Passive End-to-End Packet Loss Estimation for Grid Traffic Monitoring

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Roadmap

• Introduction
• Passive Packet Loss Measurement Characteristics
• Methodology
• Integration within a Network Monitoring Service
• Experimental Evaluation
• Conclusions
Why to Measure Packet Loss?

- Accurate network monitoring is vital for Grids
  - Resource allocation
  - Scheduling decisions
  - Performance debugging

- Packet loss is an important performance metric
  - Identify poor network conditions
  - Highly affects the TCP throughput and the overall end-to-end data transfer quality
Existing Measurement Tools

• Most existing tools for packet loss estimation use active probes
  – ping, zing, badabing, sting
  – Incur network overhead due to the injected packets

• Existing passive monitoring techniques are based on TCP’s loss recovery algorithms

• A passive monitoring tool for packet loss estimation at the IP layer is still missing
Passive Packet Loss Measurement Characteristics (1/2)

- Non-intrusive
  - It does not inject any probe packets
- **Real-time** measurement of the **actual** loss ratio
- **Scalability**
  - Measure end-to-end packet loss between many different domains
- **Per-application** measurement
  - Differentiated services or rate limiting may result to different loss ratios in the same path
- **IP-level** measurement
• Limitations:
  – Requires two passive monitors at the ends of the measured path
  – Presence of real traffic in the path

• Can be used as complementary to existing active probing techniques
Our Approach

- Based on distributed passive network monitoring
- Two passive monitors at the two ends
- Send periodically information to a central application that computes the loss ratio
A Naive Algorithm

- Count the number of packets at both ends
- The application periodically subtracts the number of packets received from the number of packets that were actually sent

- Major drawback: inaccuracy
  - We cannot accurately synchronize the monitoring points to count the same window of packets
  - Packets in transit are not counted
• Measure the packet loss in each flow separately
• A flow is defined as a set of IP packets with the same 5-tuple:
  – Protocol
  – Source and destination IP address
  – Source and destination port (for UDP and TCP)
• An expired flow is a flow with no arriving packets for a specified timeout (e.g. 60 seconds)
• Expired flow is well defined: we know the first (e.g. TCP SYN) and the last (e.g. TCP FIN) packet of the flow
• Each monitoring sensor sends periodically statistical information about the expired flows it has seen
• The monitoring application correlates the statistics regarding the same expired flow
• The difference of the number of packers gives an accurate estimation of the loss ratio for this flow
In each measurement point we run two daemons:

- **mapid**: A passive monitoring daemon that identifies and collect the expired flows
- **mapicommd**: A communication daemon that accepts monitoring requests and sends back the results

Using a distributed monitoring API (DiMAPI) we manipulate multiple monitoring sensors from the same application
Identification of Expired Flows

• Every new packet is associated with exactly one active flow record
• Hashtable for fast lookup
• Linked list with temporal order for immediately identifying the expired flows

A Flow record

<table>
<thead>
<tr>
<th>Source IP address</th>
<th>Destination IP address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source port</td>
<td>Destination port</td>
</tr>
<tr>
<td>Protocol</td>
<td></td>
</tr>
<tr>
<td>Timestamp of first packet</td>
<td>Timestamp of last packet</td>
</tr>
<tr>
<td>Packet counter</td>
<td>Byte counter</td>
</tr>
</tbody>
</table>
Distributed Sensor Management

- The monitoring application communicates with many distributed sensors
- It periodically collects the expired flows from them
- Then, it correlates the pairs of statistics regarding the same flow
- For every matched pair, it computes the packet and byte loss ratios
- It reports both the total loss ratio, and loss ratio per every individual flow
• **Network Monitoring Element (NME)**
  – Offers an interface for measurement requests
  – Plug-in based interface for publishing measurements
  – Access a database that contains information about Grid resources and other NME

• **Network Monitoring session for packet loss ratio measurement**
  – Identify the source and destination domains
  – Type of service that the measurement corresponds
  – Time period of the measurement (historical, most recent, one-shot, or periodic)
Integration within a Network Monitoring Service (2/2)
Experimental Evaluation

- Packet Loss Measurement Accuracy
- Experiences with Grid Network Traffic
Artificially generated packet loss

Before artificial packet loss

Sender

Gateway

After artificial packet loss

Receiver
### Packet Loss Measurement Accuracy (1/2)

<table>
<thead>
<tr>
<th>Artificially Generated Loss (%)</th>
<th>Estimated Loss (min/avg/max %)</th>
<th>Measurement Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00/0.002/0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>1</td>
<td>0.91/0.98/1.06</td>
<td>0.020</td>
</tr>
<tr>
<td>5</td>
<td>4.80/5.014/5.13</td>
<td>0.014</td>
</tr>
<tr>
<td>10</td>
<td>9.86/10.09/10.18</td>
<td>0.090</td>
</tr>
<tr>
<td>25</td>
<td>22.24/24.74/25.32</td>
<td>0.260</td>
</tr>
</tbody>
</table>

- Packet loss measured while generating 10 parallel UDP flows over a 2 hour period
- Accurate results, very close to the generated loss
- Small aberrations due to the probabilistic nature of loss generation
Packet Loss Measurement Accuracy (2/2)

<table>
<thead>
<tr>
<th>Artificially Generated Loss (%)</th>
<th>Estimated Loss (min/avg/max %)</th>
<th>Measurement Error (%)</th>
<th>Served Requests</th>
<th>Rate (Mbit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00/0.06/0.17</td>
<td>0.060</td>
<td>2944</td>
<td>38.75</td>
</tr>
<tr>
<td>1</td>
<td>1.02/1.078/1.16</td>
<td>0.078</td>
<td>1666</td>
<td>22.23</td>
</tr>
<tr>
<td>5</td>
<td>4.92/5.07/5.23</td>
<td>0.070</td>
<td>1058</td>
<td>14.11</td>
</tr>
<tr>
<td>10</td>
<td>9.86/10.086/10.12</td>
<td>0.086</td>
<td>290</td>
<td>3.90</td>
</tr>
<tr>
<td>25</td>
<td>24.89/25.235/25.50</td>
<td>0.235</td>
<td>0</td>
<td>0.26</td>
</tr>
</tbody>
</table>

- Packet loss measured while performing normal HTTP requests
- Packet loss ratio significantly affects the number of completed requests
- TCP throughput drops dramatically from 38.75 Mbit/s to 0.26 Mbit/s
Experiences with Grid Network Traffic (1/2)

- Deployment of the technique to an operational Grid network path
- Running for a 24-hour period with measurements every 30 seconds
- Generating more traffic using HTTP and GridFTP
Experiences with Grid Network Traffic (2/2)

- Bursts of HTTP and FTP transfers result in higher loss rates.
- The 83% of the 30-seconds intervals indicate 0% loss ratio (89% and 87% for HTTP and FTP).
- 0.09% overall loss ratio over the 24-hour period for total traffic, 0.13% for HTTP-only and 0.19% for FTP-only traffic.
Conclusions

• A novel **passive** monitoring technique for packet loss estimation between different Grid domains

• **Scalable, non-intrusive and real time**

• Can be **complementary** to active monitoring tools

• Based on tracking the **expired flows** at each monitoring sensor

• Uses a **distributed** infrastructure for gathering and correlating the results

• **Validated** using realistic traffic
Thanks!

Any questions?