Online Games: Traffic Characterization and Network Support

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Goals of this presentation

• Information about current practices in online games industry

• Traffic of online games – trends and characteristics

• Current network related issues and Quality of Experience (QoE) requirements

• Live QoE testing
Goals of this presentation

• Information about current practices in online games industry

• Traffic of online games – trends and characteristics

• Current network related issues and Quality of Experience (QoE) requirements

• Live QoE testing - a perfect excuse to play for a while...
Gamer population

Global Population vs Gamers
Per region for the top 110 countries: Population, Online Population, Gamers, Money (2013E)

MILLIONS

“MATURE” MARKETS REPRESENT
14.9% of people
31.5% of online people
37.1% of gamers
37.8% of paying gamers
73.6% of money spent on games

<table>
<thead>
<tr>
<th>Region</th>
<th>Total Population (6.4bn)</th>
<th>Online Population (2.4bn)</th>
<th>Active Gamers (1.2bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOR/JP/Oceania</td>
<td>200M</td>
<td>275M</td>
<td>165M</td>
</tr>
<tr>
<td>NAM</td>
<td>350M</td>
<td>190M</td>
<td>85M</td>
</tr>
<tr>
<td>West Europe</td>
<td>400M</td>
<td>310M</td>
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<tr>
<td>East Europe</td>
<td>410M</td>
<td>205M</td>
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<tr>
<td>LATAM</td>
<td>570M</td>
<td>120M</td>
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<tr>
<td>MEA</td>
<td>880M</td>
<td>245M</td>
<td>145M</td>
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<tr>
<td>APAC (Others)</td>
<td>1.0B</td>
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<td>140M</td>
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<td>India</td>
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<td>China</td>
<td>1.3B</td>
<td>540M</td>
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</tr>
</tbody>
</table>

SHARE OF MONEY

17.9%  32.4%  23.2%  2.8%  4.3%  1.8%  1.8%  0.7%  15.2%

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2013 Global Games Market Report | www.globalgamesmarket.com

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Size of the gaming industry

The Global Games Market | Per Region | 2013E

- **LATIN AMERICA**
  - $3.0Bn
  - 4%
  - 11% YoY
  - 116M GAMERS

- **NORTH AMERICA**
  - $22.8Bn
  - 32%
  - 2% YoY
  - 192M GAMERS

- **ASIA-PACIFIC**
  - $25.1Bn
  - 36%
  - 11% YoY
  - 477M GAMERS

- **EUROPE**
  - $19.5Bn
  - 28%
  - 4% YoY
  - 446M GAMERS

- **MIDDLE-EAST**
  - $6.6Bn
  - 28%
  - 4% YoY
  - 446M GAMERS

**TOTAL**
- $70.4Bn
- 6% YoY
- 1,231M GAMERS

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Shift towards online

- Multiplayer games
- Social games
- Mobile games
- Content distribution
- DRM

Recent Digital* and Physical Sales Information

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<tr>
<th>Year</th>
<th>Total Digital Format</th>
<th>Total Physical Format</th>
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<tbody>
<tr>
<td>2009</td>
<td>80%</td>
<td>20%</td>
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<tr>
<td>2010</td>
<td>72%</td>
<td>28%</td>
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<tr>
<td>2011</td>
<td>69%</td>
<td>31%</td>
</tr>
<tr>
<td>2012</td>
<td>60%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Source: The NPD Group/Games Market Dynamics: U.S.

Facebook Games

> 250 million monthly players

Peak Concurrent Players

- Top 100 Games on Steam: 650,000
- Call of Duty Modern Warfare 3 on Xbox Live: 1.4 Million
- League of Legends: 3 Million

10.01.2014
Shift towards online

- Multiplayer games
- Social games
- Mobile games
- Content distribution
- DRM

Xbox One is supported by 300,000 servers, compared to 30,000 of Xbox Live.

Recent Digital* and Physical Sales Information

- Total Digital Format
  - 20% 28% 31% 40%
  - 80% 72% 69% 60%

Facebook Games

> 250 million monthly players

Peak Concurrent Players

- 650,000: Top 100 Games on Steam on Friday 10/5/12
- 1.4 Million: Call of Duty Modern Warfare 3 on Xbox Live
- 3 Million: League of Legends average number of players online simultaneously on a typical May Month of July
Types of multiplayer

• Earliest ways – hot seat and split screen
• Playing over local networks
• Playing through Internet (online)
• The most popular online multiplayer games:
  – MMORPG (Massively Multiplayer Online RPG)
  – FPS (First Person Shooter)
  – RTS (Real Time Strategy)
  – MOBA (Multiplayer Online Battle Arena) – combination RTS and RPG genres
Social games

- Facebook by far the biggest platform, but its overall market share is decreasing
- Casual games
- Gambling games

Source: SuperData research
Mobile games - The next big thing?

- Estimated to double by 2016 and reach $23.9BN
Content distribution

• Digital distribution taking over
• Steam reached over 65 million active monthly users
Who are the consumers?

The average game player age is:

30

- 32% under 18 years
- 31% 18-35 years
- 37% 36+ years

Are video games only for kids?

Source: Entertainment Software Association (ESA)
10.01.2014.
Device types

Global Games Market Per Segment | 2013 E
Games Played on the PC screen generate most revenues globally

- **Handheld Console**: 7% of $5.1Bn
- **PC Boxed Download & MMO**: 30% of $21.0Bn
- **TV / Console**: 36% of $25.4Bn
- **Smartphone**: 12% of $8.5Bn
- **Tablet**: 6% of $3.8Bn
- **Casual / Social**: 9% of $6.6Bn

**Total**: $70.4Bn

Source: Newzoo Global Games Market Report
Estimated growth

Global Games Market 2012 - 2016

ALL SEGMENTS: CAGR +6.7%
MMO'S: CAGR +10.4%
PC/MAC: CAGR -6.4%
TABLET: CAGR +47.6%
SMARTPHONE: CAGR +18.8%
HANDHELD: CAGR -15.0%
TV/CONSOLE: CAGR +3.5%
SOCIAL/CASUAL: CAGR -1.7%

Source: Newzoo, 2013 Global Games Market Report

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Personal Computer (PC)

- Multi purpose device – not dedicated purely for purpose of playing games
- “Natural” place for networked games
- Almost all PCs equipped with a network interface
- “Core players” – perceived as a device for core gaming audience
Consoles

• Consoles of the newest generation are equipped with network interfaces
• Supported by cloud server infrastructure
• XboX One supported by 300 000 servers
• Additional payment for multiplayer
  – PlayStation Plus account
  – Microsoft Xbox Live account
Mobile

• Mobile phones, tablets, handheld consoles
• Relatively new but very large market
• Clash of Clans – 1 million dollars a day
• Time spent in games can be larger than even time spent in social networks (some of the games work offline and do not generate network traffic)
• Biggest problems for Quality of Experience of online games – variability of network parameters (latency, latency variation, and packet loss)

Business models

• Pay to play
  – Game client/account
  – Subscription
  – Additions to existing games

• Free to play (F2P)
  – Micro transactions
  – Additional content
  – Premium accounts
  – Cosmetic/usability improvements

• Combinations

• F2P demands full server control!!!
F2P and scalability

• F2P enables much easier entry point for players – much larger player numbers
• Example - battle for the Defense of the Ancients (DOTA) “heir”
  – Dota is a highly popular custom map for Blizzard Entertainment’s Warcraft 3 (millions of players)
  – Enough for development of stand alone games
  – Released: HoN May, 2010 and LoL October 2009
  – Similar scores on metacritic: LoL – 78%, HoN – 76%
  – LoL – F2P, HoN – P2P
  – Today: LoL – 30 million unique players, HoN around 2million
Subscription based model in decline (MMORPGs)

A player in the USA:
$15 a month
12 months
$180 a year

Source: mmodata.org
Peak concurrent users (MMORPGs)

Source: mmodata.org
Game network traffic - global trends

• Global game traffic
  – Very small share of the global volume
  – 22% CAGR (Compounded Annual Growth Rate)

<table>
<thead>
<tr>
<th></th>
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<td>By Subsegment (PB per Month)</td>
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<td>Internet video</td>
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<td>25,800</td>
<td>32,962</td>
<td>41,916</td>
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<td>Web, email, and data</td>
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<td>6,336</td>
<td>7,781</td>
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<td>11,828</td>
<td>14,494</td>
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<tr>
<td>File sharing</td>
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<td>7,119</td>
<td>7,816</td>
<td>8,266</td>
<td>8,478</td>
<td>8,667</td>
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<tr>
<td>Online gaming</td>
<td>22</td>
<td>26</td>
<td>32</td>
<td>39</td>
<td>48</td>
<td>59</td>
<td>22%</td>
</tr>
</tbody>
</table>
Game network traffic growth estimation


10.06.2013.
Architecture

• Increasing dominance of client – server (C-S)
  – Cheating avoidance
  – Easier synchronization
  – Billing

• Peer to Peer (P2P)
  – Very few true Peer to Peer games (e.g., Demigod)
  – Great scalability for large scale virtual worlds
  – A lot of research activity (e.g., scalability for Minecraft projects – Manycraft, Koekepan,
Bottlenecks

• Three potential bottlenecks:
  - uplink: gamers send their actions
  - server: calculation of the next state
  - downlink: send the state to players
Server organization in C-S model

• Server included in the game and one client acts as the server (e.g., *Warcraft 3*)

• Dedicated server application released and players create their own servers (e.g., *Call of Duty*)

• *Server fully controlled by the developer/publisher* (e.g., *World of Warcraft*)

• Multiplayer match organization may be orchestrated by the game provider, third parties, or by players themselves
Client versions

• Specific application per game
  – Full clients (all the information stored in the client on player’s device – single player games)
  – Hybrid clients (need to communicate with the server)

• Clients encompassing multiple games
  – Browser based games
  – Cloud based games (thin clients)

• Client version is dependant of where game logic and rendering is executed which heavily affects traffic characteristics
Game logic and rendering

• Stored fully on the client side (no information exchange with the server)
• Game rendering on the client, game logic on the server
  – Most games
  – Virtual world updates from the server side
  – Commands from client side
• Game rendering and logic on the server (cloud games)
  – Video transferred from server to client
  – Very sensitive to delay
• Game logic on the server and most of the rendering on the server
  – Only visual indicators of input on client (e.g., a flashing of a button when the command is issued)
Information transferred

• What information does the traffic comprise?
  – Player commands/inputs
  – Virtual world state refreshes
  – Chat
  – Audio flows for player communication
    • Some games have in-built VoIP systems
    • Many players use stand alone applications (Teamspeak, Ventrilo, Skype...)
  – 3D data describing virtual world (Second Life)
  – Video
    • Send by cloud based games
    • Streaming of gaming sessions
Traffic characterization

• Game flows:
  – Long lived
  – High packet rate
  – Small payload sizes
  – Low bandwidth usage
  – Using both UDP and TCP
  – Dependant on the game genre

• Identified issues:
  – Delay sensitivity
  – Low but very inefficient bandwidth usage
  – Variable delivery requirements

• Thin client games are an exception
Why so small?

- Market penetration!
- *World of Warcraft* was released in 2004 – in order to reach as much users as possible it needed to work on 33,6k modem
- *Unreal Tournament* on 14,4k 😊
- High broadband penetration – will games use more and more bandwidth?
  - No (and yes)
Game traffic evolution? – Not really

**StarCraft I (1998-2010)**
1-5kbps
(2-8 players)

**StarCraft II (2010-present)**
2-3 kbps
(independent of number of players)


10.01.2014.
Game traffic revolution? Yes*

- Cloud gaming traffic
  - Very high bandwidth usage
  - High quality video
  - Very delay sensitive (no client side optimization)
  - * no high market penetration

RTP/UDP flows of the OnLive Streaming Protocol

<table>
<thead>
<tr>
<th>Direction</th>
<th>RTP SSRC</th>
<th>RTP Payload Type</th>
<th>Flow description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream</td>
<td>0x00000000</td>
<td>100</td>
<td>QoS monitoring flow</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00010000</td>
<td>100</td>
<td>OnLive Control</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00030000</td>
<td>100</td>
<td>Audio stream (CBR Codec)</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00040000</td>
<td>100</td>
<td>Cursor position</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00050000</td>
<td>101</td>
<td>Audio stream (VBR Codec)</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00060000</td>
<td>96</td>
<td>Video stream</td>
</tr>
<tr>
<td>Downstream</td>
<td>0x00080000</td>
<td>100</td>
<td>Voice Chat (Sound from other players)</td>
</tr>
<tr>
<td>Upstream</td>
<td>0x0000XXXX</td>
<td>100</td>
<td>User input (keyboard and mouse buttons)</td>
</tr>
<tr>
<td>Upstream</td>
<td>0x0001XXXX</td>
<td>100</td>
<td>Cursor movement</td>
</tr>
<tr>
<td>Upstream</td>
<td>0x0004XXXX</td>
<td>100</td>
<td>OnLive Control ACK</td>
</tr>
<tr>
<td>Upstream</td>
<td>0x0008XXXX</td>
<td>100</td>
<td>Voice Chat (Microphone from the user)</td>
</tr>
</tbody>
</table>
Game genres

- Game categorization:
  - Action (e.g., Grand Theft Auto)
  - Adventure (e.g., Broken Sword)
  - Arcade (e.g., Pinball)
  - Children’s Entertainment (e.g., Bob the Builder)
  - Family Entertainment (e.g., Mahjongg)
  - Fighting (e.g., Mortal Combat)
  - Flight (e.g., Wing Commander)
  - Racing (e.g., Need For Speed)
  - Role Playing (e.g., World of Warcraft)
  - Shooter (e.g., Quake)
  - Strategy (e.g., Starcraft)
  - Other Games

Bandwidth usage across genres

- Warcraft III (RTS)
- World of Warcraft (MMORPG)
- Madden NFL (Sports)
- Unreal Tournament (FPS)
- Second Life (CVE)
- Crazy Taxi (Cloud)
First Person Shooters (FPS)

• Gameplay characteristics:
  – Very fast paced
  – Very delay sensitive (in fact delay is usually shown as main information on the server listings)
  – Several tens of players in one virtual world

• Traffic characteristics
  – Use UDP
  – Loss tolerant (dependant on particular game)
  – Latency very important (usually displayed on server lists, or score lists)
  – Very high packet rate
  – Fairly regular packet sizes
  – Fairly regular packet inter-arrival times
  – In general most demanding game genre bandwidth wise (usually less then 300kbps)
QoE for FPS

• For unimpaired < 80 ms of one way delay (160 ms RTT)
• Loss tolerance dependant on the game (from 1% to 30%)
• Methods to combat delay
  – Cause inconsistencies, but increase QoE
  – Client side prediction
  – Server side delay compensation (merging virtual realities which are out of sync due to network delay)
Shooting around the corner problem (virtual world inconsistency)
Shooting around the corner problem (virtual world inconsistency)
Shooting around the corner problem
(virtual world inconsistency)
Shooting around the corner problem (virtual world inconsistency)

Network delay scheme
Server organization

- Small virtual worlds
- Usually less than 100 players per map
- Servers hosted by players (lower complexity)
- Very densely geographically distributed (to maximally reduce network delay)
CDF’s of different FPS games

World of Tanks

- Effect of player’s death on downlink

Server-to-client bandwidth

Bandwidth [kbps] vs. game time [s]
World of Tanks

• No effect of death on uplink
QoE testing

• Counter Strike Source 1.4
• Two players
  – Small map
  – Death match
• 3 scenarios
  – No network degradation
  – Inserted delay
  – Inserted packet loss
Massively Multiplayer Role-Playing Games (MMORPGs)

• Gameplay characteristics
  – Wide range of possible activities
  – Very large virtual worlds
  – Virtual economies
  – Large number of players in same virtual world (up to tens of thousands)

• Traffic characteristics
  – Much more variable traffic characteristics
  – Less fault tolerance
  – TCP and UDP
  – Looser latency constraints
  – Lower packet rate
  – Lower bandwidth usage
MMORPG - examples

- RuneScape
- EverQuest
- World of Warcraft
- EVE Online
MMORPGs and media

• MMORPGs are not only for hardcore gamers
• *Defiance:* The First Video-Game Television Show
• WoW inspired:
  – Southpark
  – WoW Movie (2015)
  – Countless machinima (i.e., movies made in game engine)
MMORPG architecture: challenges

• **Massively** Multiplayer Online Role-Playing Games
  – A large number of players which share one virtual world
  – WoW – 12 million players (at the peak of popularity)

• Main issues:
  – Calculation of the virtual world state
  – Consistency
  – Cheating avoidance
  – Scalability (all servers need to be under control of the provider)

• Two solutions:
  – Single space worlds (using huge server farms e.g., EvE Online)
  – “Sharding” of virtual word into multiple replicas of the virtual world across which the players are distributed
    • In recent years overlay systems are created over shards (e.g., World of Warcraft)
Single shard worlds

- All players inside one virtual world (EvE online, World of Tanks)
- Great server farms
- What if a lot of users decides to fight at one solar system??
The Asakai incident

Youtube link: [http://www.youtube.com/watch?v= iQw3YcLoQU](http://www.youtube.com/watch?v= iQw3YcLoQU)
Integration of multiple games into one virtual world (Dust 514 and EvE Online)

Youtube link: http://www.youtube.com/watch?v=eS4rAYrRHWc
Shards

- Each shard holds a copy of the whole virtual world
- Players are divided on shards and cannot interact or communicate (although this is changing)
War without the warchief

Youtube link: http://www.youtube.com/watch?v=ZzsIiSTnQfI
10.06.2013.
Example of MMORPG architecture with multiple servers
Transport protocols

• Which protocol TCP or UDP?
  – Depending on the game genre and mechanic

<table>
<thead>
<tr>
<th>Protocol</th>
<th>MMORPGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>World of Warcraft, Lineage I/II, Guild Wars, Ragnarok Online, Anarchy Online, Mabinogi</td>
</tr>
<tr>
<td>UDP</td>
<td>EverQuest, City of Heroes, Star Wars Galaxies, Ultima Online, Asherons Call, Final Fantasy XI</td>
</tr>
<tr>
<td>TCP/UDP</td>
<td>Dark Age of Camelot</td>
</tr>
</tbody>
</table>
MMORPGs and TCP

• TCP not designed for a real time interactive application!!! (yet it works)
• Application limited not network limited flows
• Multiple thin TCP flows behave unlike one fat TCP flow
• Mechanisms in TCP directly deteriorate the experience of the players (delayed ACK, Nagle algorithm)
• Mechanisms of TCP do not work efficiently for MMORPG (cwnd reduced due to application not having something to send)
• High signaling overhead due to small packets
• High number of “pure” ACKS
Specific game transport protocol?

- Game transport protocol
  - Suggested in 2002 for MMORPGs
  - Not really accepted

- Prerequisites of MMORPG Transport Protocol
  - Must be transmitted in order and reliably (chat)
  - Reliable but not in order (attack)
  - Not reliable or in order (move)

- Transport options
  - Multi-streaming
  - Optional ordering
  - Optional reliability

CDF’s of different MMORPGs

MMORPG action diversity
Impact of MMORPG actions on network traffic

- Use case World of Warcraft
- Bandwidth difference – up to 5 times

### Impact of MMORPG actions on QoE

<table>
<thead>
<tr>
<th>Latency</th>
<th>Loss ratio</th>
<th>Frame rate</th>
<th>Jerkiness</th>
<th>Action category</th>
<th>QoE</th>
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<td>D</td>
<td>0.5</td>
</tr>
</tbody>
</table>


10.01.2014.
QoE testing

• World of Warcraft
• Duels!
  – Hunter vs. Warrior
  – Warrior overpowered at lower levels ;)
• 3 scenarios
  – No network degradation
  – Inserted delay
  – Inserted packet loss
Real Time Strategies (RTS)

- Usually omnipresent perspective
- Two major components
  - Development
  - Fighting
- Smaller scale in multiplayer commonly < 10 players in a match
- Recently a sub-genre of RTS games has increased in popularity – Action RTS (or Multiplayer Online Battle Arena – MOBA)
Game network engines

• Synchronization of the game state between participating players

• Starcraft 2 uses the “simulation model”
  – P2P in a client server model!
  – No central authority (server does NOT hold the game state)
  – Game completely deterministic – same inputs should yield the same results
  – Every player’s command is queued up to be done at some point in the future (typically, around 12 frames i.e. 200ms).
  – Every player sends the inputs to other players (through the server)
  – Once all inputs are received game tick is calculated on client side
Pros and cons

• Pros:
  – Synchronization of only a few commands instead of positions of thousands of units
  – Very low bandwidth usage

• Cons
  – Observable input delay (i.e., “lag”) – units do not respond immediately
  – Slowest player slowing down the game for all
  – Possible desynchronization – end of a match
Why is there a server in SC2?

- Traffic scaling - all players send their commands to the server which distributes them to others (no need for each player to send its data to all other players)
- Storing player’s data
- Matchmaking (i.e., matching players with similar skill levels)
- Anti-cheating mechanisms
- Anti-piracy
ARTS (MOBA)

- Started as a community created map for RTS Warcraft 3 (Defense of the Ancients – DOTA)
- DOTA suppressed the popularity of Warcraft 3
- Industry got interested in the “player created genre” dozens of games
- Comparison of 3 different games League of Legends, Heroes of Newerth and DOTA 2
- League of Legends got very popular in a very short while – how to scale such a game?

<table>
<thead>
<tr>
<th>Date</th>
<th>Registered players</th>
<th>Monthly players</th>
<th>Daily players</th>
<th>Peak concurrent players</th>
<th>Daily hours of play</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul. 11</td>
<td>15 million</td>
<td>4 million</td>
<td>1.4 million</td>
<td>0.5 million</td>
<td>3.7 million</td>
</tr>
<tr>
<td>Nov. 2011</td>
<td>32.5 million</td>
<td>11.5 million</td>
<td>4.2 million</td>
<td>1.3 million</td>
<td>10.5 million</td>
</tr>
</tbody>
</table>
Networking model of the source engine (DOTA 2)

- Packet regularity
- Noticeable input delay in comparison with HoN which does client side state calculation

Source: Valve Developer Community
Traffic characteristics comparison

![Packet size comparison](image1)

- **Packet size [b]**
  - HoN
  - LoL
  - Dota2

![Packet rate comparison](image2)

- **Packet rate [pps]**
  - HoN
  - LoL
  - Dota2

![Bandwidth usage comparison](image3)

- **Bandwidth usage [bps]**
  - HoN
  - LoL
  - Dota2

![CDF of IAT](image4)

- **CDF [%]**
  - Dota 2 server
  - HoN server
  - LoL server

10.01.2014.
QoE testing

- More robust to network impairments
- Testing one game 2 actions
- Warcraft III
- Building the base – delay not an issue
- Fighting – delay more noticable
Let us play that online race!

• The web page starts the game application

• One of the players acts as the server
  – It is not the one who creates the race
  – Perhaps the one with the best connection

• Scalability advantage
  – The game company does not have to set up a high number of servers
  – They only orchestrate the players
Let us play that online race!

- Problems:
  - You have to deal with NAT, since a computer has to be the server
  - You have to download the characteristics of the other cars, since they are improved and painted
- Extra delay does not affect, since interaction between cars is not very significant (only at the beginning)
Traces with 8 players (myself + 7)

I am the server. I have to send a burst of 7 packets every 10 ms.
Genre differences in cloud games

- Differences due to game dynamics – different video characteristics

<table>
<thead>
<tr>
<th></th>
<th>pes2012</th>
<th>unreal3</th>
<th>crazytaxi</th>
<th>aircombat</th>
<th>4elements</th>
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<tbody>
<tr>
<td><strong>Downstream</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total time (s)</td>
<td>249.41</td>
<td>261.16</td>
<td>200.56</td>
<td>239.68</td>
<td>236.59</td>
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<tr>
<td>Number of packets</td>
<td>149004</td>
<td>174265</td>
<td>13867</td>
<td>153798</td>
<td>108619</td>
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<tr>
<td>Avg. packets / sec</td>
<td>597.41</td>
<td>667.25</td>
<td>691.39</td>
<td>641.66</td>
<td>459.09</td>
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<tr>
<td>Avg. packet size (B)</td>
<td>915.57</td>
<td>975.05</td>
<td>1014.99</td>
<td>955.65</td>
<td>722.58</td>
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<td>Bit rate (Mbps)</td>
<td>4.37</td>
<td>5.21</td>
<td>5.61</td>
<td>4.91</td>
<td>2.65</td>
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<tr>
<td><strong>Upstream</strong></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Total time (s)</td>
<td>249.48</td>
<td>261.31</td>
<td>200.69</td>
<td>239.83</td>
<td>236.72</td>
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<td>14849</td>
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<tr>
<td>Avg. packets / sec</td>
<td>35.86</td>
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<td>34.01</td>
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<td>62.72</td>
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<tr>
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<td>0.067</td>
<td>0.046</td>
<td>0.075</td>
<td>0.077</td>
</tr>
</tbody>
</table>
GamingAnywhere - Open Source cloud gaming testbed

- Testing different genres and created network traffic
- "Snapping" desktop image at 40FPS
- Traffic properties dependant of the game dynamics (rate of the change of the video stream)

Battlefield 3 (FPS)

Civilization 5 (TBS)
Summary of problems

• Delay sensitivity
• Sensitive to varying network conditions (mobile networks)
• Very low (and inefficient) bandwidth usage of “regular” games
• Very high bandwidth requirements of cloud based games
• Issues regarding consistency of the distributed virtual world state (network engines)
• Fairness
• Scalability problems
• Adapting to player behavior
• Protocol related issues
TCM-TF advertisement

• In need of some flexibility (game release, rush hour, certain places):
  – What if we can multiplex traffic flows when required?
  – What if we save bandwidth in bottlenecks?
First Person Shooter game:

Four IPv4/UDP client-to-server packets of Counter Strike
$\eta = \frac{61}{89} = 68\%$

One IPv4/TCM packet multiplexing four client-to-server Counter Strike packets
$\eta = \frac{244}{293} = 83\%$

MMORPG:

Seven IPv4/TCP client-to-server packets of World of Warcraft. $E[P]=20$ bytes
$\eta = \frac{20}{60} = 33\%$

One IPv4/TCM packet multiplexing seven client-to-server W. of Warcraft packets
$\eta = \frac{120}{187} = 64\%$

VoIP (exactly like RFC4170):

Five IPv4/UDP/RTP VoIP packets with two samples of 10 bytes
$\eta = \frac{20}{60} = 33\%$

One IPv4 TCMTF Packet multiplexing five two sample packets
$\eta = \frac{100}{161} = 62\%$

TCP ACKs without payload

saving
Acknowledgments

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  – Project Catedra Telefonica, University Zaragoza;
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Thank you!

 Marshal McBride