A Hybrid Packet/Circuit Router for NoC

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ABSTRACT

Under the intensive computing tasks, distributed routing lack of complex high-performance algorithms lead to link congestion. High link congestion rate will seriously degrade the overall performance of the NoC. Considering the variety of the data size of transmission on the NoC (dense/non-dense), this paper presents a hybrid router encapsulated the lumped routing and distributed routing in the same one router. At the same time, the performance of 4x4 Mesh of hybrid routing network show that hybrid routing can improve transmission bandwidth and link success rate effectively.

KEYWORDS

NoC, Packet/Circuit-Switch, Hybrid Routing, Distributed Routing, Lunmed Routing.

INTRODUCTION

With chip’s scale and density improving, the NoC based on packet switching instead of bus architecture is becoming the mainstream intra-connection on chip, for it has excellent expansibility and parallelism[1]. As a key technology of NoC study, routing policy, which determines the link congestion and transaction parallelism, is used to find the active link, on which the transaction data is transmitted from the origin end to the destination end. The good routing policy has to fit the following points:

1. There are not deadlock and live lock;
2. There is simplest deduction from routing information with the minimum and fastest hardware;
3. The link created by routing policy must be shortest;
4. The nodes on the NoC have to be treated equally by routing policy.

According the method of establishment of link, there are conventional two kinds of routing policy divides, one is distributed routing and the other is lumped routing. The former’s link is created by the information carried by transaction. The link of the latter is created before every transaction begin. In recently, the hybrid routing policies has been introduced to meet QoS of different transmissions.[4][5] both raised hybrid pocket/circuit switching to improve the data bandwidth on various scale NoC. Hung K. etc. proposed a new router integrated both wormhole and virtual channel to gain better performance of the whole NoC[6].

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All above studies were based on one routing policy, and the router cannot have merits of distributed routing and lumped routing. Considering the reuse of hardware of router, this paper presents a new hybrid router encapsulated both distributed and lumped routing policies into one router to enhance efficiency of NoC dealing with different transactions.

HYBRID ROUTER IMPLEMENTATION

SYSTEM OVERVIEW

The hybrid routing policies NoC presented in this paper is a mesh based on Packet-Connected Circuit (PCC) [7], and its structure is shown in Figure 1.

If it accepted the request of one source end, the PCC would select appropriate node to establish the link in order of precedence. The input port and output port occupied in the router on the link would unshared by the other source end until this link would be cancel. If there were not suitable port and the PCC received the fail signal, the PCC would send request repeatedly until link establishment would success.

The router designed in this paper consists of NoC and router configuring net (RCN). The RCN is a broadcast net by which configuration context would transmit to every router.

ROUTER ARCHITECTURE

The lumped policy unit will set the current hybrid router into distributed policy or the other according to the control signal from parser and port detecting machine, which analyze the configuration context via RCN. The Figure 2. shows the structure of hybrid router.

As a single access networks, the five ports of router are local port, east port, south port, west port and north port, every one of them have an input port and an output port. The fault policy of NoC is distributed policy, which means that if some nodes were set into lumped routing, the other nodes and the remains port of the lumped routing node all abide distributed routing.
As mentioned above, one router has five pairs of input/output ports. If one router being in lumped routing, the number and combination of input port and output port of current router are free, besides two ports are in the same direction.

The workflow of the port detecting machine is introduced as below:

Firstly, a detection is executing whether there are conflicts of ports combination between lumped routing and the distributed routing.

Secondly, only two ports waiting for lock being in idle, the lumped routing can lock them as an active channel.

Then, the distributed routing will yield control of two ports locked by lumped routing.

At last, the distributed routing is charge of remains ports of current router.

THE ANALYSIS OF ROUTING POLICY

The hybrid router can work alone in distributed mode or lumped routing or can be set into mixed routing.

DISTRIBUTED ROUTING

In this paper, the distributed routing adopts typical XY dimensional routing[8], where, at first, data transmits along the X axis until X coordinate is equal, then data direction turns Y axis until arrival of the destination node.

LUMPED ROUTING

If being in lumped routing, hybrid router locks combination ports to create active link by configuration context via RCN. In this paper, NoC is single access networks and router has five directions, so there are at most five port combinations in a router. One of five port combinations is shown in Figure 3, there are five active links configured by lumped routing policy in the router (2,2).

As shown in Fig.3, there is a data transmission from the source router (2,3), (3,2), (2,1), (1,2), (2,2) to the destination router (2,2), (2,1), (1,2), (2,3), (3,2). Five data transmissions form among above routers. The more detail describe as follow: first is from source router (2,3) to destination router (2,2), the second is from source router (2,2) to destination router (3,2), the third is from source router (3,2) to destination router (2,1), the fourth is from source router (2,1) to destination router (1,2), the rest is from source router (1,2) to destination router (2,3).
Under lumped routing, the input port and the output port of all selected routers on the link are locked before transaction starts. For example, the process of one transaction from source router (3,2) to destination router (2,1) through router (2,2) is as follow. Firstly, the data enters router (3,2) from local port (0 port) and departs it from north port (4 port); then the data enter router (2,2) from south port (2 port) and leaves it from west port (3 port); at last, data arrival port on destination router (2,1) is east port (0 port) and departure port is local port (0 port).

**HYBRID POLICIES**

Under hybrid policies mode, for ports listed in lumped configuration context, the lumped routing can deal them with high priority. Meanwhile distributed routing has the access of remainder ports. The relation between two routing policies is as follow: if number of lumped routing link is k, the number of distributed routing link is (5-k), where k equals 0 to 5.
At this moment, one port locked by lumped routing returns “fail” signal to distributed routing for its pathfinding request, and the distributed routing will be rerouting until that port will free.

Case 3: if lumped routing occupies all input ports and output ports, shown in Figure.6(f), the number of lumped routing link is 5. The distributed routing among all directions would receive “fail” signal until the current router left lumped routing status.

THE LINK RECONFIGURATION

The link establishment on NoC based on PCC, whatever it adopts distributed routing, such as XY dimensional routing, turn routing or retrograde-turn routing, follows shortest route principle. But hybrid routing integrated lumped routing can conquer the defect of XY dimensional routing by configuration of a new link as substitute for high congestion link path under distributed routing.

In the Figure 8, there is a congestion created by two links distributed routing links, as the dotted arrow express, between router (2,2) and router (2,3). Because of this congestion, the transaction will try to reestablish link frequently in next dozen cycles to thousands cycles and the parallelism of transaction on the NoC is destroyed. The above problem can be overcome by using lumped routing links, indication of solid line, instead of distributed routing. As Figure 8 shown, there are more than 4 optional reconfiguration links. Considering the reality of NoC, user can choose an appropriate reconfiguration link to skirt around the congestion point and improve performance of NoC.

EXPERIMENT AND ANALYSIS OF PERFORMANCE

In this section, a series experiments are used to estimate the performance of hybrid routing policies. All works are based on 4x4 mesh network which is implemented on Xilinx XC6VLX240T FPGA chip. Table 1 shows the hardware consume of 4x4 hybrid routing network and 16 data two-way transceivers.

| TABLE I. 4X4 HYBRID ROUTING NETWORK RESOURCE CONSUME. |
|------------|-----------|----------|
|            | Used      | Available| Percentage |
| Register   | 5950      | 301440   | 1%         |
| LUT        | 8941      | 150720   | 5%         |

Figure 5. Sketch of link reconfiguration.
For evaluation of the improvement of hybrid routing, the experiment start with 16 pair distributed routing transactions and the 2 distributed routing links replace 2 lumped routing links every time. Repeat the above operation 8 times. There are 16 pair data transmissions are under distributed routing policy on the 4x4 mesh network at beginning. Then, the 2 lumped routing links replace the 2 distributed one. Above operation is repeated 8 time and the transmission parameters are observed.

![Link establishment success rate](image1)

Figure 6. Link establishment success rate.

As Figure 6 shown, the link establishment success rate raises from 50% up to 84% with the number of lumped routing link increasing. If there are 10 lumped routing links, the rate of success reaches a maximum and then drops down.

![Packet average delay](image2)

Figure 7. Packet average delay.

As seen in the Figure 7, the packet average delay decreases from 40 cycles down to 26 cycles with the number of lumped routing link increasing. If there are 10 lumped routing links, the delay reaches a minimum and then returns up.

![Network throughput](image3)

Figure 8. The throughput of the network.

The Figure 8 shows that throughput of the networks raises from 110 package/100 cycles up to 260 package/100 cycles with the number of lumped routing link increasing. If there are 10 lumped routing links, the rate of success reaches a maximum, 260 package/100 cycles, and then drops down.
CONCLUSION

This paper introduces a hybrid routing router, which supports kinds routing policies, integrated lumped routing policy and distributed routing policy based on PCC. Especially under hybrid routing mode, the lumped routing can reestablish or reconfigure links with non-shortest path rule. This feature increases the flexibility of node layout on the NoC.

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