A High Performance Reliable NoC Router

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Background

- highly integrated chips
- Reliability challenges on NoC

Purpose

- permanent faults on router components
- High reliability, high performance and low cost
Related Work

- **BulletProof**
  N-modular redundancy techniques
  heavy hardware overhead

- **Vicis Router**
  low area cost
  error detection & system recovery

- **Pavan Poluri’s design**
  low cost correction circuitry
  poor performance under heavy network
Contribution

Fault tolerant strategies on 4 main pipeline units

- Double routing strategy for the RC failure
- Default winner strategy for the VA failure
- Runtime arbiter selection strategy for the SA failure
- Double bypass bus strategy for the crossbar failure
Contribution

- Maintain performance in fault tolerance
- Pipeline optimization
- Routing algorithm

- Reliable NoC router
- High performance
- High reliability
- Low cost
Proposed Reliable NoC Router

Fault tolerant RC design

- Double Routing strategy for the RC failure

One extra cycle to computer current output port
Proposed Reliable NoC Router

Fault tolerant RC design

- Fault detection circuitry for the RC

Key idea

Check functional rule

Invalid output direction

Illegal Y-X turn
Proposed Reliable NoC Router

Fault tolerant VA design

VA fault scenario
first step: Input VC arbiter is faulty
  ➡️ Flit is blocked
  need tolerate fault

second step: Output VC arbiter is faulty
  ➡️ Flits can be re-allocated to other VCs
  need avoid performance degradation
Proposed Reliable NoC Router

Fault tolerant VA design

- Default winner strategy

Add restrictions on VA requests to avoid re-allocation

Red part acts as the second path to tolerate fault
Proposed Reliable NoC Router

Fault tolerant VA design

- arbiter detection circuitry
Proposed Reliable NoC Router

Fault tolerant SA design

- Runtime arbiter selection strategy

![Diagram of runtime arbiter selection strategy with hardware redundancy and low cost considerations.]

- Hardware redundancy: two parallel switch allocators
- Runtime select non-faulty arbiter to proceed non-speculative SA request
- Low cost: only several 2:1 mux
Proposed Reliable NoC Router

Fault tolerant crossbar design

- double bypass bus strategy

traverse flits from x-dimension or local router

traverse flits from y-dimension
Performance Analysis

- Saturation throughput comparison

(a) Average latency in Poluri’s proposed reliable NoC router
(b) Average latency in our proposed fault tolerant router
Performance Analysis

- Extra latency evaluation for different strategies
Reliability Analysis

- Hardware consumption analysis

entire overhead: 9.8%

increase to 27% when incorporating the detection circuitry
Reliability Analysis

- Reliability comparison using SPF
- SPF faults to cause a failure /area overhead

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Area</th>
<th>Faults to cause failure</th>
<th>SPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>BulletProof</td>
<td>52%</td>
<td>3.15</td>
<td>2.07</td>
</tr>
<tr>
<td>Vicis</td>
<td>42%</td>
<td>9.3</td>
<td>6.55</td>
</tr>
<tr>
<td>Poluri’s design</td>
<td>31%</td>
<td>15</td>
<td>11.4</td>
</tr>
<tr>
<td>Our reliable router</td>
<td>27%</td>
<td>21</td>
<td>16.5</td>
</tr>
</tbody>
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Thank you!