On the Sensitivity of Online Game Playing Time to Network QoS

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Chin-Laung Lei

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Talk Outline

- Overview
- Trace collection
- Analysis and modeling of the relationship between session times and QoS
- Implications and applications
- Summary
Motivation

- Real-time interactive online games are generally considered QoS-sensitive
- Gamers always complain about high “ping-times” or network lags
- Online gaming is increasingly popular despite the best-effort Internet

Q1: Are players really sensitive to network quality as they claim?

Q2: If so, how do they react to poor network quality?
Assessment of User Satisfaction

Which path can provide the best user experience?

<table>
<thead>
<tr>
<th>Path</th>
<th>Latency</th>
<th>Delay Jitter</th>
<th>Loss</th>
<th>Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Good</td>
<td>Poor</td>
<td>Average</td>
<td>?</td>
</tr>
<tr>
<td>2</td>
<td>Average</td>
<td>Good</td>
<td>Poor</td>
<td>?</td>
</tr>
<tr>
<td>3</td>
<td>Poor</td>
<td>Average</td>
<td>Good</td>
<td>?</td>
</tr>
</tbody>
</table>
Previous Work

- Evaluating the enjoyment of game playing in a controlled network environment

  - Subjective evaluation is costly and not scalable
  - Objective evaluation is not generalizable
    - Shooting games: number of kills
    - Racing games: time taken to complete each lap
    - Strategy games: capital accumulated

Real-life user behavior is not measurable in a controlled experiment
Our Conjecture

- Poor Network Quality
- Unstable Game Play
- Less Fun
- Shorter Game Play Time

Verified by real-life game traces
Key Contributions / Findings

- **Session time** as a means to measure users’ feeling about network quality

- Players are **sensitive** to network conditions (in terms of game playing time)

- Proposed a time-QoS model to **quantify** the impact of network quality

\[
\log(\text{departure rate}) \propto 1.27 \times \log(\text{rtt}) + 0.68 \times \log(\text{jitter}) + 0.12 \times \log(\text{closs}) + 0.09 \times \log(\text{sloss})
\]
On the Network QoS-Sensitivity of Online Game Playing Times

ShenZhou Online

- A commercial MMORPG in Taiwan
- Thousands of players online at anytime
- TCP-based client-server architecture
On the Network QoS-Sensitivity of Online Game Playing Times

<table>
<thead>
<tr>
<th>Session #</th>
<th>Avg. Time</th>
<th>Top 20%</th>
<th>Bottom 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,140</td>
<td>100 min</td>
<td>&gt; 8 hours</td>
<td>&lt; 40 min</td>
</tr>
</tbody>
</table>

(20 hours and 1,356 million packets)
Round-Trip Times vs. Session Time

y-axis is logarithmic

On the Network QoS-Sensitivity of Online Game Playing Times
Delay Jitter vs. Session Time
(std. dev. of the round-trip times)
Hypothesis Testing -- Effect of Loss Rate

Null Hypothesis:
All the survival curves are equivalent

Log-rank test: $P < 1\times10^{-20}$

We have > 99.999% confidence claiming loss rates are correlated with game playing times.
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Effect of QoS Factors -- Overview

<table>
<thead>
<tr>
<th>QoS Factor</th>
<th>Significant?</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average RTT</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Delay Jitter</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Client Packet Loss</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Server Packet Loss</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Queueing Delay</td>
<td>No</td>
<td>N/A</td>
</tr>
</tbody>
</table>

(significant: p-value < 0.01)
Linear regression is not adequate for modeling violations of the assumptions (normal errors, equal variance, ...)

The Cox regression model provides a good fit

- Log-hazard function is proportional to the weighted sum of factors
  \[ \log h(t|Z) \propto \beta^t Z \]  
  (our aim is to compute \( \beta \))

where each session has factors \( Z \) (RTT=x, jitter=y, ...)

### Hazard function (conditional failure rate)

The instantaneous rate of quitting a game for a player (session)

\[
h(t) = \lim_{\Delta t \to 0} \frac{\Pr[t \leq T < t + \Delta t|T \geq t]}{\Delta t}
\]
Model Fitting

- $h(t|Z) \propto \exp(\beta^t Z)$ must be conformed

- Explore true functional forms of factors by goodness-of-fit and Poisson regression

- A standard Poisson regression:
  \[
  E(X) = \exp(\beta^t Z) \exp(\text{intercept})
  \]
  \[
  h(t|Z) = \exp(\beta^t Z)
  \]
  \[
  E[s] = \exp(\beta^t s(Z))
  \]

- All factors are better describing user departure rate in the logarithmic form

Human beings are known sensitive to the scale of physical magnitude rather than the magnitude itself

- Scale of sound (decibels vs. intensity)

- Musical staff for notes (distance vs. frequency)

- Star magnitudes (magnitude vs. brightness)
On the Network QoS-Sensitivity of Online Game Playing Times

The Logarithm Fits Better (client packet loss rate)
Final Model & Interpretation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef</th>
<th>Std. Err.</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(RTT)</td>
<td>1.27</td>
<td>0.04</td>
<td>&lt; 1e-20</td>
</tr>
<tr>
<td>log(jitter)</td>
<td>0.68</td>
<td>0.03</td>
<td>&lt; 1e-20</td>
</tr>
<tr>
<td>log(closs)</td>
<td>0.12</td>
<td>0.01</td>
<td>&lt; 1e-20</td>
</tr>
<tr>
<td>log(sloss)</td>
<td>0.09</td>
<td>0.01</td>
<td>7e-13</td>
</tr>
</tbody>
</table>

Interpretation
A: RTT = 200 ms
B: RTT = 100 ms, other factors same as A

Hazard ratio between A and B:
\[ \exp((\log(0.2) - \log(0.1)) \times 1.27) \approx 2.4 \]

A will more likely leave a game \((2.4 \text{ times probability})\) than B at any moment
How good does the model fit?

Observed average session times are almost within the 95% confidence band.
On the Network QoS-Sensitivity of Online Game Playing Times

Earlier studies neglected the effect of delay jitter. Current games rely on only "ping times" to choose the best server.

Client packets convey user commands.
Server packets convey response and state updates.

- Latency = 20%
- Delay jitter = 45%
- Client packet loss = 20%
- Server packet loss = 15%
Applications of the Time-QoS Model

- An index to quantify user intolerance of network quality:
  \[
  \log(\text{departure rate}) \propto 1.27 \times \log(\text{rtt}) + 0.68 \times \log(\text{jitter}) + 0.12 \times \log(\text{loss}) + 0.09 \times \log(\text{slloss})
  \]

- [Application 1] Optimizing user experience
  - Allocate more resources to players experience poor QoS

- [Application 2] Design tradeoffs
  - Is it worth to sacrifice 20ms latency for reducing 10ms jitters?

- [Application 3] Path selection

<table>
<thead>
<tr>
<th>Path</th>
<th>Latency</th>
<th>Jitter</th>
<th>Loss rate</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 ms (G)</td>
<td>50 ms (P)</td>
<td>5% (P)</td>
<td>-5.6</td>
</tr>
<tr>
<td>2</td>
<td>150 ms (A)</td>
<td>20 ms (G)</td>
<td>1% (A)</td>
<td>-6.0</td>
</tr>
<tr>
<td>3</td>
<td>200 ms (P)</td>
<td>30 ms (A)</td>
<td>1% (A)</td>
<td>-5.4</td>
</tr>
</tbody>
</table>

(Best choice)
Summary

- **Session time** as a means to assess the impact of network quality on users in real-time applications

- Game players are not only **sensitive**, but also **reactive**, to network conditions they experience

- Proposed a time-QoS model as a utility function to optimize user experience and network infrastructure design
Thank You!

Kuan-Ta Chen