Understanding the Processing Delay of Peer-to-Peer Relay Nodes

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Motivation

Peer-to-peer relaying is commonly used

- **Purpose**
  - overlay routing (for better quality)
  - connection establishment (for peers behind NAT/firewall)
  - data aggregation (lower bandwidth usage)

- **Application**
  - Conferencing: [skype](#), [Google talk](#)
  - Video Streaming: [Anysee](#), [PPLive](#)
The Problem

currently relaying is achieved at application-level

TCP implementation (user space)

Application

Network Interface Card (kernel space)

scheduling delay (depending on workload and scheduler)
What We Do

- **Measure** the processing delays at relay nodes
  proposed a measurement methodology and performed a large-scale Internet measurement (> 1000 nodes)
- **Understand the** characteristics of processing delays
  unreliable and predictable
- **Examine whether these** processing delays **degrade** application quality
  yes, they can significantly affect VoIP quality
Talk Progress

- Overview
- Measuring processing delay (PD)
  - Large-scale measurement
  - PD characterization
  - Impact of PD on VoIP quality
  - Conclusion
Our Basic Method for Measuring PD

Assumptions

- No intentional delays at the relay node
- Source transmits packets with TCP
- TCP implementation is running at high priority, while application is running at low priority
- Sender and receiver are colocated at the same place
The Idea

PD = t3 - t2

*if network delay is approximately constant*
Verifying The Assumption: “Is TCP implementation running at high priority?”

- LAN experiment
- Windows XP on commodity PC
- 200-byte packets sent at 30pkt/sec
- 10 random movie clips to simulate workload

\[ X: \text{how much time relay packets are generated} \]
\[ Y: \text{how much time ack packets are generated} \]
The Problem of Our Basic Method

Network delays are NOT constant
(mostly because of queueing delays)

⇒ t3 – t2 ≠ PD
Proposed Improvement: IPIID Filtering

- Filter out seriously delayed packets
- IPIID: the ID field of IP packets
  - monotonically increasing
  - infer the order of data packets generated by the sender
  - infer the order of ack packets generated by the relay node
  - infer the order of relay packets generated by the relay node

- If any pair of packets is reordered along their transmission
  - discarding both packets
  - LIS (longest increasing subsequence) algorithm
Some Common Network Reordering Scenarios
Effectiveness of IPID Filtering

- LAN experiments
- Evaluate the differences between measured PD and true PD

![Average error of inferred PD](a) Real processing delay (ms)

![Maximum error of inferred PD](b) Real processing delay (ms)
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Large-Scale Measurement

- **Goal:** To understand PD at real-life relay nodes

- **Testbed:**
  - > 200 thousands super nodes available anytime
  - Skype finds a usable relay node automatically if the caller cannot reach the callee
  - We can force Skype to pick an alternate super node for relaying a VoIP call
Collection Methodology

- Automatically call establishment and drop (10 min each)
- Human speech recordings form Open Speech Repository
- Use firewall to block caller <-> callee direct connection
- We block used relay nodes to force Skype find a new one
Geographical Diversity of Observed Relay Nodes
Call Information

<table>
<thead>
<tr>
<th># Calls</th>
<th>Time</th>
<th># Pkts/call</th>
<th>ART</th>
<th>DDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,115</td>
<td>10 min</td>
<td>19,210 pkts</td>
<td>203 ms</td>
<td>212 ms</td>
</tr>
</tbody>
</table>

On average, data packets incur 9 ms PD

Estimated Processing Delays

<table>
<thead>
<tr>
<th># Samp.</th>
<th>Samp. dens.</th>
<th>PD (Avg / Max / SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,739 per call</td>
<td>26 samp. / sec</td>
<td>5 ms / 239 ms / 7 ms</td>
</tr>
</tbody>
</table>

On average, maximum PD is around 240 ms
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A Classification of PD Patterns
A Classification of PD Patterns (1)

Typical Processing Delays

- variation of PDs is small
- magnitude is rarely higher than 20 ms

⇒ the relay node is lightly-loaded and the computer is not in use
A Classification of PD Patterns (2)

Variable Processing Delays

- PDs are stable most of the time, but occasionally very different
- e.g., the PDs of call 561 are relatively high during the 250–450 ms period, which is likely due to a person using the computer, or an application with a time-varying workload is running.
A Classification of PD Patterns (3)

Level-shifted Processing Delays

- The levels of PDs are increased or decreased by a significant magnitude, say, larger than 10 ms
  - likely a heavily loaded task starts or stops running on the relay node
Bursts of high PDs occur at regular intervals, possibly because of the behavior of an application.

- e.g., the 1-minute interval in Call 214 may be caused by an email notification program with a one-minute check interval.
A Classification of PD Patterns (5)

Loaded Processing Delays

- The level of PDs remains large, say 100 ms or higher.
- the relay node should be running computation- or I/O- intensive applications
Busy Levels

- The level of workload on the relay node
- 95% percentile of PD within a 10-second window
  - Lightly-load host: application always serviced when needed
  - Even on a heavily load machine, the PD incurs by relay packets are not always large
    - A packet arrives just before the application’s execution quantum ➔ get serviced immediately
    - otherwise ➔ has to wait some time
- If busy level changes > 10 ms in successive 10-second windows ➔ unstable relay nodes
Average Ratios of All Relay Nodes and Unstable Relay nodes

Unstable nodes are mostly observed in work hours at local time
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- Impact of PD on VoIP quality

- Conclusion
Impact of PD on VoIP Quality

- p2p relaying is commonly used by VoIP applications
  - bypass firewall/NAT
  - network latency may be reduced by overlay routing
  - VoIP bandwidth requirement is not high, e.g., 32 Kbps

- Use trace-driven simulations to assess the impact of PD
  - combine different network delays and processing delays
  - simulate VoIP calls with and without processing delays
  - examine their differences in VoIP quality
Methodology

- Measuring VoIP quality degradation
  - ITU-T E-model (G.711) based on delay and loss rate
  - yields a R-score ranges from 0 -- 100
  - R-score > 80 ➔ satisfactory
  - R-score < 70 ➔ unacceptable

- Two classes of VoIP playout buffer sizing schemes
  - **static buffer** (60 ms according to Skype)
  - **adaptive buffer** (according to Ramjee INFOCOM’94)
    - size = mean delay + 4 x standard deviation of delays
    - mean and std dev are derived from EWMA processes

- 50,000 random samples from 1,243,225 (1,115 x 1,115) possible configurations
R-scores Decrease due to PD

20% of calls incur significant average R-score decrease

40% and 60% of calls incur significant maximum R-score decrease

PD leads to larger playout buffer that leads to lower e2e packet loss rate
Original R-scores vs. Average R-scores

More degradation than static buffer with original scores $\geq 40$
1. Higher scores $\Rightarrow$ lower net delay
2. PD impact buffer size more

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What busy levels of PD would significantly impact VoIP quality?

busy level > 20 ms

significant quality degradation
Busy Period Characterization

- We define a node as busy when its busy level is higher than 20 ms.
- 23% of relay nodes were ever busy during a 10-minute call.

The nodes tend to switch between busy and non-busy states frequently.

- **mean:** 18 sec
- **65% shorter than 10 sec**

- **mean:** 25 sec
Summary

- consider a hidden aspect of peer-to-peer relaying ---
  processing delays at relay nodes
- PD can be detrimental to VoIP quality
- we should avoid a relay node with a busy level higher than 20 ms
- we have to monitor the processing delays of a relay node continuously (like we do for the network delays)
Questions?
Thank You!

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