Introduction to Networked Graphics

Part 2 of 5: Requirements and Constraints
Overview

- **Goal:**
  - To give an overview of the performance of the Internet and how it affects how NVEs can work.

- **Topics:**
  - Internet performance
  - Why are all types of networked graphics non-standard networking applications?
  - Requirements on consistency
  - Implications for latency and scalability
Internet performance

- Latency (Round Trip Time)
  - Time to transmit data (speed of light, modems)
- Jitter
  - Routers insert bandwidth
- Bandwidth (Capacity)
  - Broadband for WAN, Ethernet for LAN?
- Loss (Congestion, Reliability)
  - Routers drop packets, links do go down
- Not fully connected
  - Network address translation
Latency

- Sources of latency
  - Speed of copying to link (e.g. modem)
  - Speed of transmission in link (e.g. speed of light)
  - Client scheduling (when packets arrive compared to the commitment to render the effect)
  - Server scheduling (e.g. server updates at a fixed frequency)
Jitter

- Jitter is change in latency
- Jitter is caused by the technology of the Internet
  - Wired routers
  - Wireless access
- Two problems:
  - Routers are almost certainly capacity bound and demand on routers changes rapidly
  - Some link layers (notably wireless) are shared medium so transmitters will conflict
Latency and Jitter: Network Perspective

Transmission Delay: time it takes to put a packet on the outgoing link
Propagation Delay: time it takes for the packet to arrive at destination
Bandwidth

- Bandwidth is a shared resource
- At local level we shared the wireless or share a home or office router
  - Can be much more outbound or requested inbound traffic that the local network can access
- However probably, the bottleneck is likely to be upstream to our ISP
- ISP have intra-ISP (and “senior” ISP) bottlenecks
- The destination site (BBC, Facebook) might have inbound capacity limits
Loss

- Loss is good
- Loss is the Internet’s way of protecting itself from overload
- Principally caused by congestion: a router can’t cope with the throughput OR it can’t copy all incoming traffic on to the desired outgoing route
- End to end protocols need to detect loss
  - TCP does this for you
- Protocols need to rate limit because not doing so will likely make the situation worse
Loss : Network Perspective
Bandwidth and Latency: Wired

- Much literature in the area is based on 56kbps modems …
- Broadband is now common in homes
  - 500Kbps – 1Gbps
  - Depends on technology (twisted-pair v. optical)
- Offices have always been different
  - 1Gbps Ethernet, switched (not shared) is common
  - Outbound varies enormously
- Latency is good
Bandwidth and Latency: Wireless

- 2G
  - Don’t try, run web or sms-based applications!
- 3G / 4G
  - 3G: ~2.4Mbps
  - 4G: 100Mbps – 1Gbps
- 802.11a-n
  - b: 11 Mbps
  - n: 54 Mbps
- Be skeptical: its shared bandwidth
- Latency is moderate-poor: its shared bandwidth
### Bandwidth Availability

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Mbps Q1, 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Global</td>
<td>2.1</td>
</tr>
<tr>
<td>1</td>
<td>South Korea</td>
<td>14.4</td>
</tr>
<tr>
<td>2</td>
<td>Hong Kong</td>
<td>9.2</td>
</tr>
<tr>
<td>3</td>
<td>Japan</td>
<td>8.1</td>
</tr>
<tr>
<td>4</td>
<td>Netherlands</td>
<td>7.5</td>
</tr>
<tr>
<td>5</td>
<td>Romania</td>
<td>6.6</td>
</tr>
<tr>
<td>6</td>
<td>Czech Rep.</td>
<td>6.5</td>
</tr>
<tr>
<td>7</td>
<td>Latvia</td>
<td>6.3</td>
</tr>
<tr>
<td>8</td>
<td>Switzerland</td>
<td>6.2</td>
</tr>
<tr>
<td>9</td>
<td>Belgium</td>
<td>6.1</td>
</tr>
<tr>
<td>10</td>
<td>Ireland</td>
<td>5.6</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>United States</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Average connection speed by country, Q1 2011. Based on Akamai, State of the Internet, 4(2)
**Effect of distance on throughput**

<table>
<thead>
<tr>
<th>Distance from Server to User (miles)</th>
<th>Network Latency (ms)</th>
<th>Typical Packet Loss (%)</th>
<th>Throughput (Mbps)</th>
<th>4GB DVD Download Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local: &lt;100</td>
<td>1.6</td>
<td>0.6</td>
<td>44</td>
<td>12min</td>
</tr>
<tr>
<td>Regional: 500-1,000</td>
<td>16</td>
<td>0.7</td>
<td>4</td>
<td>2.2hrs</td>
</tr>
<tr>
<td>Cross-continent ~3,000</td>
<td>48</td>
<td>1.0</td>
<td>1</td>
<td>8.2hrs</td>
</tr>
<tr>
<td>Multi-continent ~6,000</td>
<td>96</td>
<td>1.4</td>
<td>0.4</td>
<td>20hrs</td>
</tr>
</tbody>
</table>

Based on (Leighton, 2009)
Why NVEs are unique

• NVEs are not “standard” network applications
• Unlike video/audio streaming, or web browsing, in an NVE or NG client, networking is NOT the main activity: rendering probably is
• Some information changes very quickly and smoothly
  • E.G. player positions
• Can incorporate other web-enabled media
  • Audio/video
• Often require bulk download of assets
• NVEs mix different types of requirement
Why NVEs are unique

- Internet is built to move bulk traffic, but not for end to end speed
- You can’t reserve bandwidth (except in certain situations)
- Latency and bandwidth will vary
- Streaming for audio and video will buffer significantly and loss is not important
- For NVEs loss can be critical, but also buffering is usually not appropriate
Consistency : System Perspective

- C1 : Local changes replicated at each site
- C2 : Simulation should not diverge over time
- C3 : Casual order of events should be preserved
- C4 : Temporal and motion characteristics of events should be preserved
Consistency : User Perspective

- C5 : The joint perception of events should be plausible
- C6 : The outcome of the events should be fair
- C7 : The system should preserve the users’ intentions
Impact: Timing Activity
Onset

Car_A Car_B

Car_A A=1, V=0
Car_A A=1, V=1
Car_A A=1, V=2
Car_A A=1, V=3

Car_B A=1, V=0
Car_B A=1, V=1
Car_B A=1, V=2
Car_B A=1, V=3

Client_A

Client_B

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Impact: Inconsistent State Changes

Door is Closed & Unlocked

Can’t apply open state

Door is Closed & Locked

Door is Open & Unlocked

Client_A

Lock Door

Open Door

Client_B

Door is Open & Unlocked

Door is Closed & Locked
Impact: Fireproof

Players

Shooter
(Player_A)

Target
(Player_B)

Client_A

Server

Client_B

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Impact: Shooting Around Corners

Shooter (Player$_A$)  Target (Player$_B$)

Client$_A$  Server  Client$_B$
Bandwidth Requirements

- Obviously depends on activity
  - Downloading models
  - Sending small, game specific commands
  - Rate of command sending (very sensitive to type of game)
- Typically:
  - FPS & real-time send commands at fixed rate (e.g. 20 Hz)
  - RTS and other send commands at issue rate (e.g. up to 5Hz with StarCraft)
## Packet Rates

Server packet rates and sizes for three FPS games, from Feng et al. (2005)

<table>
<thead>
<tr>
<th>Game</th>
<th>Packet Rate In (pps)</th>
<th>Packet Rate Out (pps)</th>
<th>Packet Size In (bits)</th>
<th>Packet Size Out (bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day of Defeat</td>
<td>421.85</td>
<td>341.92</td>
<td>41.73</td>
<td>162.78</td>
</tr>
<tr>
<td>Medal of Honor: Allied Assault</td>
<td>379.67</td>
<td>294.10</td>
<td>50.10</td>
<td>291.71</td>
</tr>
<tr>
<td>Unreal Tournament 2003</td>
<td>469.89</td>
<td>123.43</td>
<td>27.92</td>
<td>117.74</td>
</tr>
</tbody>
</table>
Client packet rates and sizes for four MMORPG games, from Molnár & Szabó (2008)

<table>
<thead>
<tr>
<th>Game</th>
<th>Packet Rate In (pps)</th>
<th>Packet Rate Out (pps)</th>
<th>Packet Size In (bytes)</th>
<th>Packet Size Out (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World of Warcraft</td>
<td>6.39</td>
<td>6.21</td>
<td>220.25</td>
<td>71.12</td>
</tr>
<tr>
<td>Guild Wars</td>
<td>3.76</td>
<td>3.83</td>
<td>183.19</td>
<td>57.78</td>
</tr>
<tr>
<td>Eve Online</td>
<td>0.84</td>
<td>0.86</td>
<td>261.18</td>
<td>64.41</td>
</tr>
<tr>
<td>Star Wars Galaxies</td>
<td>12.26</td>
<td>6.34</td>
<td>156.47</td>
<td>77.25</td>
</tr>
</tbody>
</table>
### Packet Rates

Bandwidth of Second Life for different region types and different modes of travel. From Kinicki & Claypool (2008)

<table>
<thead>
<tr>
<th>Zone Type</th>
<th>Direction</th>
<th>Standing (kbps)</th>
<th>Walking (kbps)</th>
<th>Teleport (kbps)</th>
<th>Flying (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense &amp; Crowded</td>
<td>S-C</td>
<td>192</td>
<td>703</td>
<td>1164</td>
<td>877</td>
</tr>
<tr>
<td></td>
<td>C-S</td>
<td>15</td>
<td>31</td>
<td>33</td>
<td>31</td>
</tr>
<tr>
<td>Dense &amp; Deserted</td>
<td>S-C</td>
<td>141</td>
<td>278</td>
<td>445</td>
<td>821</td>
</tr>
<tr>
<td></td>
<td>C-S</td>
<td>30</td>
<td>46</td>
<td>36</td>
<td>52</td>
</tr>
<tr>
<td>Sparse &amp; Deserted</td>
<td>S-C</td>
<td>10</td>
<td>31</td>
<td>448</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C-S</td>
<td>13</td>
<td>74</td>
<td>36</td>
<td>73</td>
</tr>
</tbody>
</table>

From Kinicki & Claypool (2008)
Network Address Translation

- The biggest hiccup for any peer to peer networking
- Many (most?) computers on the Internet are behind a NAT
- We are behind a NAT
  - 192.168.14.32 is in a reserved IP address domain
- Your home network probably runs a NAT
  - You have one address from your ISP
  - You might pay to have this be a static IP address
- NATs complicate
Comments on NATs

- Many types of NAT, port static, symmetric, etc.
- You can bypass NATs with “hole-punching” techniques
- Many game middleware have a function for this BUT
  - Game providers need to provide a rendezvous service
  - Need a packet relay service when it fails
- For a peer to peer game, middleware tries to assess which client has best connectivity
- NATs often are combined with the functionality of firewalls whose role is to protect the LAN from malicious incoming traffic
Summary

- Broadband accessibility is growing
- NVEs and NGs tend to demand a lot from the network
  - Some games have low latency requirements
  - Packet rates vary enormously depending on the game type
- The immediate impact of Internet performance can lead to de-synchronization and player frustration
- The Internet is not symmetrically connected