Alarm Correlation for Congestion Diagnosis in ATM Networks

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Summary

In this work, we examine the tradeoff between fine-grade and coarse-grade OAM measurements. The fine-grade OAM measurement, with the overhead of voluminous measurement information, leads to pin-pointed identification when problems occur ; while coarse-grade OAM measurement, without detailed information, needs to correlate many alarms which may be triggered by a single problem. Alarm correlation, however, requires some heuristics for problem diagnosis and has some degree of uncertainty.

Taking VP(virtual path) congestion diagnosis as our target example, we present the path intersection heuristics as the alarm correlation method to analyze the congestion alarms and find the congestion areas. Our simulation results show that the intersection heuristics with output link consideration locates the congestion nodes precisely. We also analyze the congestion pattern and find that the congestion area has the tendency of expanding from one node to its neighbors.

After identifying the congested nodes, we apply three methods to choose the congested VPCs for rerouting. The results show that the method of Less Summed Capacity performs the best in terms of average rerouted capacity.

In the future, we plan to implement the heuristics into the network management system of a practical ATM testbed. This includes two parts: the agents which perform coarse-grade OAM measurement and the manager which collects the alarms ,correlates them to locate the source of congestion, and furthermore, applies the VP rerouting.

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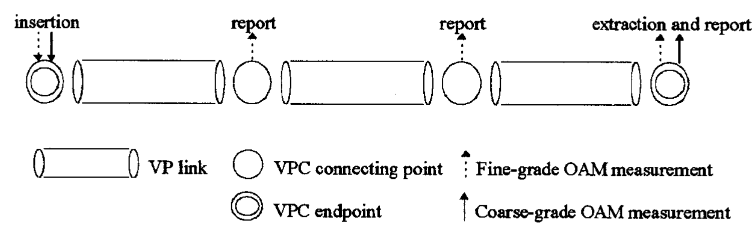
Alarm Correlation for Congestion Diagnosis

- Problem Description
  - Congestion diagnosis: OAM measurement of VPC exceeds threshold → alarms
  - Given performance alarms from many VPCs, find the congestion area
- Two Approaches
  - Fine-grade OAM measurement: quick identification, high overhead
  - Coarse-grade OAM measurement: low overhead but correlation required



If the cell loss ratio obtained from OAM measurement is higher than the threshold of cell loss ratio, the destination VPC endpoint sends an alarm to the network manager. Given these performance alarms from many VPCs, how can we find the congestion area? There are two approaches to solve the congestion diagnosis problem: fine-grade OAM measurement and coarse-grade OAM measurement. The fine-grade OAM measurement approach monitors and reports the cell loss and cell transfer delay of each link for each VPC such that this approach may find out the congested nodes specifically. The coarse-grade OAM measurement can only monitor and report end-to-end cell loss and cell transfer delay for each VPC such that this approach may not find out the congested nodes specifically. Thus, this approach need a heuristics alarm correlation method to locate the congested nodes.

Heuristics for Congestion Diagnosis

- Heuristics 1: Pure Intersection

  $\{\text{congested nodes}\} = \bigcap_{i \in \{\text{congested VPCs}\}} \text{Path}(\text{VPC}i)$

  - Congested nodes: Passed by more than one congested VPCs
- Heuristics 2: Intersection with Output Link Consideration
  - Congested nodes: Passed by more than one congested VPCs and these VPCs compete the same output link on the node

Heuristics 1: Pure Intersection

The nodes in the intersection area of all congested VPCs may be the sources which result in the congestion. We define degree of node i as the number of congested VPCs that pass node i. The network manager finds all the nodes which are passed by more than one congested VPC in the intersection area of all congested VPCs. That is, the network manager collects those nodes whose degrees are larger than one. These nodes are regarded as congested nodes.

Heuristics 2: Intersection with Output Link Consideration

According to the characteristics of output queueing in ATM switches, VPCs will only congest if they compete the same output link in a switch. The congestion will not happen, however, at the nodes that no VPC competes the same output link. We propose another heuristics that only the nodes with more than one congested VPC competing the same output link are the sources which result in the congestion. That is, if a node is passed by more than one congested VPC and these congested VPCs have the same output port on the node, this node is included. These nodes will be regarded as the congested nodes.

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Proposed Alarm Correlation Heuristics (cont.)

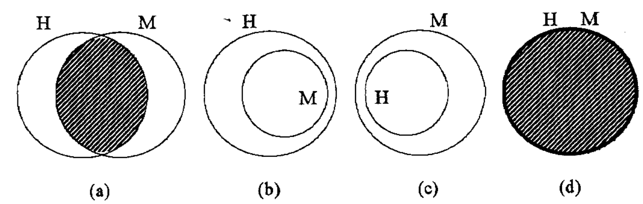
- Evaluation

  H={suspected congested nodes obtained from the heuristics}

  M={real congested nodes measured in the network}

  $$\text{Hit ratio} = \frac{H \cap M}{H}$$

  $$\text{Miss ratio} = \frac{M - H}{M}$$



In order to evaluate the above two heuristics, we need to compare the set of congested nodes obtained from the heuristics with the set of real congested nodes, which are measured in a network environment. We define hit ratio and miss ratio.

Figure (a) shows a general condition. If the hit ratio is high and the miss ratio is low, we may say that the heuristics is good. Figure (b) shows the condition of miss ratio=0 and hit ratio<1; all real congested nodes are captured but some suspected congested nodes are not real congested nodes, i.e., the heuristics is not precise enough. Figure (c) shows the condition of hit ratio=1 and miss ratio>0; although all suspected congested nodes are real congested nodes, the heuristics doesn*t capture all real congested nodes. Figure (d) shows the condition of hit ratio=1 and miss ratio=0, i.e., the best condition; the set of suspected congested nodes obtained from the heuristics exactly matches the set of real congested nodes.

Simulation Results (cont.)

- Effectiveness of the Heuristics
  - Miss ratio=0
  - Hit ratio: Bernoulli source≒GOO source
  - Hit ratio: Bernoulli source≧DOO source
  - Hit ratio: Heuristics 2≧Heuristics 1
  - Traffic load ↑ Hit ratio for Heuristics 1 ↑
  - No evident influence for the network size
  - Same observations for balanced and unbalanced traffic

Miss ratio of heuristics 1 and heuristics 2 in any condition is 0. That is, the heuristics can capture all real congested nodes in the simulation network.

Hit ratio of the heuristics for Bernoulli sources and GOO sources are almost the same. Perhaps it's because we set the parameters of probability_of_on_to_off and probability_of_off_to_on for GOO sources equal to 0.5. The distribution of GOO sources and the distribution of Bernoulli sources are very alike.

Hit ratio of the heuristics for Bernoulli sources is higher than DOO sources. That is, the heuristics works better when traffic sources are Bernoulli sources. Perhaps it's because the DOO sources are more bursty than the Bernoulli sources.

The hit ratio of heuristics 2 is always higher than or equal to heuristics 1. This is because heuristics 2 considers the characteristics of output queueing in ATM switches so that it may hit real congested nodes more precisely.

Higher traffic load leads to higher hit ratio for heuristics 1. For heuristics 2, when the traffic load exceeds a certain value, higher traffic load also leads to higher hit ratio. This is because when the traffic load exceeds a certain value, the congested VPCs are fixed such that the number of suspected congested nodes is fixed. And the number of real congested nodes goes up as the traffic load goes up.

The influence of the network size for the heuristics is inevident and the influence of unbalanced traffic for the heuristicsare is the same as balanced traffic.

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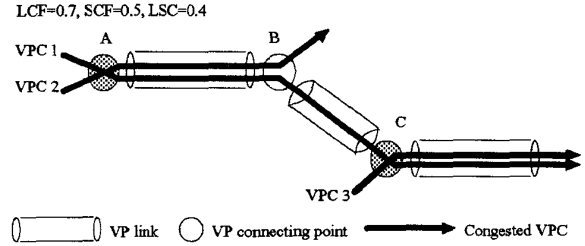
Rerouting based on the Proposed Heuristics

- Large Capacity First (LCF)
- Small Capacity First (SCF)
- Less Summed Capacity (LSC)
  - Compare the congested VPC which passes more than one congested node with smallest VPCs which pass through these nodes
- Example

(a) VPC 1=0.9, VPC 2=0.1, VPC 3=0.2: LCF=0.9, SCF=0.1+0.2=0.3, LSC=01+0.2=0.3
(b) VPC 1=0.5, VPC 2=0.3, VPC 3=0.4: LCF=0.5, SCF=0.3+0.4=0.7, LSC=0.5
Average removed capacity:
LCF=0.7, SCF=0.5, LSC=0.4



Large Capacity First (LCF): For every congested node, remove the congested VPC with the largest capacity, then remove the congested VPC with the second large capacity, and the same process goes on until the node is not congested.
Small Capacity First (SCF): Same as LCF but smallest capacity first.
Less Summed Capacity (LSC): In some cases, a congested VPC may pass through more than one congested node. By comparing the capacity of this specified VPC and the sum of the smallest capacities from each congested nodes that the specified VPC passes, we choose the one which needs to remove less capacities.
As shown in the Figure, LCF removes VPC1 in both conditions; SCF removes VPC 2 and VPC 3 in both conditions; In condition (a), LSC removes VPC 2 and VPC 3 because the sum of the capacities of VPC 2 and VPC 3 is smaller; In condition (b), LSC removes VPC 1 because the capacity of VPC 1 is smaller. In this example, average capacities of removed VPCs for three methods are: LCF = 0.7, SCF = 0.5, LSC = 0.4, where LSC needs to remove the least VPC capacities.

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Conclusion and Future Work

- OAM Measurements: Fine-grade vs. Coarse-grade
- Alarm Correlation Heuristics: Pure Intersection and Intersection plus Output Link
- Simulation Study
  - The heuristics of intersection with output link consideration is more precise.
  - The number of congestion areas is almost always 1.
  - The method of Less Summed Capacity needs to reroute the least capacity.
- Implement the heuristics on real ATM networks
  - QoS Agents: coarse-grade performance measurements and alarm reporting
  - QoS Manager: collect, correlate alarms, and reroute VPCs
- Evaluate the Heuristics
- Fine-grade vs. Coarse-grade OAM measurements: tradeoff between the performance and overhead

We have reviewed the OAM measurement methods. Based on the OAM measurements, we propose two heuristics to find the congestion areas in ATM networks and we evaluate the heuristics by simulation. The simulation results show that the heuristics of intersection with output link consideration may locate the congestion nodes more precisely. Also, according to the simulation results, we analyze the congestion pattern and find that the congestion area has the tendency of extending from one node to its neighbors. In addition, to utilize our heuristics on rerouting, we propose three methods to choose the congested VPC for rerouting in order to eliminate the congestion and the result shows that the method of Less Summed Capacity is the best among these three methods.
We have evaluated our alarm correlation heuristics by simulation and found that the heuristics is applicable to locate the congested nodes in ATM networks. In the future, we plan to implement the heuristics to the network management systems in practical ATM networks. This includes two parts: (1) The agents measure the performance for each component (i.e., switch or virtual connection) in the ATM network by OAM measurement methods. When the performance degradation occurs, it sends an alarm to the manager. (2) The manager collects the alarms and correlates them to localize the source of congestion. We plan to evaluate the proposed heuristics in a real system and compare the tradeoff between the performance and overhead of fine-grade with coarse-grade OAM measurements.

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