups, do in parallel
    j=0;
    for $i = j$ to n-1
    {
      Broadcast the content of P_5 locally in G_i
      Group Move (i)
      Calculate Sum
      $j = j$+1
    }

Time Complexity: Step 1 takes 0.5n+1 electronic moves. Step 2 needs 3(n-1) electronic moves and 2(n-1) OTIS moves. The overall requirement is (3.5n+2) electronic moves and 2(n-1) OTIS moves.

4. Conclusion

In this paper, we have presented an algorithm for prefix computation on OTIS-HHC architecture. The time complexity of the algorithm has been represented in terms of data movement through the links; $O(n)$ electronic moves and $O(n)$ OTIS moves for n^2 data elements.

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