Network Telemetry for Measuring and Enhancing Online Gaming Experience

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Outline

- Gaming opportunity
  - Market growth, network requirements, game acceleration

- Gaming anatomy
  - Game detection
  - Game discovery

- Gaming experience
  - Contention / congestion
  - Network jitter

- Implementation and evaluation
  - What can ISPs do?
  - Neutrality concerns
The Gaming Market

- eGaming made $140 billion in 2018
  - **Shooting**: Fortnite ($2.4b); Crossfire ($1.3b); Call-of-Duty ($689m); CS:GO ($414m)
  - **Strategy**: Honour of Kings ($2.1b); League of Legends ($1.4b); Dota2
  - **Sports**: FIFA 18 ($830m); Madden

![Image of Apex Legends and Fortnite](image1.png)

- Cloud gaming coming soon:
  - Google Stadia, Microsoft xCloud
  - Amazon? Facebook? Apple?

### Top free-to-play games by revenue, 2018

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title</th>
<th>Publisher</th>
<th>Genre</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fortnite</td>
<td>Epic Games</td>
<td>Shooter</td>
<td>$2.4B</td>
</tr>
<tr>
<td>2</td>
<td>Honour of Kings</td>
<td>Tencent</td>
<td>MOBA</td>
<td>$2.1B</td>
</tr>
<tr>
<td>3</td>
<td>Dungeon Fighter Online</td>
<td>Nexon</td>
<td>RPG</td>
<td>$1.5B</td>
</tr>
<tr>
<td>4</td>
<td>QQ Speed</td>
<td>Tencent</td>
<td>Racing</td>
<td>$1.4B</td>
</tr>
<tr>
<td>5</td>
<td>League of Legends</td>
<td>Riot Games, Tencent</td>
<td>MOBA</td>
<td>$1.4B</td>
</tr>
<tr>
<td>6</td>
<td>Crossfire</td>
<td>Neowiz Games</td>
<td>Shooter</td>
<td>$1.3B</td>
</tr>
<tr>
<td>7</td>
<td>Pokemon GO</td>
<td>Niantic</td>
<td>Adventure</td>
<td>$1.1B</td>
</tr>
<tr>
<td>8</td>
<td>Candy Crush Saga</td>
<td>King, Activision Blizzard</td>
<td>Puzzle</td>
<td>$1.0B</td>
</tr>
<tr>
<td>9</td>
<td>Fate/Grand Order</td>
<td>Aniplex</td>
<td>RPG</td>
<td>$1.0B</td>
</tr>
</tbody>
</table>
Gaming Network Requirements

- Gaming is extremely real-time, needs consistent latency < 250ms
  - Glitch of 100ms can kill, causing extreme frustration
  - Game-play streams are usually in Kbps

- Current methods do not suffice
  - Buffering is not an option
  - Over-provisioning is expensive (and will be used by video anyway)
  - Edge compute can reduce baseline latency, but congestion in access still causes jitter

- Cloud gaming:
  - High bandwidth (15Mbps) + low latency (250 msec) = huge stress on the network
Gaming acceleration (and monetization)

- Subscribers paying $7-$15 per month for boosted gaming
  - “Middle-mile” acceleration (rerouting)
  - Client-based detection and tunneling

- “Last mile” acceleration
  - Transparent to user
  - Network detection and prioritization (non-neutral)

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**Outfox**

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**WTFast**

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**Haste**

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**Online Gaming**

Cox Internet now charges $15 extra for faster access to online game servers

Cox is reselling a PC-only game service—there’s no net neutrality issue here.

**Light Reading, 14-Jun-2019**

Operators’ best bet is perhaps to court business customers and technology partners. Niantic, a games company in edge trials with Deutsche Telekom, might be persuaded to pay the German operator for low-latency guarantees -- effectively sharing its gaming revenues -- although Deutsche Telekom has acknowledged that commercial arrangements are still "up in the air."
Anatomy of modern games

- Analyzed 12 games:
  - **Shooting**: Fortnite, PUBG, PUBG Mobile, CS:GO, Apex Legends, Overwatch, CoD
  - **Strategy**: League of Legends, Starcraft II, Dota2
  - **Sports**: FIFA, Rocket League

- Variety of distributor/developers:
  - Epic, Steam/Valve, Tencent, Blizzard, Riot, Origin

- Common state machine:
Foreplay vs Gameplay

- Foreplay services:
  - Encrypted TCP connections (with DNS lookup and TLS certificates)

<table>
<thead>
<tr>
<th>Service</th>
<th>SNI</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launcher</td>
<td>launcher-public-service-prod06.ol.epicgames.com</td>
<td>Epic games launcher for login and authentication</td>
</tr>
<tr>
<td>Waiting Room</td>
<td>fortnitewaitingroom-public-service-prod.ol.epicgames.com</td>
<td>The user decides the game mode</td>
</tr>
<tr>
<td>Party</td>
<td>party-service-prod.ol.epicgames.com</td>
<td>Lobby area to invite friends to play together</td>
</tr>
<tr>
<td>Social Network</td>
<td>Friends-public-service-prod.ol.epicgames.com</td>
<td>In-game social network</td>
</tr>
<tr>
<td>Matchmaking</td>
<td>fortnite-matchmaking-public-service-live-prod-b.ol.epicgames.com</td>
<td>Groups waiting players to start a match</td>
</tr>
<tr>
<td>Anti-cheat</td>
<td>hydra.anticheat.com</td>
<td>Third-party service to prevent cheating</td>
</tr>
<tr>
<td>Data reporting</td>
<td>data-router.ol.epicgames.com</td>
<td>Anonymous stats reporting for analytics purposes</td>
</tr>
</tbody>
</table>

- Gameplay is UDP
  - Game-server IP address exchanged during foreplay
    - Pings may be done to determine best server from a small set
  - Packet up/down rates are reasonably steady for most games (30-60 pkts/sec)
    - Data rates very low: < 100 Kbps
Game detection and discovery

- Look for foreplay: indicates which client and which game title
- Look for ping-tests
- Look for UDP stream with known server-side port range
- Verify rate and duration of UDP stream
- CS:GO example:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Match values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator SNI</td>
<td>api.steampowered.com</td>
</tr>
<tr>
<td>Server-side UDP Port</td>
<td>27000-27100</td>
</tr>
<tr>
<td>Upstream packet rate</td>
<td>64 pkt/sec</td>
</tr>
<tr>
<td>Downstream packet rate</td>
<td>64 pkt/sec</td>
</tr>
<tr>
<td>Duration</td>
<td>&gt; 10 sec</td>
</tr>
</tbody>
</table>
Gaming experience

- Latency jitter is affected by other traffic (browsing, streaming, downloads, …)
- Jitters can be estimated from network traffic (model validated against game-reported lag)
Implementation

- Virtual 10G and programmable-switch based 100G systems operating live at UNSW
- Commercialized offering from Canopus Networks
UNSW traffic patterns

Classifying Flows - 199

Video Flows - 932

Non-Video Flows - 2472

Gameplay Flows - 49

Type Break-up (Last Hour)

Video Consumption (Last Hour)

Non-Video Consumption (Last Hour)

Active Gamers (Last Hour)
UNSW gaming patterns

- Fortnite comes via AWS links


- Bar graph showing gameplay flows and campus load over time.

### Per-stream Gaming Experience

<table>
<thead>
<tr>
<th>Client IP</th>
<th>Server IP</th>
<th>Title</th>
<th>Down Packet Rate</th>
<th>Average Jitter</th>
<th>Duration</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>129.94.8.212</td>
<td>103.10.124.161</td>
<td>Dota2</td>
<td>31 pps</td>
<td>16 ms</td>
<td>4.7 mins</td>
<td>Active Now</td>
</tr>
<tr>
<td>129.94.8.188</td>
<td>150.109.11.147</td>
<td>PUBG Mobile</td>
<td>21 pps</td>
<td>28 ms</td>
<td>1.2 mins</td>
<td>Active Now</td>
</tr>
<tr>
<td>129.94.8.86</td>
<td>103.10.125.162</td>
<td>Dota2</td>
<td>30 pps</td>
<td>13 ms</td>
<td>5.6 mins</td>
<td>Active Now</td>
</tr>
<tr>
<td>131.236.156.4</td>
<td>35.189.45.127</td>
<td>Fortnite</td>
<td>43 pps</td>
<td>36 ms</td>
<td>9.4 mins</td>
<td>Active Now</td>
</tr>
<tr>
<td>129.94.8.63</td>
<td>103.240.227.191</td>
<td>League of Legends</td>
<td>22 pps</td>
<td>59 ms</td>
<td>4.5 mins</td>
<td>Active Now</td>
</tr>
</tbody>
</table>

**Packet Rate**

- Range: 0 pps to 150 pps
- Graph showing packet rate over time from 14:51 to 14:55

**Jitter**

- Range: 0 ms to 600 ms
- Graph showing jitter over time from 14:51 to 14:55

**Jitter CCDF**

- Graph showing cumulative distribution function of jitter over time from 0 ms to 600 ms
Protecting gaming experience

- Game-play flows identified, isolated, prioritised, and (potentially) relayed
Gaming and Neutrality

- Gaming experience can be easily protected via prioritization
  - Increasing CVC bandwidth is expensive, and will be taken up by other traffic (e.g. video)

- Neutrality principle: network should provide a level playing field to applications
  - More applicable to monopolistic right-of-way; Australia has nationalized infrastructure
    - Mobile networks have always been non-neutral and yet seen thriving innovation in applications
  - Playing field hardly level for applications: global cache footprint + sophisticated algorithms
    - On-net content and application-specific routing violate the principle anyway
  - Neutrality inhibits network innovation and threatens growth

- Framework for a post-neutral world [2]:
  - Open, flexible, and rigorous specification of policy
  - RSPs should be able to distinguish themselves on experience
  - Let customers pick RSP to suit their preferences

Conclusions

- Gaming is growing explosively (like video was 5 years back) and making money
- Gaming experience is extremely sensitive to network conditions
- ISPs can detect gaming traffic and measure experience (at 100Gbps and above)
- ISPs are well positioned to protect gaming experience
  - Adding bandwidth is not economically viable; prioritization is
  - Consumers are willing to pay for good experience
  - Content providers cannot solve this problem on their own
- Recommend taking action now
  - Before “speed ranking” gets equated with gaming experience
  - Before cloud gaming hits