IWR, University of Heidelberg — Winter term 2014/15
Exercise Sheet 3 — 6. November 2014

Exercise for Course

Parallel High-Performance Computing

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Return: 13. November 2014 in the exercise

Task 5 Single processors (5 points)

In the lecture the following techniques for enhancement of the processor performance have been presented:

- Speculative branch prediction
- Out-of-order execution
- Superscalar design (Instruction Level Parallelism, ILP)
- Speculative execution
- Thread-level parallelism
- Multi-core design

Describe the techniques *shortly* but precise with your own words.

Task 6 Deadlock-free Routing in the Hypercube (5 points)

(a) Describe how a deadlock can occur in a connection network with $4D$ hypercube structure.
(b) Design a deadlock-free routing algorithm for the d dimensional hypercube. For this start from a non-adaptive routing and the nodes have for each dimension an input- and output buffer (in total each node has $2d$ buffers), such that each connection is bidirectional (Hint: Partition the network into d sub-networks).

Task 7 Cube Connected Cycles (5 points)

Cube Connected Cycles (CCC) can be constructed out of hypercubes of dimension d. Therefore each node of the hypercube is substituted by a (inner) ring with d nodes. An example for the case $d = 3$ is shown in Figure 0.2. CCCs have been introduced to reduce the node degree of a connection network without significantly enhancing the diameter. Within this task we thus investigate node degree and diameter of CCCs.

(a) How large is the count e of processors of a CCC, that is constructed from a d-hypercube?
(b) What is the node degree from the CCC designed in (a)?
(c) What is the diameter of a network in dependence of dimension d when *dimension-order routing* is used. The choice of the routing dimension can be performed in arbitrary order. (*arbitrary order routing*? Which complexity arises then for the diameter dependent on the processor count e?
Hint: Dimension-order routing: Start at a node of an inner ring and think about, how many hops are necessary, to reach a hypercube ring structure, that is a ring of dimension $d-1$ of the original hypercube. From this position you have to move the maximal distance to another original node. For the CCC this node also is substituted by an inner ring, such that the maximal connection count is reached for each node of this inner ring. By arbitrary-order routing the hops in the first inner ring are eliminated. Using the result of (a) leads to the required dependency.

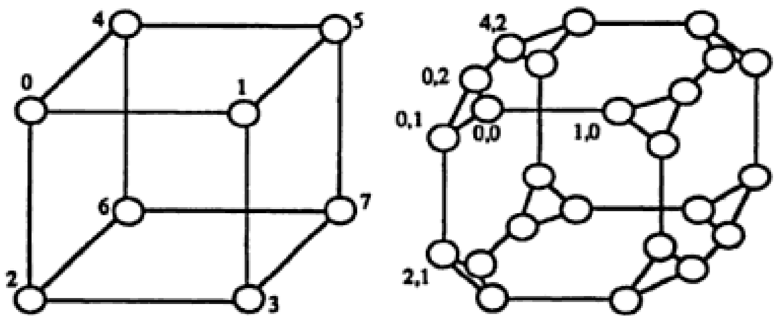

Abbildung 0.2: Cube Connected Cycles connection network constructed by a 3D hypercube. From: Parhami, B.: *Introduction to parallel processing: algorithms and architectures.*