Fast Detection of Alternative Route under Unknown Failure on SDN Network

Takumi Matsuura †, Hiroki Nakayama ‡, Tsunemasa Hayashi ‡, Katsunori Yamaoka †

† Tokyo Institute of Technology, Japan
‡ BOSCO Technologies Inc., Japan
What is silent failure?

- Difficult to detect failure point automatically
  - ex. failure beyond the OAM function’s coverage, a human error

- Happen under unknown situations
  - Difficult to specify the situation

- Various tests are required for localization

⇒ Long-term measurement is required
Example of silent failure (1/2)

How to shorten QoS degradation term?

- An alternative route is effective

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Example of silent failure (2/2)

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network</td>
<td>Silent failure</td>
<td></td>
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<tr>
<td>Administrator</td>
<td>Alternative route configuration</td>
<td>Localization</td>
<td>Fix</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>User</td>
<td>QoS degradation</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- What if an alternative route is not found immediately?
  - The flow’s allowable delay may **not** be satisfied
Strategy

An alternative route for recovery from silent failure

- Localize the failure
  - pros: Flexible route search
  - cons: Long-term measurement

- Avoid all suspicious nodes and links
  - pros: Minimum measurement
  - cons: An allowable delay may not be satisfied

A method to quickly detect an alternative route within the flow allowable delay
Key idea

- Suspicious-region pruning by recursive division

Alternative route detection

Suspicious-region pruning

Region division

Fault

OK
SDN

- Flexible route management
  - Traffic management per flow
  - Easy to change flow route

- Partial network measurement

A method to configure an alternative route quickly by using SDN functions

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SDN network model

- $G = (V, E)$: A non-directed graph
- $f$: A degraded flow
- $P_{\text{origin}}$: The route of flow $f$ in the initial condition
- $P_{\text{fault}}$: The route that contains a failure point = Suspicions-region
- $P_{\text{alt}}$: An alternative route of flow $f$
Flowchart

Alternative route detection phase

$P_{\text{fault}} < P_{\text{origin}}$

Suspicious-region pruning phase

The proper alternative route is found

End

End

The suspicious region cannot be divided

$P_{\text{fault}}$ is removed from the network

Search for $P_{\text{alt}}$

Is allowable delay satisfied?

Can $P_{\text{fault}}$ be divided?

Divide and overwrite $P_{\text{fault}}$
Example (1/4)

Remove $P_{\text{fault}}$ from network

Search for $P_{\text{alt}}$

Is allowable delay satisfied?

NO

Can $P_{\text{fault}}$ be divided?

YES

Divide and overwrite $P_{\text{fault}}$

Allowable delay: 15

$p_{\text{origin}} = s, 1, 2, 5, 6, 7, d$

Failure happens

Suspicious-region $P_{\text{fault}}$
Example (2/4)

Remove $P_{\text{fault}}$ from network

Search for $P_{\text{alt}}$

Is allowable delay satisfied?

Can $P_{\text{fault}}$ be divided?

Divide and overwrite $P_{\text{fault}}$

Allowable delay: 15

Remove $P_{\text{fault}}$

Search for alternative route $P_{\text{alt}}$

Delay = 17 → Not satisfied

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Example (3/4)

Remove $P_{fault}$ from network

Search for $P_{alt}$

Is allowable delay satisfied?

Can $P_{fault}$ be divided?

Divide and overwrite $P_{fault}$

Allowable delay : 15

OK

Divide the region

Fault

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**Example (4/4)**

1. Remove $P_{\text{fault}}$ from network
2. Search for $P_{\text{alt}}$
3. Is allowable delay satisfied? 
   - NO
   - Can $P_{\text{fault}}$ be divided?
     - NO
     - YES: Divide and overwrite $P_{\text{fault}}$
4. Search for $P_{\text{alt}}$
5. Delay = 13 → Satisfied
6. Remove $P_{\text{fault}}$
7. Allowable delay : 15
8. End
Evaluation Model

- Network: SDN architecture
  - Partial network measurement
  - Traffic management per flow

- Link bandwidth: sufficient
  - The transmission delay is included in the link delay

- SDN controller’s resources: sufficient
  - The computation time for Dijkstra’s algorithm and route configuration is omitted

- The number of faults: one
  - The silent failure happens at ONLY one node/link
Parameter

- Default setting

<table>
<thead>
<tr>
<th></th>
<th>Random graph (ER model)</th>
<th>Scale-free graph (GLP model)</th>
<th>Data center graph (Fat tree model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>3000</td>
<td></td>
<td>2500</td>
</tr>
<tr>
<td>Average degree</td>
<td>3.98</td>
<td>4.03</td>
<td>4.8</td>
</tr>
<tr>
<td>Link cost</td>
<td>5~15[ms] (Uniform distribution)</td>
<td>10[ms] (constant)</td>
<td></td>
</tr>
<tr>
<td>Allowable delay</td>
<td></td>
<td>60[ms]</td>
<td></td>
</tr>
</tbody>
</table>

- Conventional method
  - Localizing method by the sequential search
Effect of allowable delay

- Localizing fault point: 55
  - Proposed: 55
- Localizing fault point: 65
  - Proposed: 65

- Localizing fault point: 50
  - Proposed: 50
- Localizing fault point: 60
  - Proposed: 60

Hop count

ER model

GLP model

Good
Effect of average degree

![Graphs showing the effect of average degree for ER and GLP models.](image)

- Localizing fault point: 3
  - ER model: Proposed: 3
  - GLP model: Localizing fault point: 8
  - GLP model: Proposed: 8

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Evaluation (3/3)

- Fat tree model

![Diagram showing hop count vs. average number of failure measurements with points indicating good localization behavior.]

Localizing fault point
Proposed

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Summary & Future Works

■ Summary

➢ A fast configuration method of alternative routes on SDN architecture
➢ Combination of alternative route detection phase and suspicious-region pruning phase
➢ The proposed method greatly outperforms the localizing method, especially when the average degree is large

■ Future works

➢ Analysis in realistic condition
➢ Improvement of the algorithm