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INTRODUCTION TO PARALLEL PROGRAMMING

Lecture 20. Estimation of Communication Complexity for Parallel Algorithms

Nizhni Novgorod

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Lecture_20_. Estimation of Communication Complexity for Parallel Algorithms

Time delays in case of data transmission via communication channels to ensure interaction of independent processes can to a large extent determine the efficiency of parallel computations. This lecture tackles the issues of analysis of data streams generated in the course of parallel algorithm execution. It gives a general description of data transmission mechanisms, analyzes complexity of basic communication operations and reviews logical representation methods of multiprocessor structure.

This lecture is devoted to estimation of communication complexity for parallel algorithms.

In the first part of the lecture gives the general characteristics of the routing algorithms and data transmission methods. The method of *store-and-forward routing* and *cut-through routing* method are analyzed in detail. The time of communication operations is estimated for these methods.

In the second part of the lecture defines the basic types of data transmission operations, which are carried out in the course of parallel computations. The following communication operations are referred to as the basic ones:

- *data transmission among the network processors*,
- *one-to-all broadcast* or *single-node broadcast* and the reverse operation, i.e. *single-node accumulation*.

Data transmission for all the mentioned above operations are considered in terms of the ring, the grid and the hypercube topologies. For each of the algorithms described there are estimations of the complexity time both for data transmission and packet communication.

In the third part of the lecture describes the methods of logical presentations of topologies on the basis of physical interprocessor structures. The use of logical topologies simplifies the description of a number of data transmission algorithms, decreases expenses on communication operations etc.

In the final part of the lecture describes the models, which may help to estimate the time of data transmission operations for cluster computer systems. For comparing the accuracy of different time estimations a number of computational experiments have been carried out. The results of the experiments are described in the subsection. The results of the experiments makes possible to find the most precise model (model B). Besides, it is noted that for the preliminary analysis of the time communication complexity a simpler model (the Hockney model) may be more suitable.

The works by Kumar (1994) and Quinn (2004) may be recommended as additional teaching material on the problems discussed in the subsection.

Creating models for estimating the time of communication operations is widely discussed in many papers. Such works as Culler, et al. (1996), Skillicorn and Talia (1998), Andrews (2000) might be of use. The Hockney model was first published in Hockney (1994). Model B from final path of the lecture is presented in Gergel, Strongin (2001).

Test questions

1. What basic characteristics are used for the estimation of the data transmission network topology? Give the values of the characteristics for the following types of communication structures (a complete graph, a linear array, a grid etc.)
2. What basic methods are applied to routing the data transmitted in the network?
3. What are the basic methods of data transmission? Give the analytical estimations of the execution time for these methods.
4. What data transmission operations may be selected as the basic ones?
5. What are the execution algorithms of one-to-all broadcast for the ring, the grid and the hypercube topologies? Give the estimations of the time complexity for these algorithms.
6. What are the possible execution algorithms of reduction? Which of them is the best as far as the execution time is concerned?
7. What does the execution algorithm of the circular shift consist in?
8. Why is it efficient to use logical topologies? Give the examples of the algorithms for logical presentation of communication network structure.
9. How do the models for estimating the execution time of data transmission in cluster computer systems differ from one another? Which model is the most accurate? Which of them may be used for the preliminary analysis of the time comlexity of the communication operations?

Practice

1. Develop the execution algorithms of the basic data transmission operations for the network topology in the form of a three-dimensional grid.
2. Develop the execution algorithm of the basic data transmission operations for the network topology in the form of a binary tree.
3. Use model B from final path of lecture for the estimation of the time complexity of data transmission operations. Compare the obtained results.
4. Use model C from final path of lecture for the estimation of the time complexity of data transmission operations. Compare the obtained results.
5. Develop the algorithms of logical presentation of the binary tree for various physical network topologies.

References

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3. **Hockney, R.** (1994). The communication challenge for MPP: Intel Paragon and Meiko CS-2. – Parallel Computing, 20 (3), pp. 389-398.

4. **Kumar V., Grama, A., Gupta, A., Karypis, G.** (1994). Introduction to Parallel Computing. - The Benjamin/Cummings Publishing Company, Inc. (2nd edn., 2003)

5. **Quinn, M. J.** (2004). Parallel Programming in C with MPI and OpenMP. – New York, NY: McGraw-Hill.

6. **Skillicorn, D.B., Talia, D.** (1998). Models and languages for parallel computation. – ACM Computing surveys, 30, 2.