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A PERFORMANCE ENHANCED AND COST EFFECTIVE DEADLOCK RECOVERY SCHEME FOR ADAPTIVE WORMHOLE ROUTED NETWORKS

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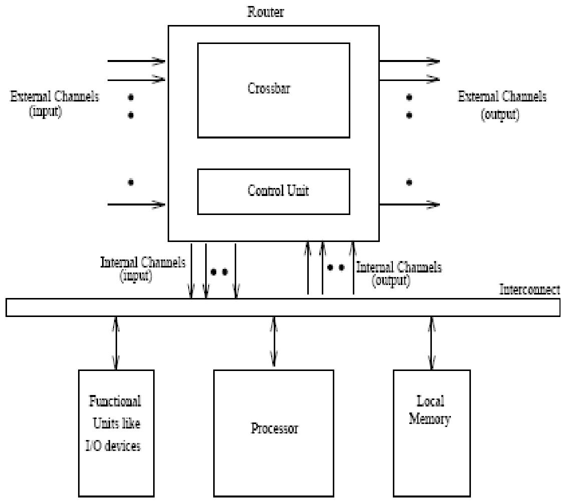
ABSTRACT

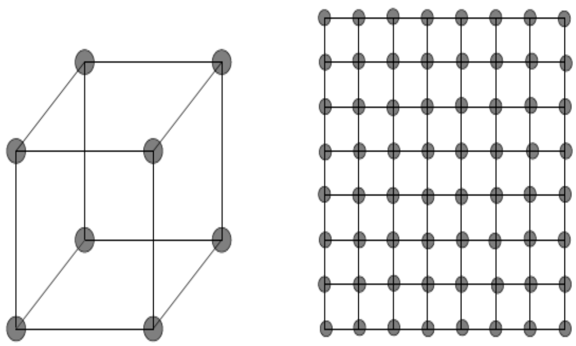
Deadlock free routing of messages is a challenge for the performance of directly connected network systems. Communication among the nodes of a directly connected multicomputer system is via message exchange. The wormhole routing is perceived as the best switching technique in directly connected systems. The technique suffers the challenges like deadlock avoidance. Deadlock recovery faces cost of implications of deadlock detection mechanism and consumes additional resources. The proposed work suggests a deadlock recovery scheme on reduced cost, with fewer resources, reduced complexity and enhanced performance.

Key Words- Switching, Wormhole routing, flit buffer, multicomputer, interconnected Network, Cost effective.

1. INTRODUCTION

Nodes of a parallel computers system are interconnected having their own memory, processor and other peripheral devices. The network is established under some topology as mesh, tree or hypercube. In the direct networks nodes have point-to-point direct connection to other nodes. These nodes communicate each other via message exchange. Each node has a router to deal with communication between the nodes. A crossbar switch is associated with every router to connect input and output channels, and a control unit for flow control. Coordination and communication of the nodes in association, facilitates massive computational power. The performance relies on the speed of processors and successful and fast communication. Message latency is a critical factor in the muticomputer systems. Message latency largely depends on routing, switching, topology and flow control.





(a) Three dimensional hypercube.   (b) Two-dimensional mesh (8x8).

2. BACKGROUND

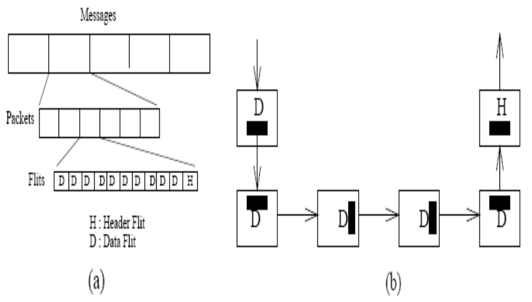
Communication in directly connected multi computer systems is established via message exchange. Messages are switched or routed from source to destination through intermediate nodes. A message is divided into manageable sized packets having all necessary routing information. Switching techniques used for routing purpose are as follows:

1.1 Circuit switching
1.2 Packet switching
1.3 Virtual cut-through switching
1.4 Wormhole switching

Wormhole Switching: Among the above techniques, the wormhole switching Technique has been found most suitable for directly connected networks in terms of efficiency, cost and performance.

In wormhole routing, a packet is further divided into small transmittable unit
of message known as flits. The leading flit is known as header flit, contains the routing information and all other flits contain data. All the data flits follow header flit in a sequence.
The major disadvantage with wormhole routing is that only header flit contains routing information and if the header flit blocks due to any reason in the network, then rest all the flits following header flit also block and this blocking may eventually create deadlock, hampering entire communication.

Virtual Channels: To reduce the occurrence of deadlocks, virtual channels are used in wormhole routing. Virtual channels provide alternative path to blocked messages and play major role in deadlock avoidance.



Types of Routing: Different strategies of routing are possible on the basis of different characteristics.

Source Routing: Path is decided from source to destination by the source node in prior.

Distributed Routing: Starting from source, routing decisions are taken by every node wherever a message reaches.

Deterministic Routing: A fixed single path is provided on the basis of source and destination address, regardless of network implications.

Adaptive Routing: Multiple path are provided from source to destination and the decision which path to traverse depends upon network and traffic conditions.

Parameters to Compare Routing Algorithms: The parameters to evaluate performance of routing algorithms are following:

1.5 average message latency
1.6 average system throughput
1.7 buffer size required
1.8 number of virtual channels required per physical channel

3. RELATED WORK

Occurrence of deadlock is one of the most crucial problems in the wormhole routing. Different approaches and measures have been taken to deal with this problem. Avoidance and recovery are two major approaches.

Routing flexibility is provided by use of virtual channels to avoid formation of cycles and thereby deadlocks, but adaptivity in routing increases hardware complexity and reduce router speed and causes adverse effect on overall performance. So the deadlock prevention mechanism not only require additional resources but degrade the performance of the network.

Experiments have shown that adaptivity does not improve performance in case of low dimensional networks and uniform traffic patterns. Moreover studies have shown that deadlock situations are rare in high dimensional multicomputer systems and it is not wise and cost effective to dedicate resources to handle rare situations.
So, the networks where deadlock situations are rare, messages can be allowed toroute fully adaptively and in case of formation of cycles a deadlock detection algorithm can be implemented and eventually a deadlock recovery mechanism can
break the cycle and resume the network again.

Reeves et. al. Scheme: Reeves et. al. proposed an adaptive routing scheme based on abort-and-retry mechanism in hypercube for recovering deadlock and minimize traffic congestion. In this scheme a message is aborted whenever it is blocked after a threshold number of cycles. This mechanism improves performance in a wider range of traffic conditions.

Kim, Liu and Chien Framework: This is called compressionless routing, an adaptive and fault-tolerant routing for broad range of topologies, without any virtual channels. The basic idea is to use fine-grain flow control and back pressure of wormhole routing to communicate routing status. The network interface uses the information to facilitate deadlock recovery and fault tolerance. This framework gives excellent performance in dimension-ordered networks.

The Disha Framework: The Disha is a deadlock recovery strategy proposed by Anjan and Pinkston. The routing uses no virtual channel or turn restrictions. In this strategy every node is equipped with an additional flit buffer which works as deadlock buffer and used only when deadlocks occur. This buffer can be shared by all neighbouring nodes. The deadlock buffers form a deadlock free lane for recovery. When deadlock occurs, only one of the blocked messages shifted to the deadlock free lane and routed along following minimal path towards its destination. In this way the cycle blocks and all the other messages resume their way.

The figure 3.1 given below shows deadlock cycle formed by four packets P1, P2, P3 and P4 which are endlessly waiting for one another and none of them is able to move, thereby hampering all.

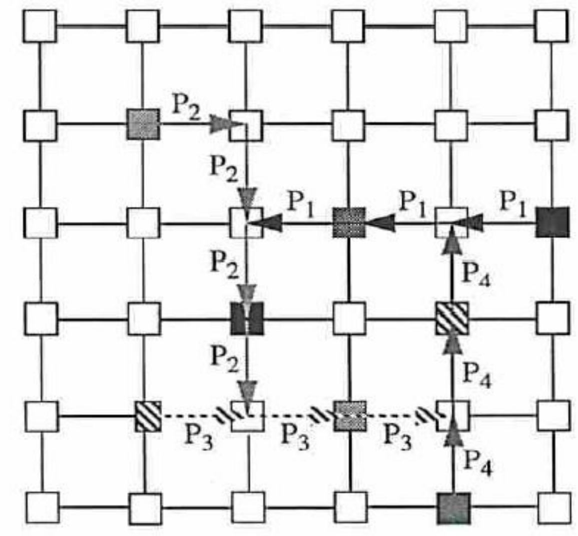


Fig. 3.1 deadlock in a mesh type network

In the figure 3.2 given below shows the recovery strategy, where the packet P1 follows the alternate path to reach its destination and let the packets P4 proceed followed by P3 and P2.

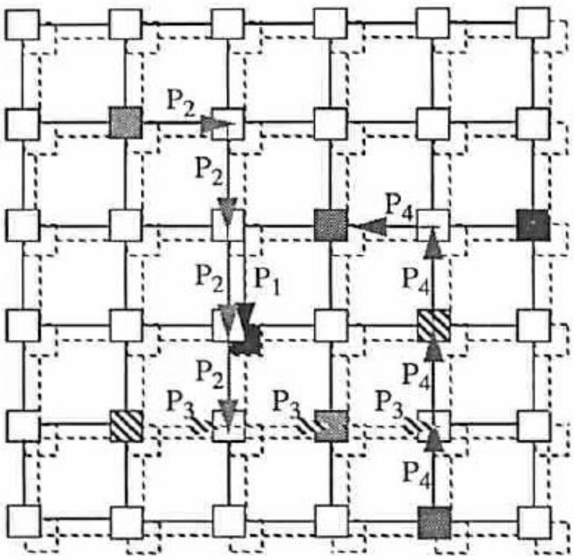


Fig. 3.2 Deadlock recovery strategy

4. PROPOSED WORK

The proposed work suggests some modification in the deadlock recovery strategy Disha, given by Anjan and Pinkston. To reduce cost, routing is done without any virtual channel and. Instead of equipping every node with additional flit buffer only alternate columns of a mesh can be equipped with flit buffers, and in case of formation of cycles the blocked messages can find alternative path through the columns having flit buffers. Once any one blocked message changes its way through deadlock free lane, the cycle breaks and all the other messages can resume their way. So the approach shall exhibit all merits of the Disha framework on 50% reduced cost of additional flit buffers. Moreover the complexity of routers because of additional flit buffers will also reduce to same extent, thereby enhanced performance on reduced cost.

Performance Analysis: Simulation results suggest that the 'Disha' strategy is far better than dimension order routing and Duato's scheme.

Comparison with Dimension Order Routing: Simulation results show that 'Disha' is 30% faster than dimension order routing for data flow through, and 25% faster in respect of clock cycles. Besides this 'Disha' with one virtual channel gives more than 25% better performance over dimension order at low load of load rate < 0.1. The figure below shows that saturation point for 'Disha' is approximate 0.1, while for dimension order, this is higher ie 0.14.

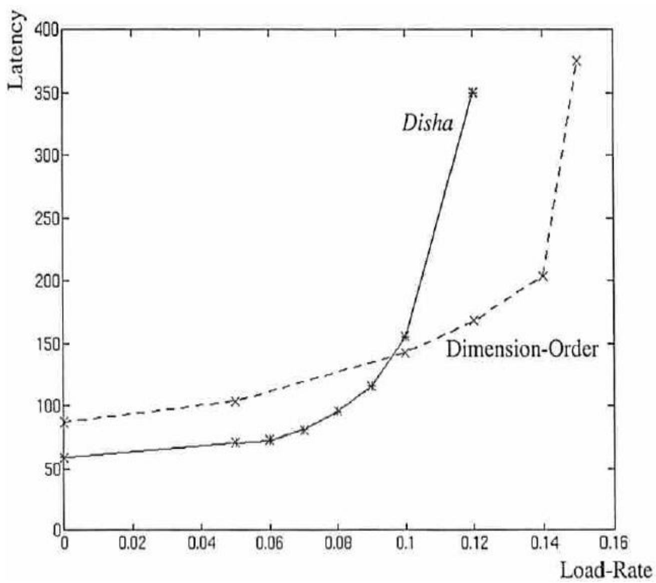


Fig. 4.1 comparison between 'Disha' and one VC dimension order routing

If we compare 'Disha' and dimension order both with two virtual channels, 'Disha' provides full adaptive routing, while saturation point of dimension order and 'Disha' is 0.14 and 0.20 respectively.

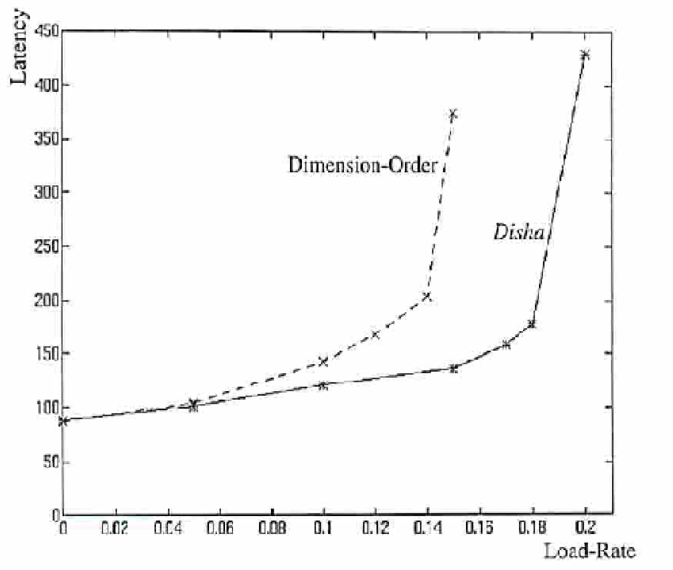


Fig. 4.2 comparison between 'Disha' and two VC dimension order routing

If we compare Duato with three virtual channels with 'Disha' providing same resources we find Duato saturates at 0.20 while 'Disha' at 0.40 that is double of Duato, so 'Disha' is two times better than Duato.

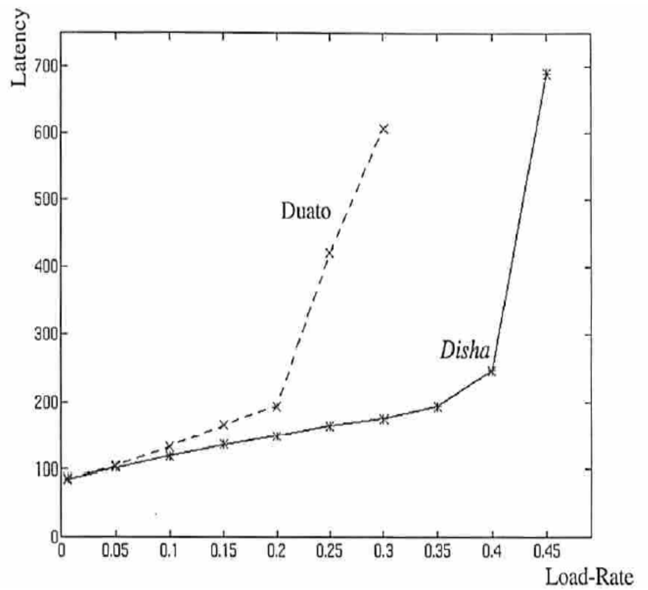


Fig. 4.3 comparison between 'Disha' and Duato's scheme

Since the proposed scheme assimilate all parameters same as 'Disha' along with 50% reduced flit buffer, this will not only reduce cost of flit buffers but complexity of routes as well. As far as distance travelled by packets in following alternate path is concerned, the wormhole routing is distance insensitive, so no adverse effect on performance at all. So, better performance on reduced cost.

The proposed work is an attempt to achieve better performance on reduced cost. The 50% cut in additional flit buffers will not only reduce the cost substantially but also minimize the complexity of the network. So, enhanced performance on reduced cost can be achieved through the proposed modification in Anjan and Pinkston framework.

Analysis1: Since the cycles of deadlock are small in interconnection network by size, number of packets forming the cycle is less, so the recovery from deadlocks is faster.

1. Deadlock buffers provide the root to the packets Involved in the cycle, one packet at a time, so there is no possibility of cycle dependency between two deadlock buffers in the network.

2. If Inet is an interconnection network and Fr is a routing function for adaptive routing, is free from deadlocks if:

   Fr: Ch1 ⊆ Ch defining a routing function Fr1, for connected and free from Cycles.

3. Since only a single packet is using deadlock buffer, the interconnection network get recovery safely from deadlocks.

4. In a deadlocked network having n cycles, a packet is shifted to deadlock buffer and finds its path eventually reaching the destination, will reduce to number of cycles = n-1, ultimately recovers deadlock safely.

Analysis2: Comparison with dimension order

- Dimension order requires two virtual channels for prevention of deadlocks in torus.
- Disha does not require any virtual channel.

Assuming the following parameters:

T_{adl} : Latency for address identification

T_{arl} : Arbitrational latency

T_{cbs} : Crossbar switch delay

T_{hfu} : Latency for header flit operation

T_{vcd} : Latency for virtual channel

T_{fcd} : Latency for flow control

T_{dort} : Latency for dimension order

T_{dish} : Latency of disha

$$T_{dish} = T_{adl} + T_{arl} + T_{cbs} + T_{hfu} + T_{vcd}$$

For disha $T_{vcd} = 0$, Since disha has no requirement of virtual channel.

$T_{dort} = T_{adl} + T_{arl} + T_{cbs} + T_{hfu} + 0 = 6.5$

$T_{dort} = T_{adl} + T_{arl} + T_{cbs} + 0 = 6.0$

Comparing T_{dish} and T_{dort}

$T_{dish} = T_{fcd} + T_{cbs} = 3.1$

$T_{dort} = T_{fcd} + T_{cbs} + T_{vcd} = 4.5$

So, 30% faster than dimension order

Since alternate flit buffers have been used in the proposed mechanism, complexity of routers will reduce 50% and cycle also 50% faster.

5. CONCLUSION

Deadlock recovery with fewer resources will not only reduce the cost but complexity as well in wormhole routed networks. Reduced complexity will lead to enhanced performance.

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