

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

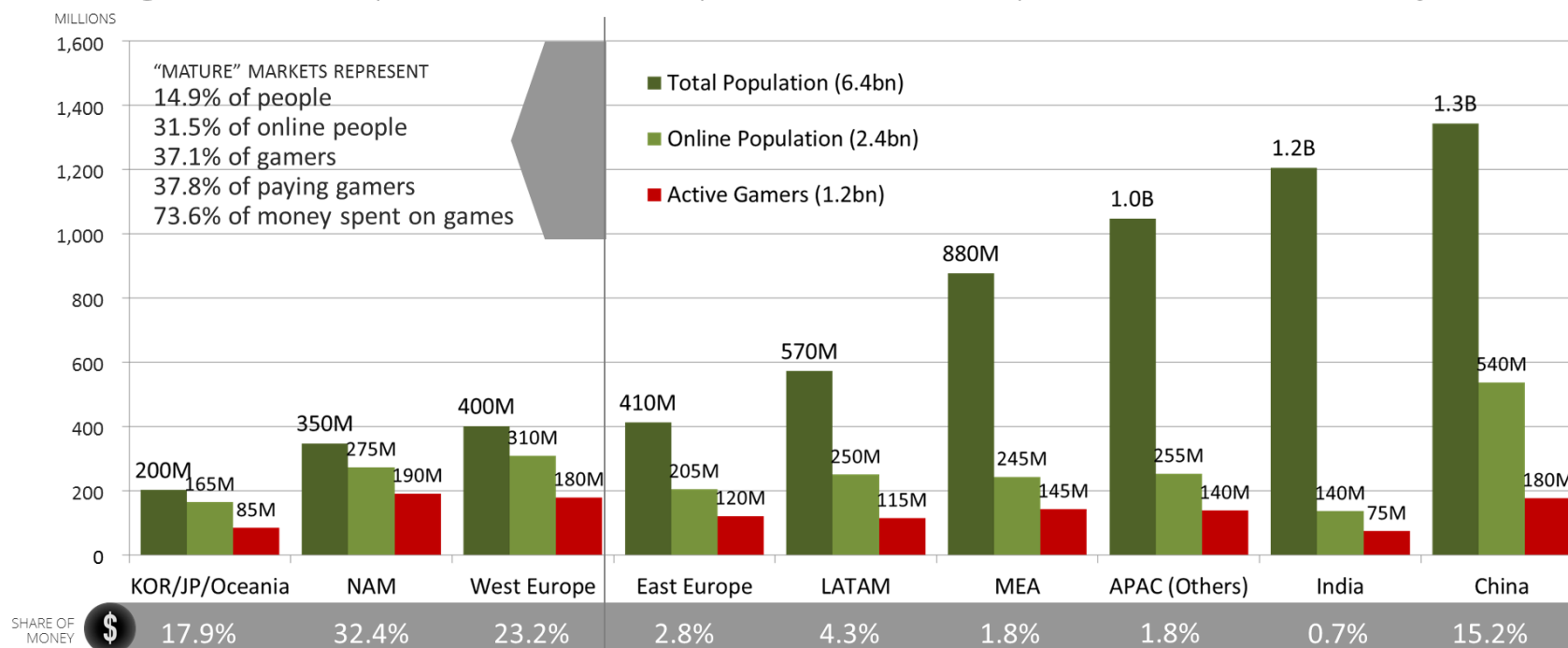
- Information about current practices in online games industry
- Traffic of online games – trends and characteristics
- Current network related issues and Quality of Experience (QoE) requirements
- Live QoE testing - a perfect excuse to play for a while...

Gamer population

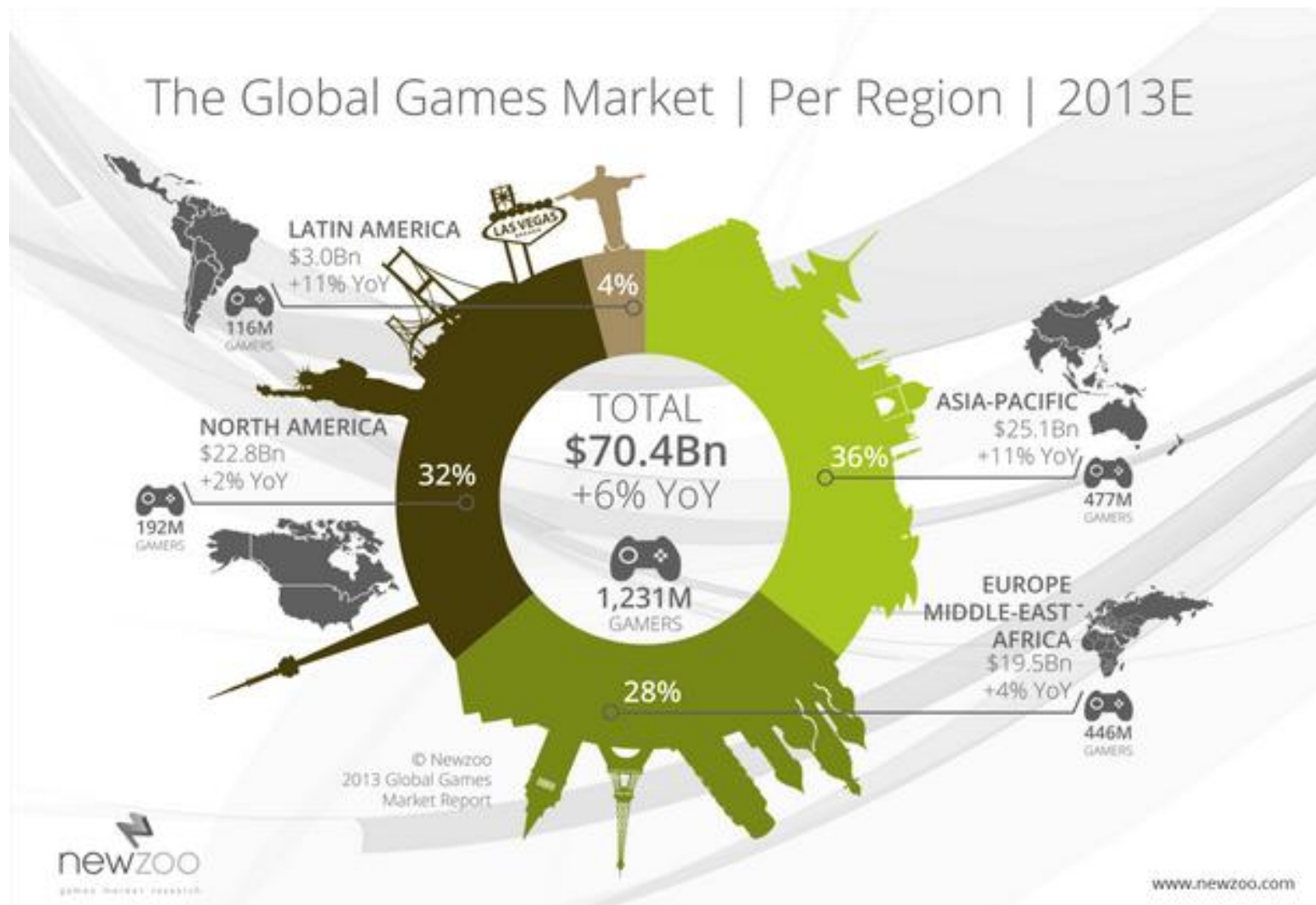
Global Population vs Gamers



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



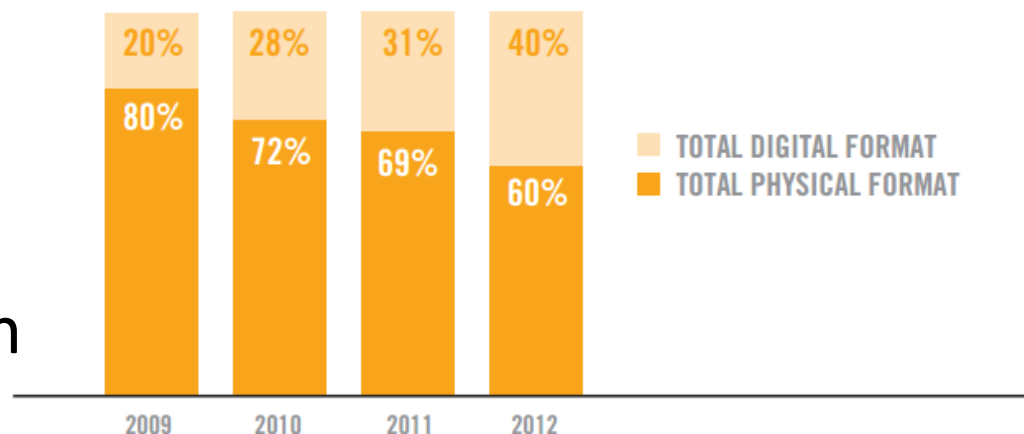
Size of the gaming industry



Shift towards online

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

Recent Digital* and Physical Sales Information



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



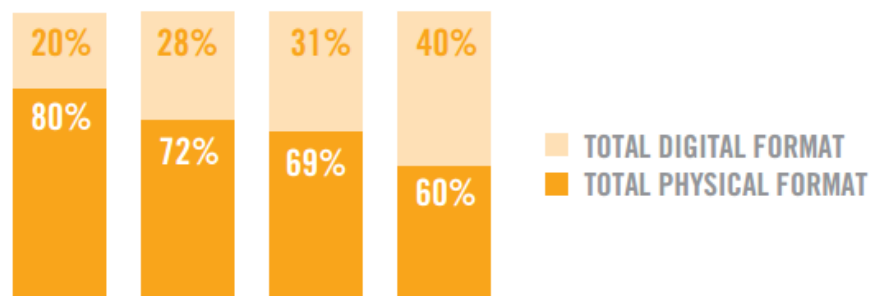
10.01.2014.



Shift towards online

- Multiplayer games
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Recent Digital* and Physical Sales Information



Xbox one is supported by 300 000 servers, compared to 30 000 of Xbox live



10.01.2014.



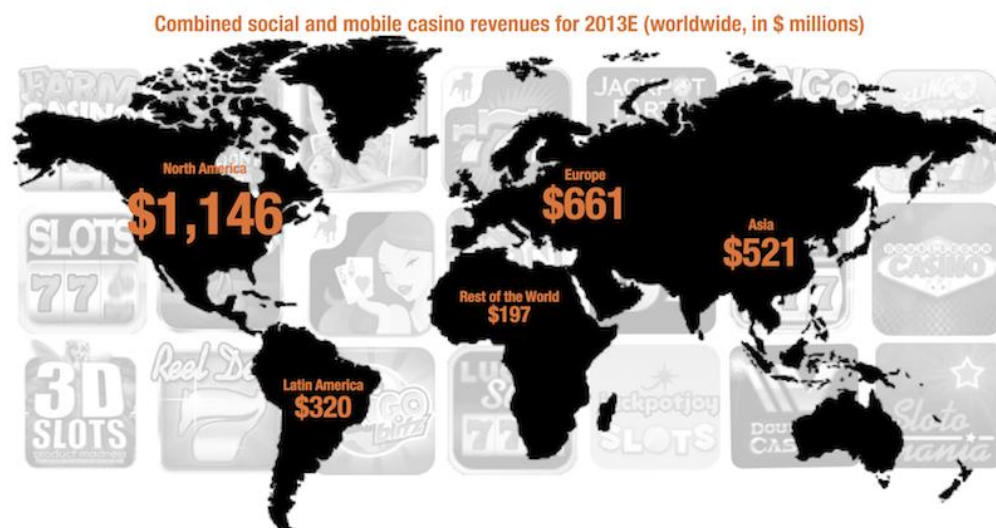
Types of multiplayer

- 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

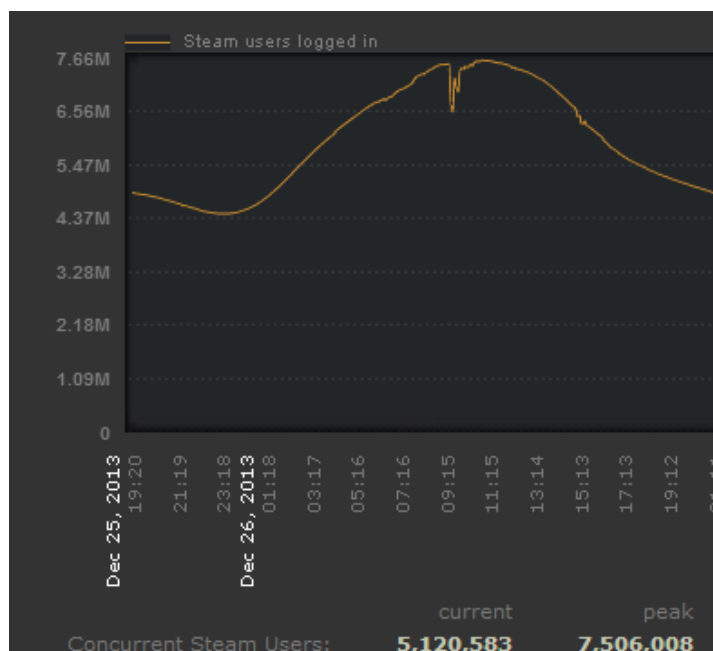
Mobile games - The next big thing?

- Estimated to double by 2016 and reach \$23.9BN

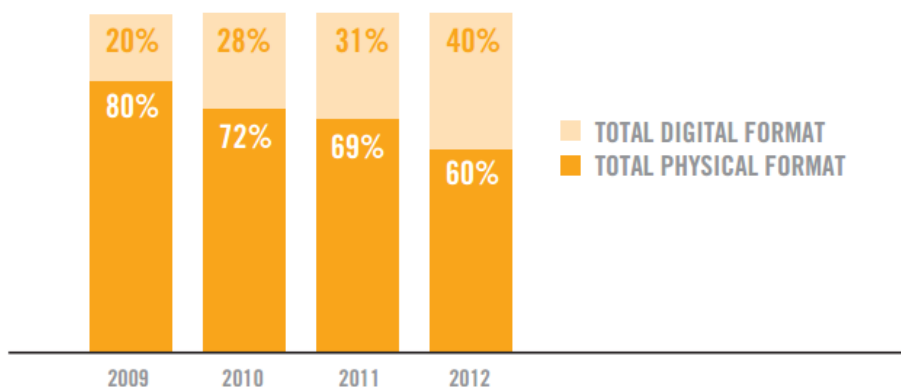


Content distribution

- Digital distribution taking over
- Steam reached over 65 million active monthly users



Recent Digital* and Physical Sales Information

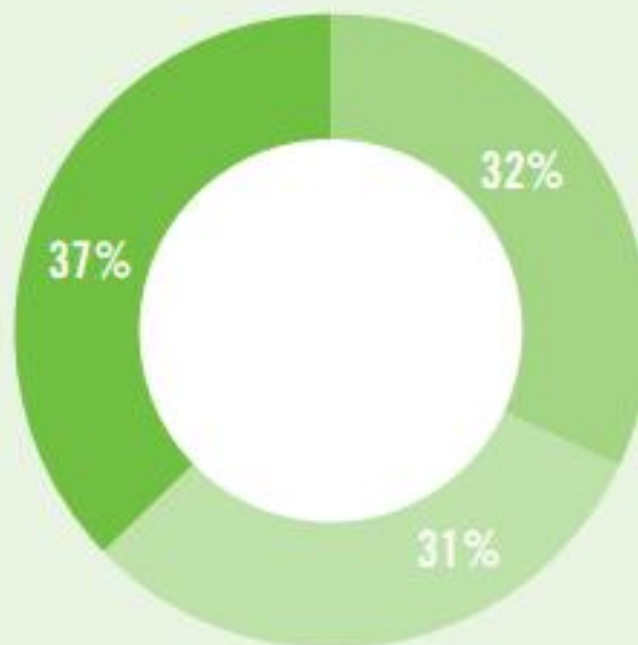


Source: The NPD Group/Games Market Dynamics: U.S

Who are the consumers?

The average game player age is:

30



AGE
of Game Players

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

Source: Entertainment Software Association (ESA) <http://www.theesa.com/facts/gameplayer.asp>
10.01.2014.

Are video games only for kids?

Did You KNOW?

According to ESA's 2012 Essential Facts, 49 percent of American households own a game console.

About the ESA

Become a Member

Industry Facts

- Economic Data
- Sales & Genre Data
- Game Player Data
- Games & Violence
- Video Game Research

Public Policy

Games: Improving What Matters

News Room

Game Player Data

Video games are now a mass medium, widely enjoyed on a variety of platforms by a diverse audience. The ESA's [2012 Essential Facts About the Computer and Video Game Industry](#) reveals interesting demographic facts about today's gamers and the games they play, including:

- The average gamer is 30 years old and has been playing for 12 years. Sixty-eight percent of gamers are 18 years of age or older.
- Forty-seven percent of all players are women, and women over 18 years of age are one of the industry's fastest growing demographics.
- Today, adult women represent a greater portion of the game-playing population (30 percent) than boys age 17 or younger (18 percent).
- Sixty-two percent of gamers play games with others, either in person or online. Seventy-eight percent of these gamers play with others at least one hour per week.
- Thirty-three percent of gamers play social games.
- Gamers play on-the-go: device.

Source: Entertainment Software Association (ESA)

<http://www.theesa.com/facts/gameplayer.asp>

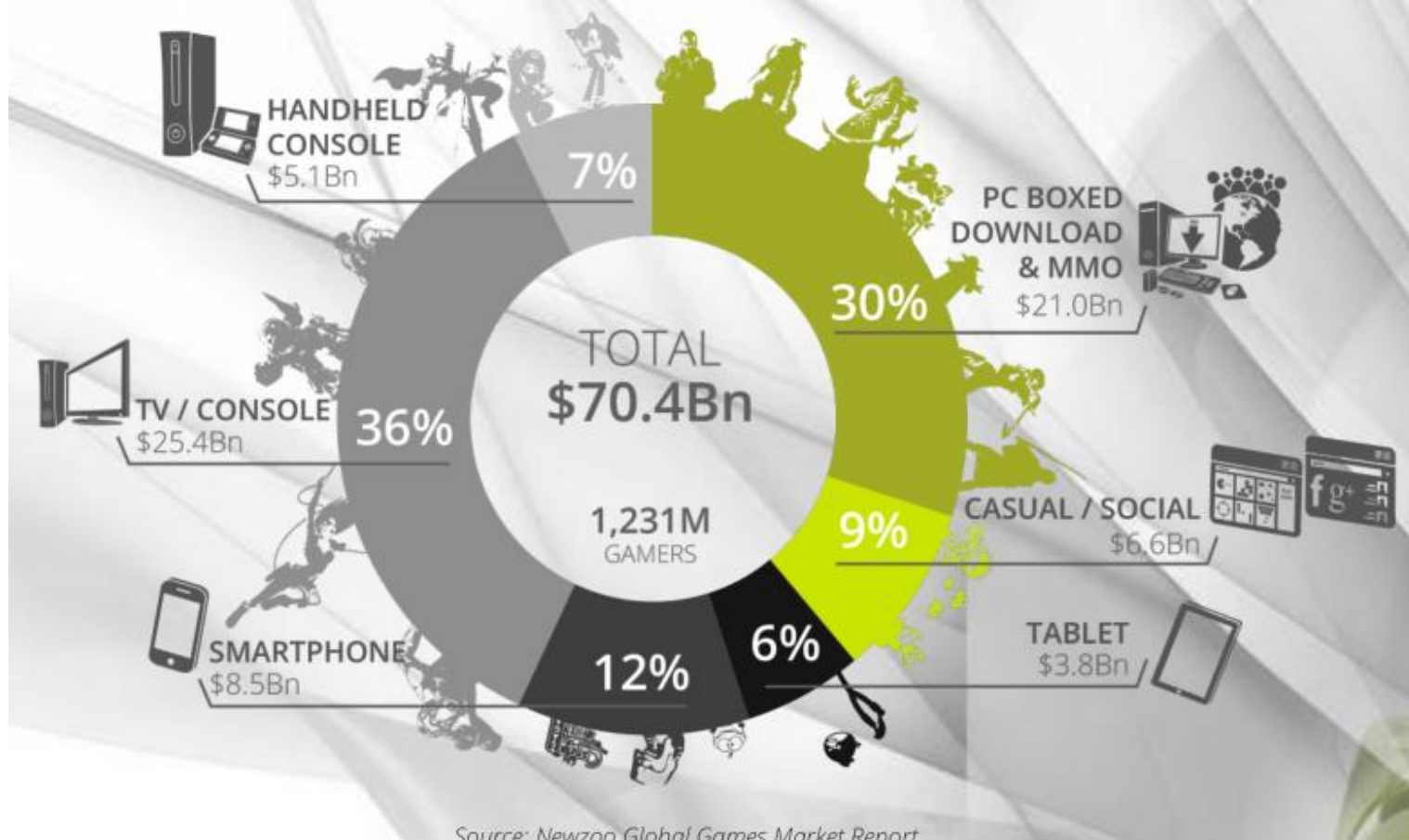
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Device types

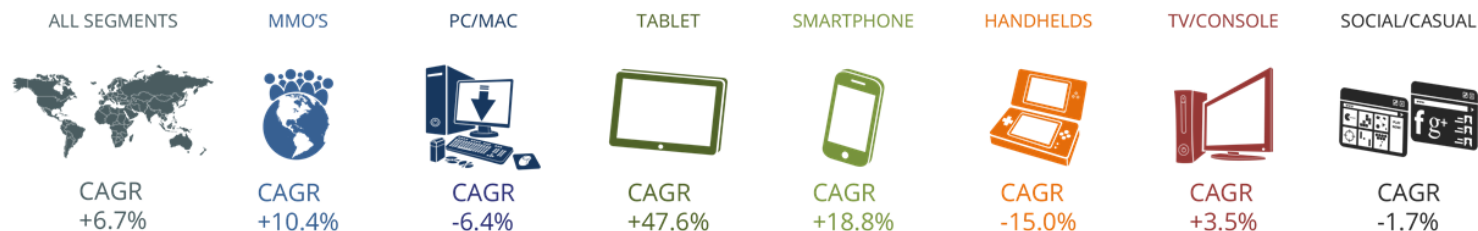
Global Games Market Per Segment | 2013 E

Games Played on the PC screen generate most revenues globally



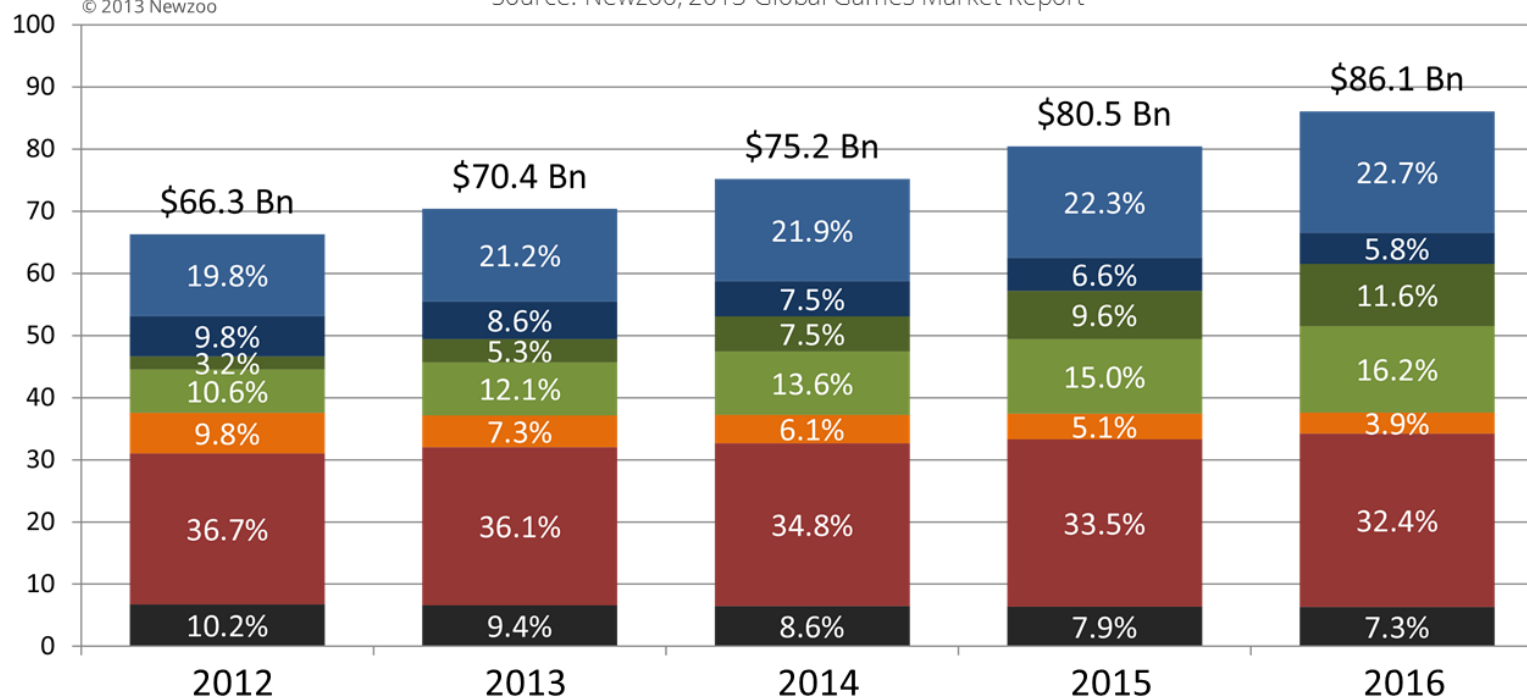
Estimated growth

Global Games Market 2012 - 2016



© 2013 Newzoo

Source: Newzoo, 2013 Global Games Market Report



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)

Source: Ericsson Mobility Report <http://www.ericsson.com/res/docs/2013/ericsson-mobility-report-june-2013.pdf>

Business models

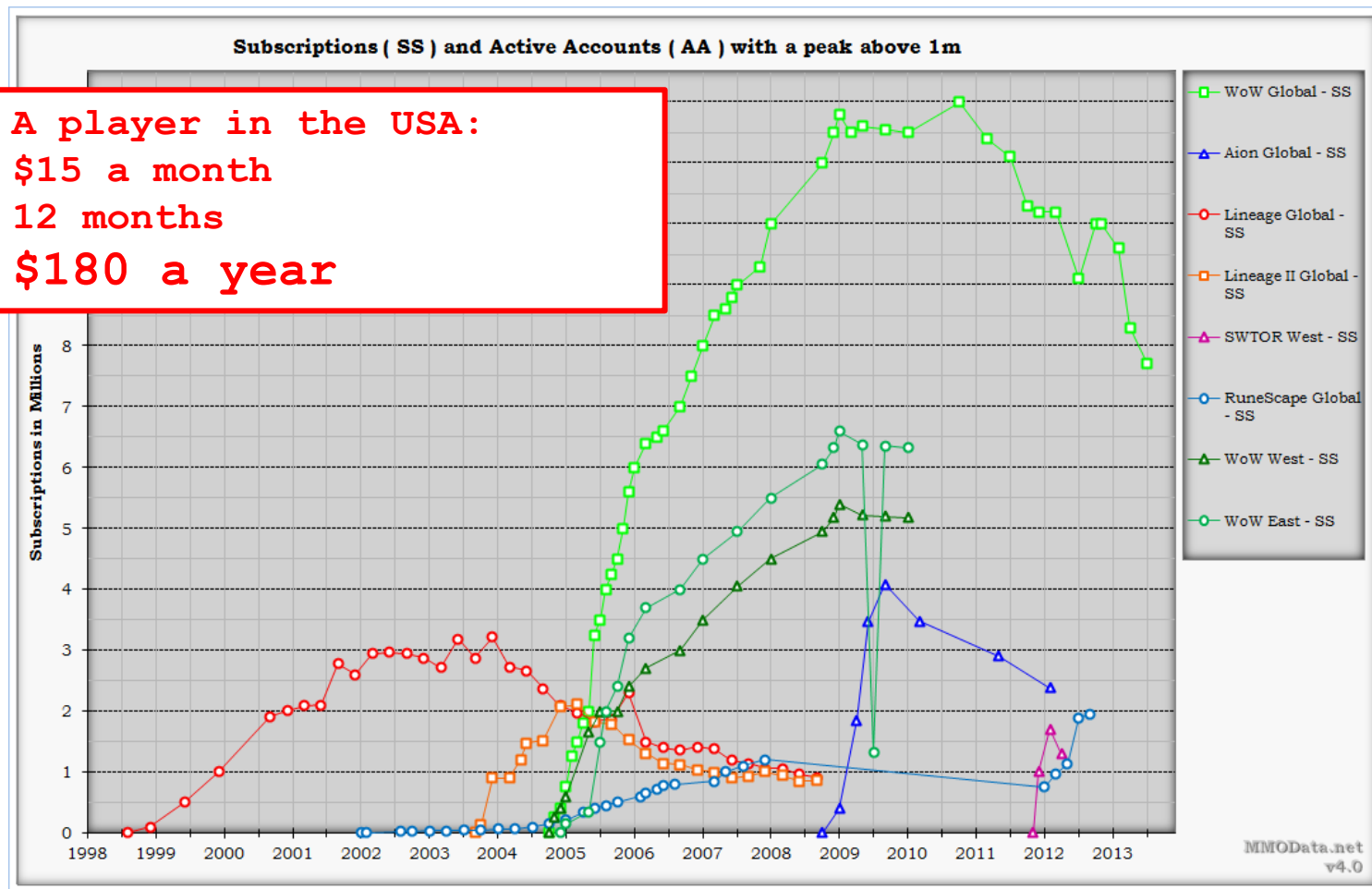
- Pay to play
 - Game client/account
 - Subscription
 - Additions to existing games
- Free to play (F2P)
 - Micro transactions
 - Additional content
 - Premium accounts
 - Cosmetic/usability improvements
- Combinations
- F2P demands full server control!!!

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

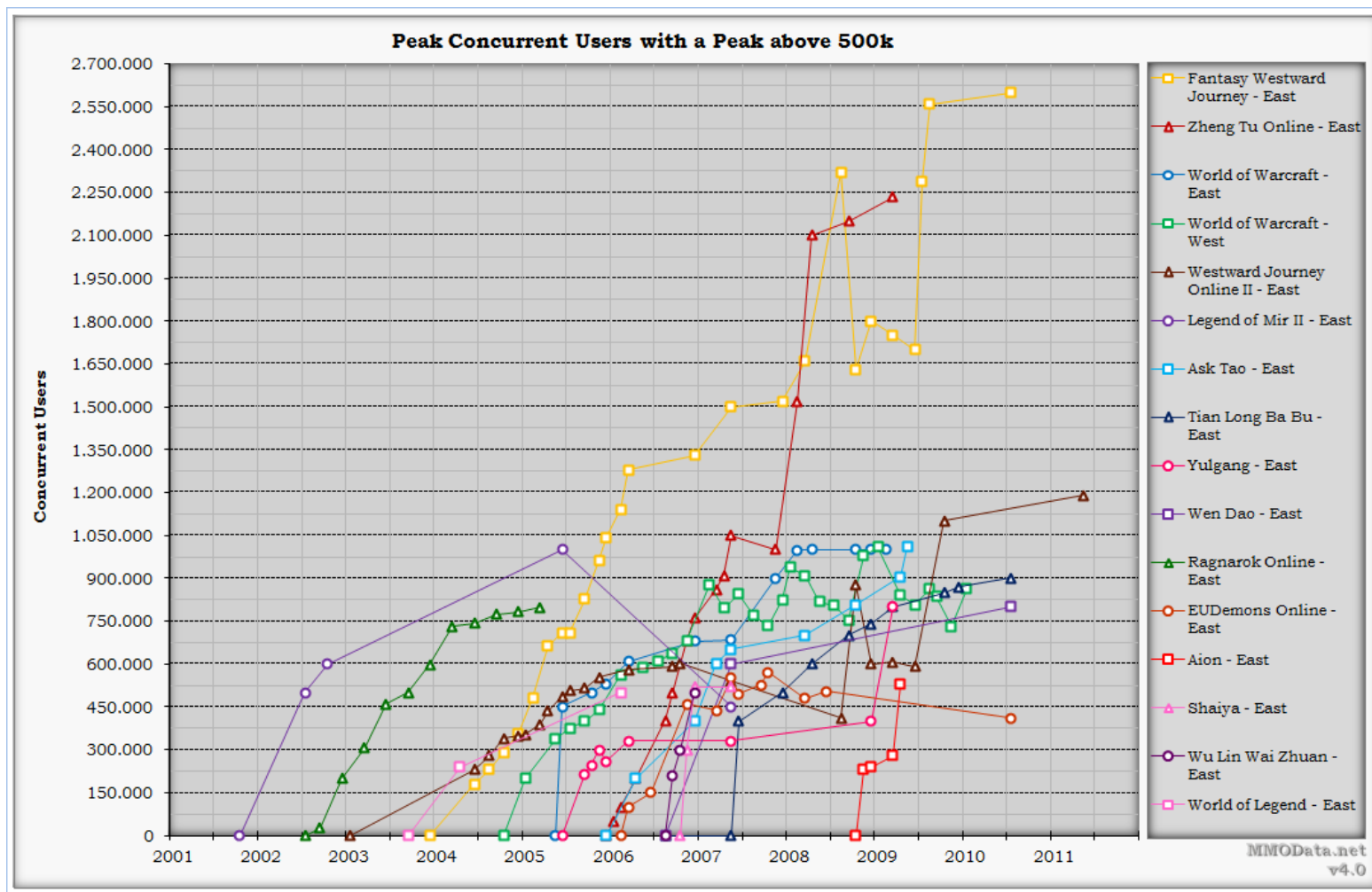
Subscription based model in decline (MMORPGs)

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



Source: mmodata.org

Peak concurrent users (MMORPGs)



Source: mmodata.org

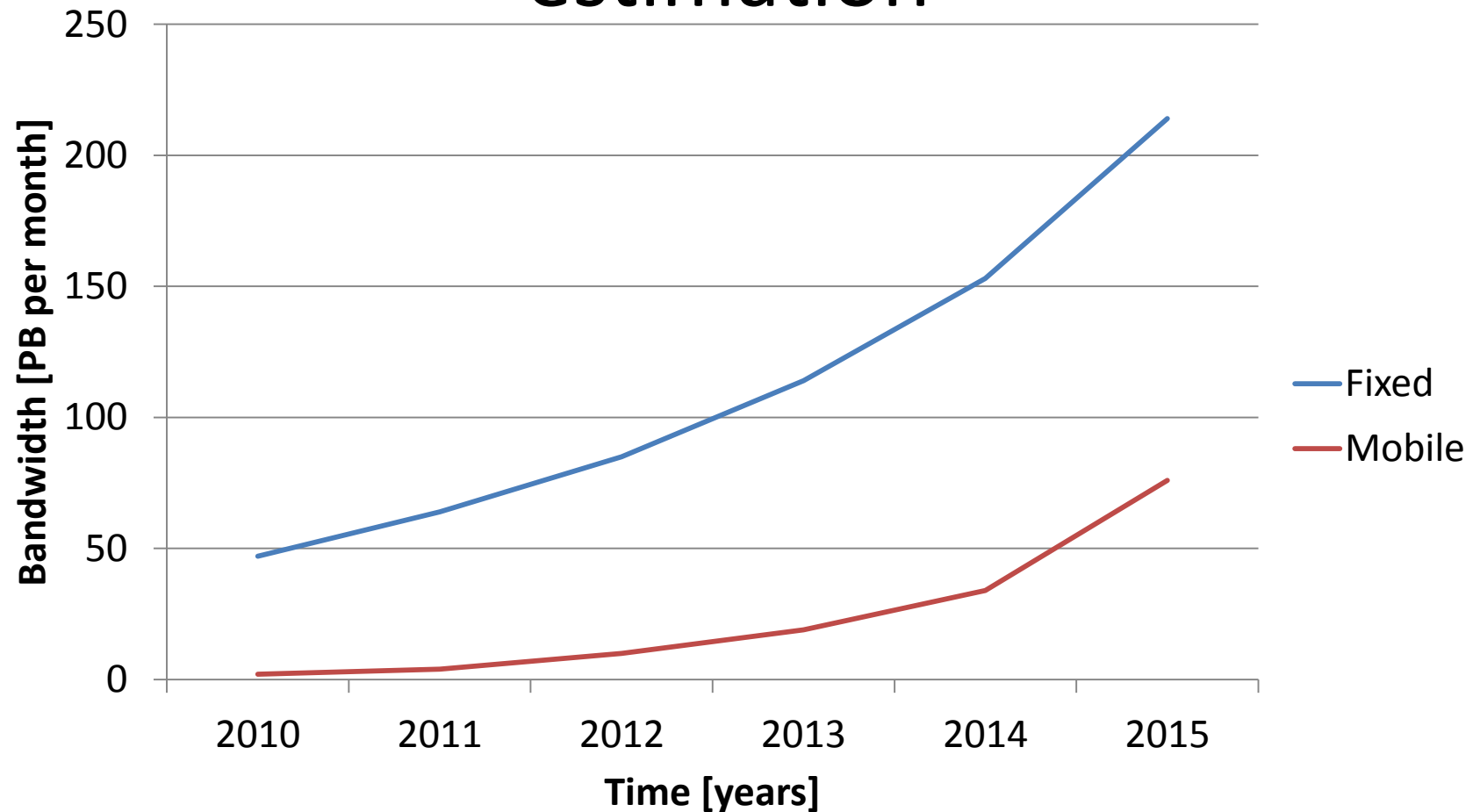
10.01.2014.

Game network traffic - global trends

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

Consumer Internet Traffic, 2012–2017							
	2012	2013	2014	2015	2016	2017	CAGR 2012–2017
By Subsegment (PB per Month)							
Internet video	14,818	19,855	25,800	32,962	41,916	52,752	29%
Web, email, and data	5,173	6,336	7,781	9,542	11,828	14,494	23%
File sharing	6,201	7,119	7,816	8,266	8,478	8,667	7%
Online gaming	22	26	32	39	48	59	22%

Game network traffic growth estimation



Source: Cisco Visual Networking Index: Forecast and Methodology, 2010–2015 Global Consumer Internet Gaming Traffic Growth

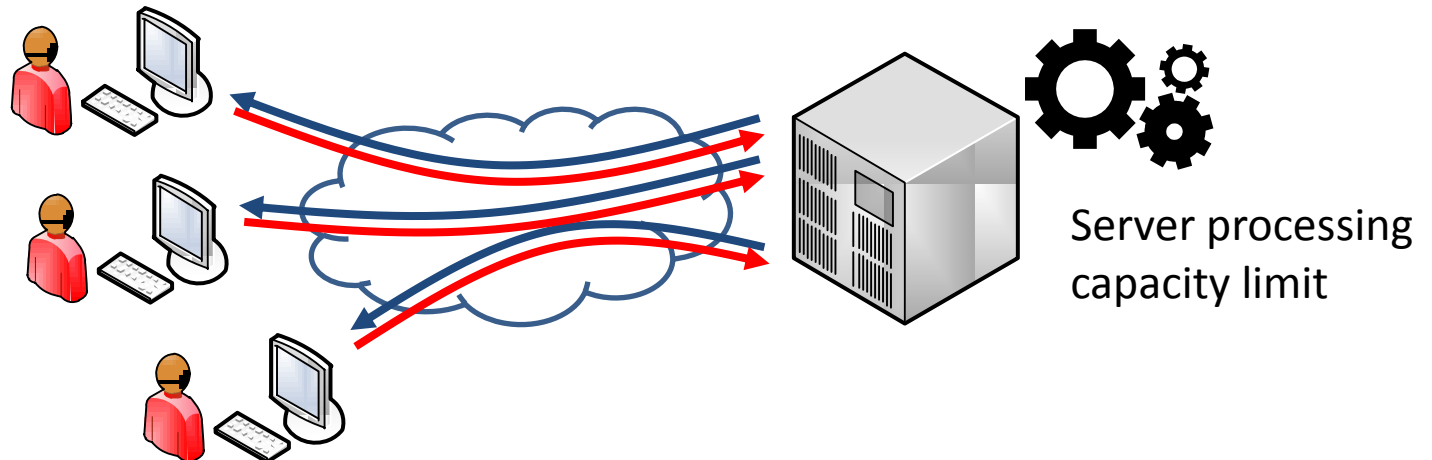
10.06.2013.

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

120 hours of World of Warcraft

by Elizabeth Harper 📅 Jul 24th 2007 at 8:10PM



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)

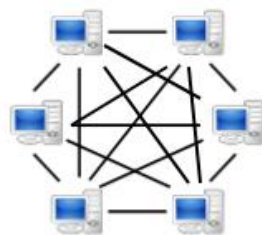


Game traffic evolution? – Not really



StarCraft I (1998-2010)

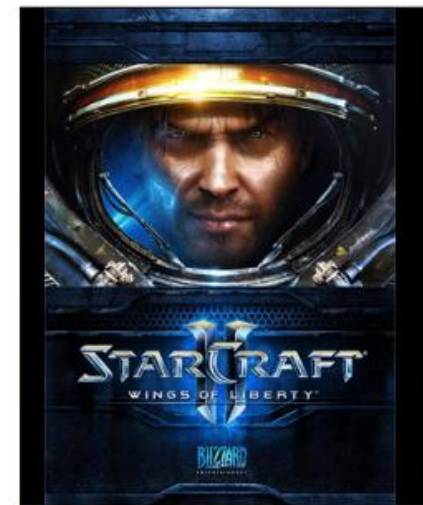
1-5kbps
(2-8 players)



Peer-to-peer
Architecture



Server-client
Architecture



StarCraft II (2010-present)

2-3 kbps
(independent of
number of players)

M. Claypool, D. LaPoint, and J. Winslow, "Network Analysis of Counter-strike and Starcraft," in Proceedings of the 22nd IEEE International Performance, Computing, and Communications Conference (IPCCC), USA, April 2003.

C-S. Lee, "The Revolution of StarCraft Network Traffic" in Proceedings of the 11th Annual Workshop on Network and Systems Support for Games NetGames 2012

Game traffic revolution? Yes*

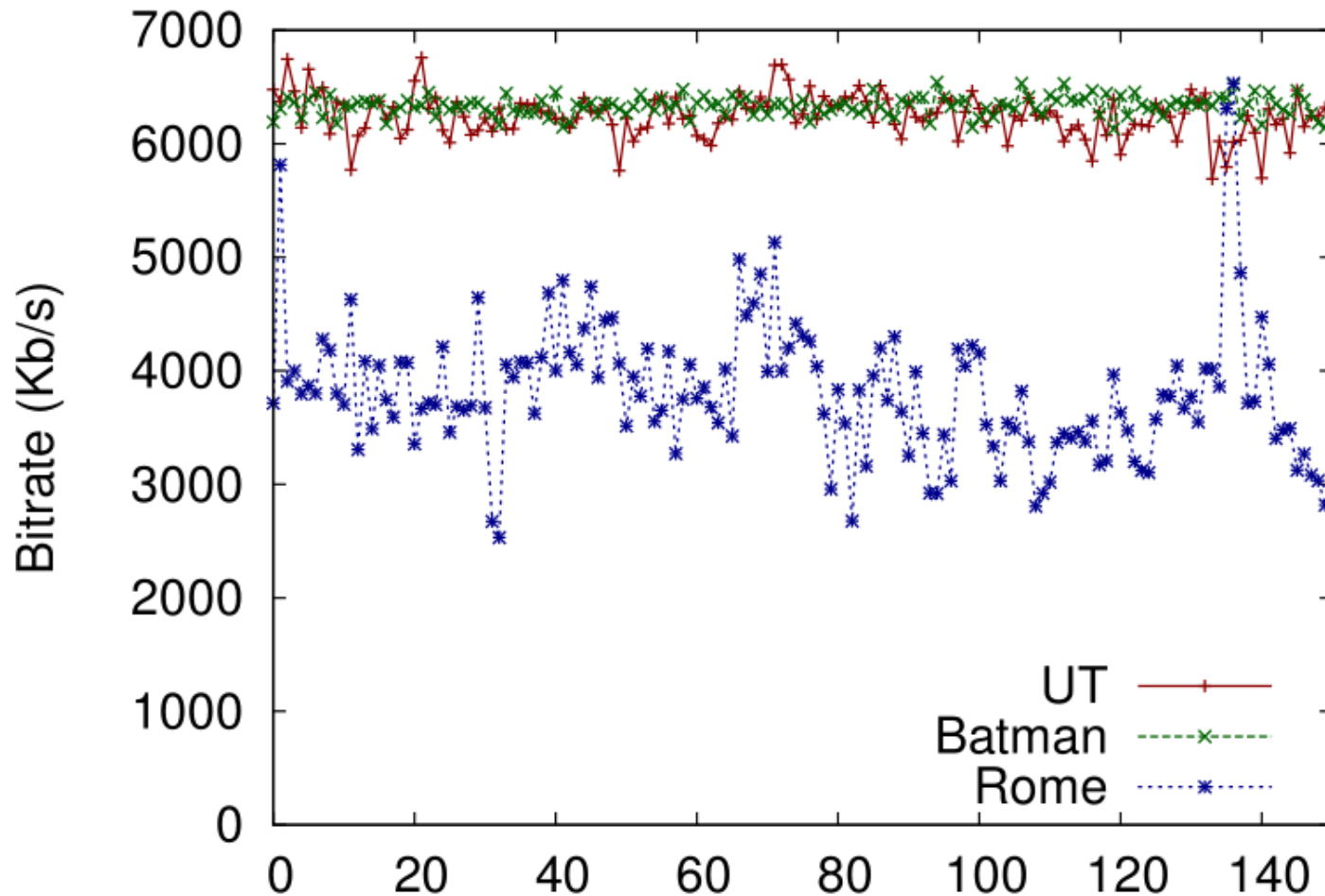
- Cloud gaming traffic
 - Very high bandwidth usage
 - High quality video
 - Very delay sensitive (no client side optimization)
 - * no high market penetration



RTP/UDP flows of the OnLive Streaming Protocol

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

OnLive downstream traffic



M. Claypool, D. Finkel, A. Grant, and M. Solano: "Thin to win? Network performance analysis of the OnLive thin client game system". *11th Annual Workshop on Network and Systems Support for Games (NetGames)*, 2012 (pp. 1-6). IEEE.

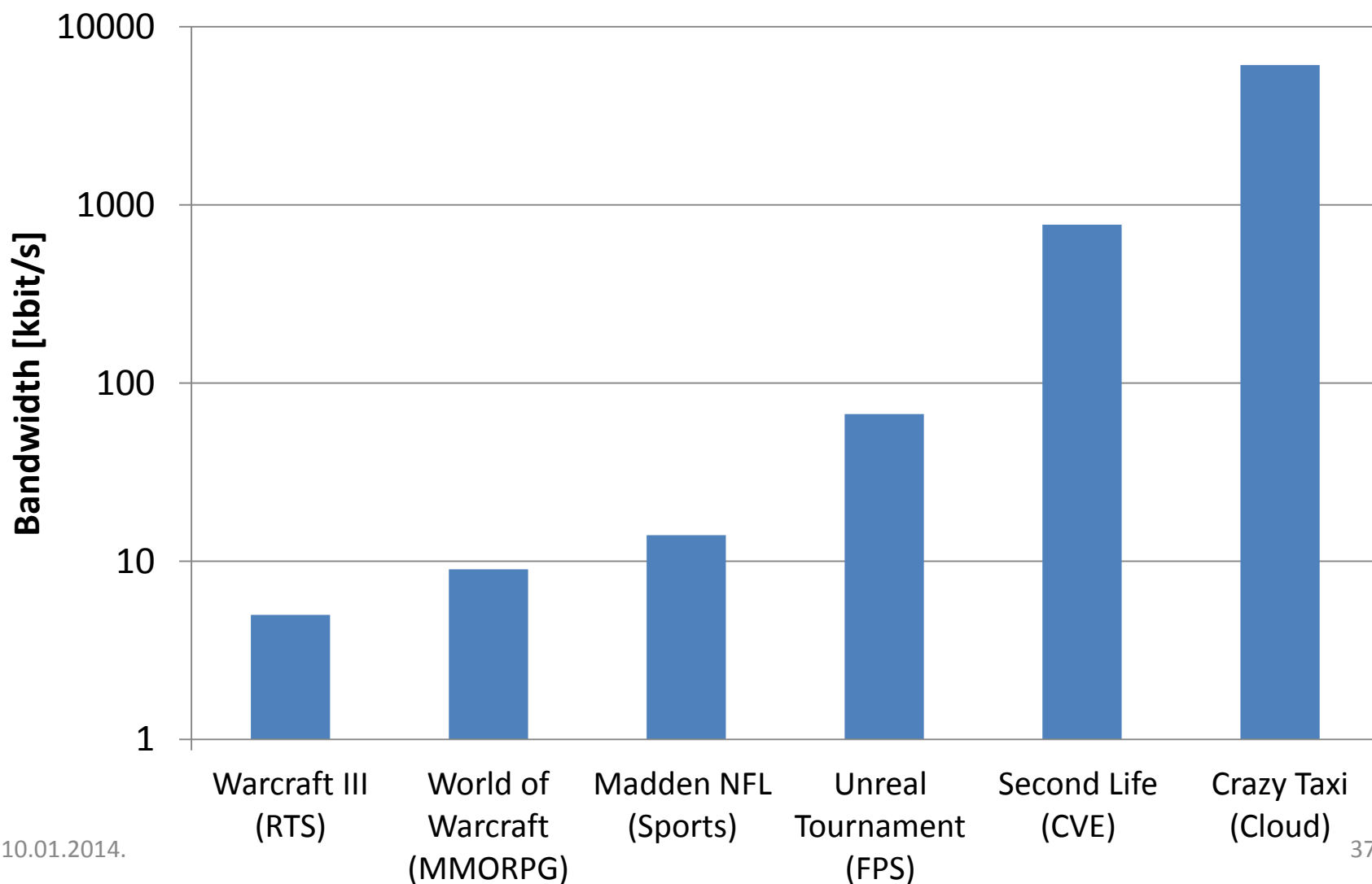
Game genres

- 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



NPD Group Inc., NDP Software Category Definitions, 2008,
<https://www5.npd.com/tech/pdf/swcategories.pdf>.

Bandwidth usage across genres



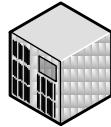
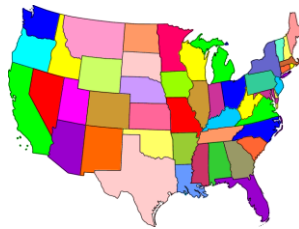
First Person Shooters (FPS)

- 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 than 300kbps)

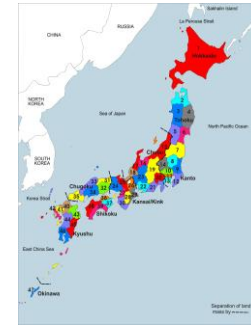
QoE for FPS

- 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)



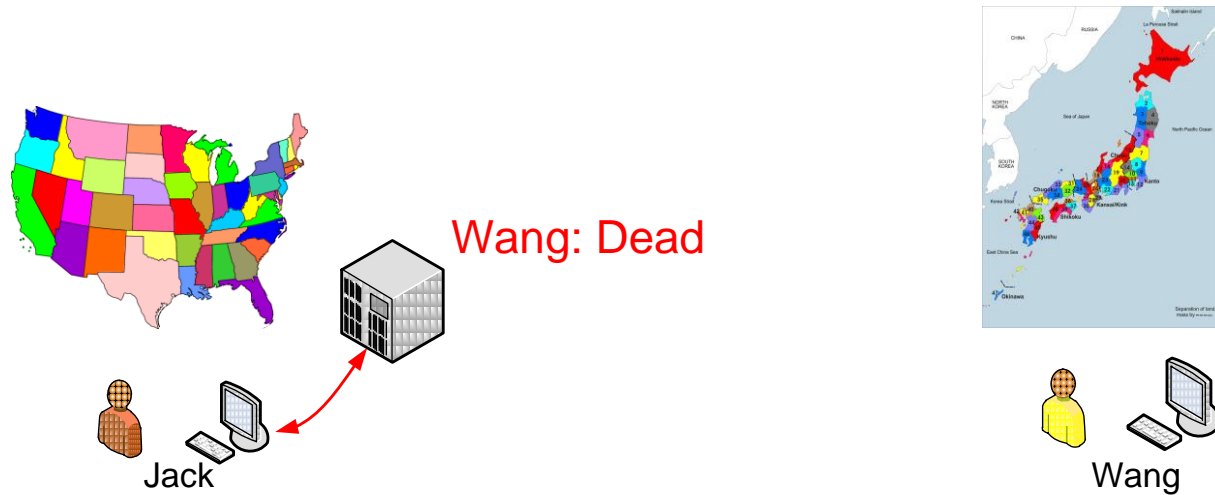
Jack



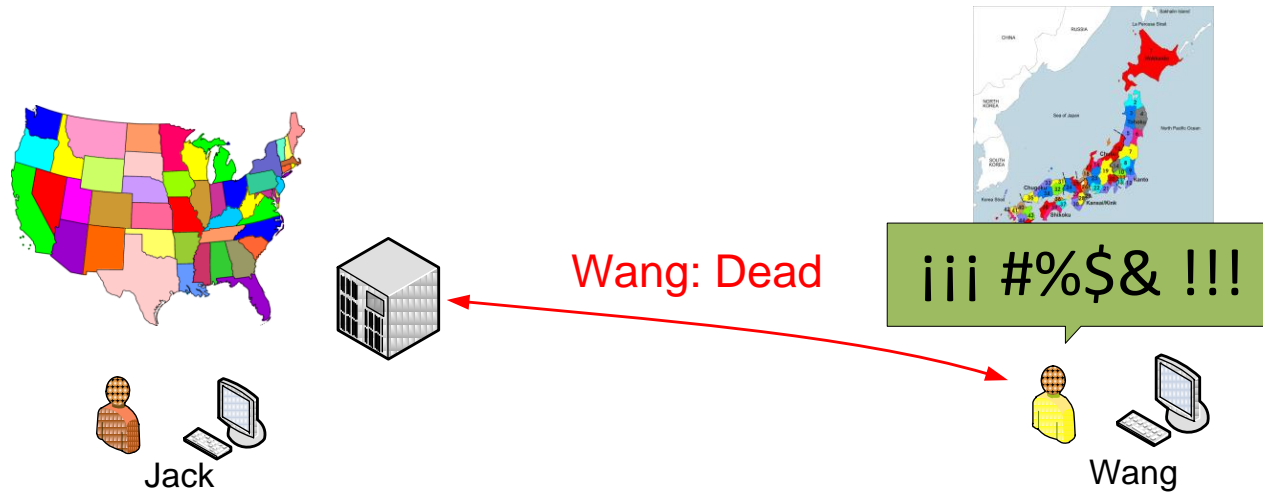
Wang



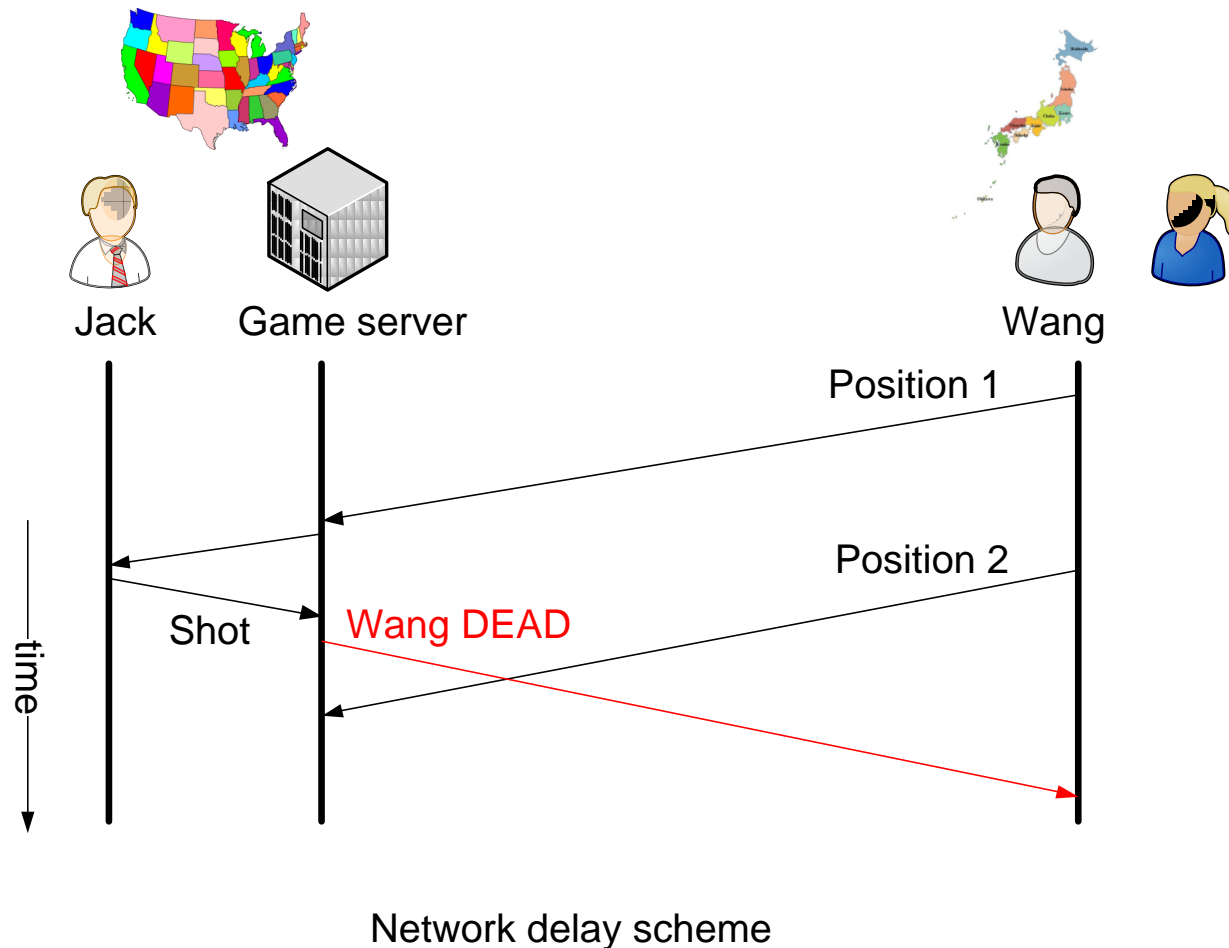
Shooting around the corner problem (virtual world inconsistency)



Shooting around the corner problem (virtual world inconsistency)



Shooting around the corner problem (virtual world inconsistency)



Server organization

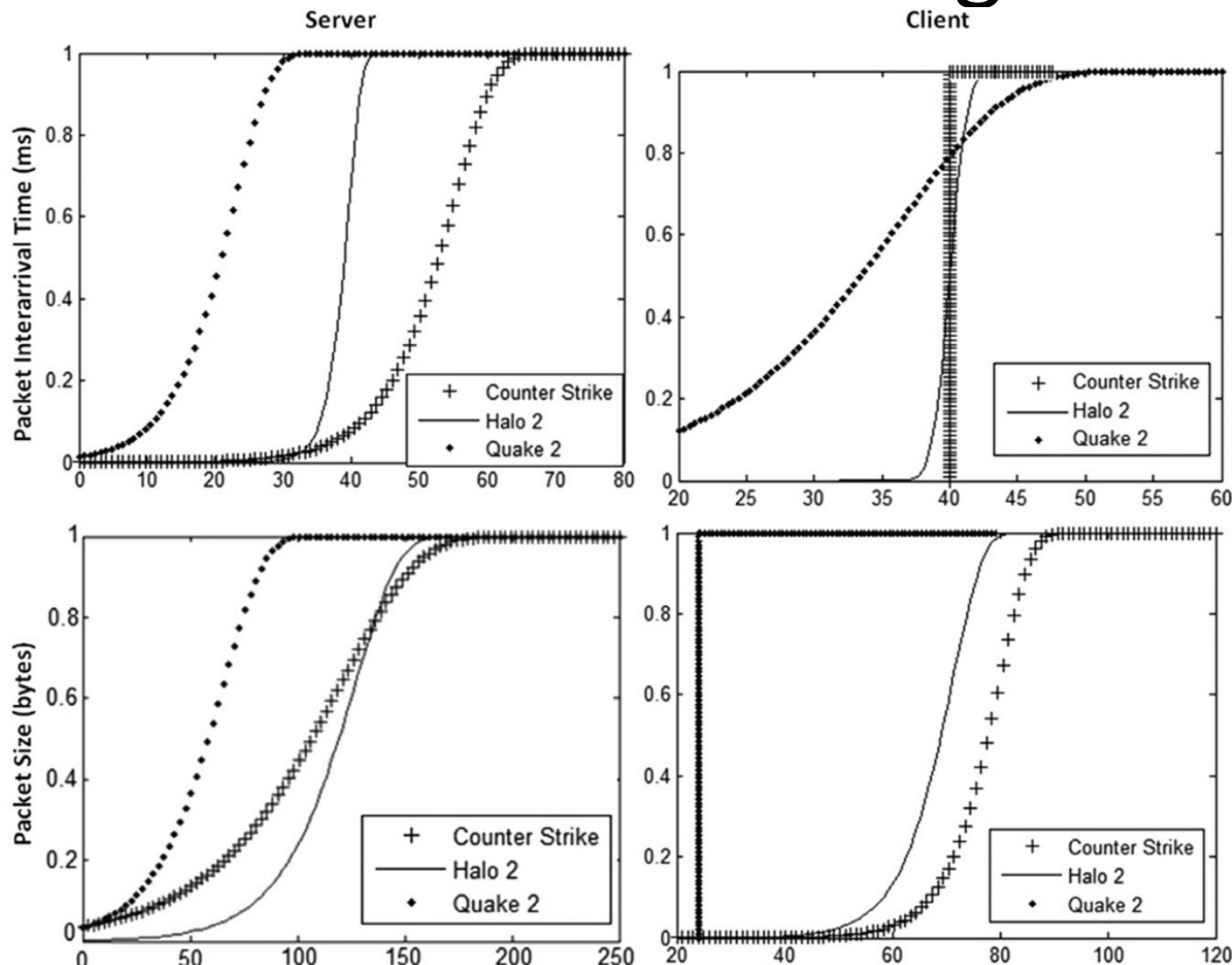
- Small virtual worlds
- Usually less than 100 players per map
- Servers hosted by players (lower complexity)
- Very densely geographically distributed (to maximally reduce network delay)

SEARCH RESULTS Searching: **Call of Duty 2 Servers** in **Croatia**

PREV < 1 2 3 4 > View 10 25 50 items per page NEXT »

Rank	Gm	Server Name	Players	Loc	IP:Port	Server Map
8.	★	Kameni*Momci Cracked TDM 7/24*hrs	24/30	HR	213.149.60.38:28952	mp_trainstation
11.	★	OMNIGENUS CALLOFDUTYMANIA SD SERVER omnige	23/26	HR	213.149.60.42:29008	mp_matmata
32.	★	Lan-Wars.com Toujane TDM Only TS3:ts.lan-wars.com	25/28	HR	212.92.192.214:28960	mp_toujane
36.	★	Crn@M@mb@CrackedExtrem1.3v	16/30	HR	213.149.60.35:28839	mp_breakout
43.	★	JigsawNetworks ~ Rifle/Scope & Toujane ~ 24/7 ~ Liv	7/28	HR	213.149.60.34:28952	mp_toujane
49.	★	Legionari Team Cracked v1.3	15/28	HR	213.149.60.35:28928	mp_decoy
59.	★	e-sport.hr DM Server Powerd by Omnigenus!	16/22	HR	213.149.60.44:28989	mp_toujane
60.	★	ZiZ Public Server All Weapons [SD] www.ziz-clan.co	2/24	HR	213.149.60.35:28957	mp_toujane
81.	★	Drunk'Clan All RIFLES MoD ToujaNe OnLy ~HardCc	20/20	HR	85.94.70.50:28870	mp_toujane
97.	★	CRO JUDGES ALL RIFLE WEAPONS TDM Powered	18/26	HR	82.193.210.125:28961	mp_toujane
101.	★	Alcoholic-Team Public server	20/28	HR	213.149.60.37:28993	mp_toujane
107.	★	EAGLESS SD ~ PUBLIC RIFLES & SNIPERS 1.0v	19/32	HR	46.4.19.83:28942	mp_toujane
113.	★	QUBic GaminG SYMBOLIC x Team Public SD Serv	12/16	HR	213.149.60.36:28945	mp_toujane

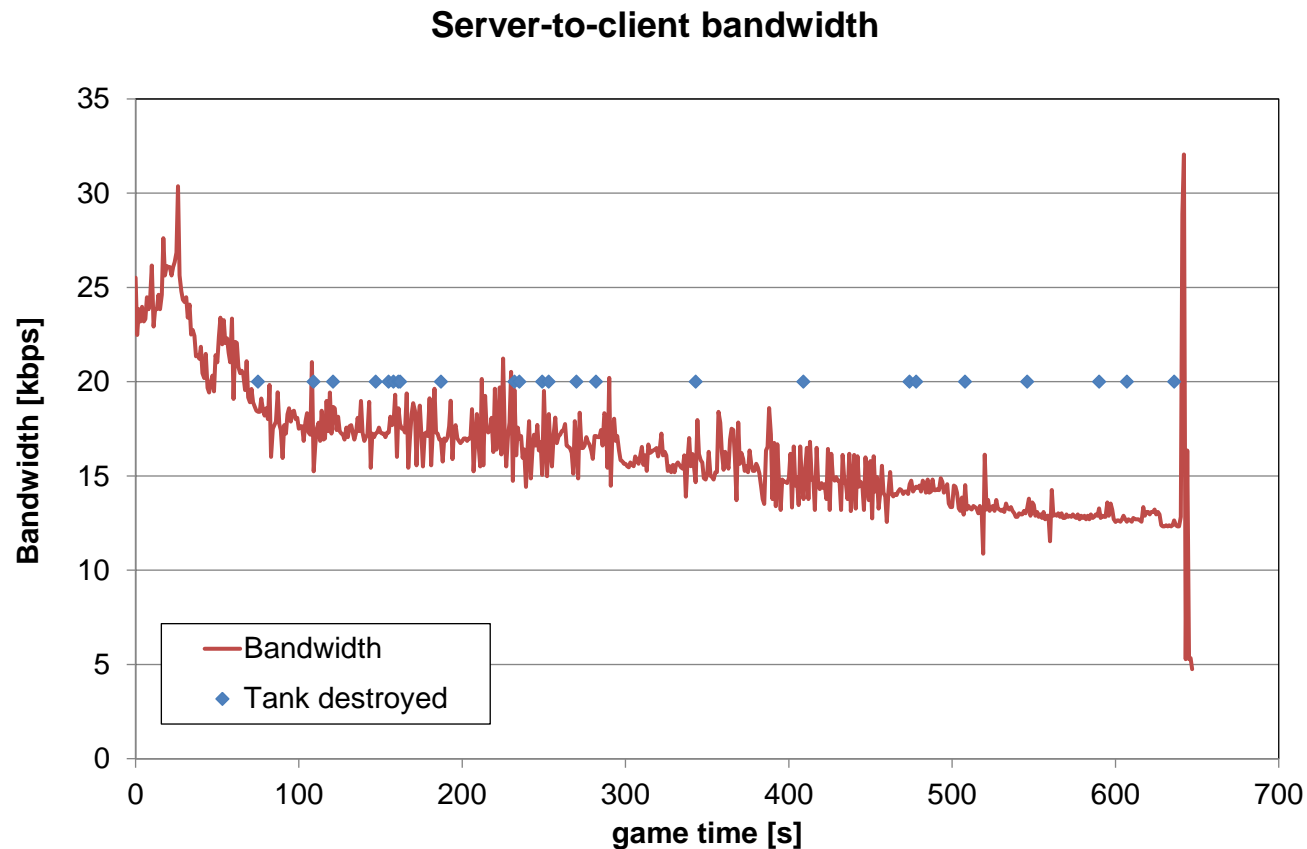
CDF's of different FPS games



X. Che and B. Ip, "Review: Packet-level traffic analysis of online games from the genre characteristics perspective", Journal of Network Computing Appl. 35, 240–252 (2012)

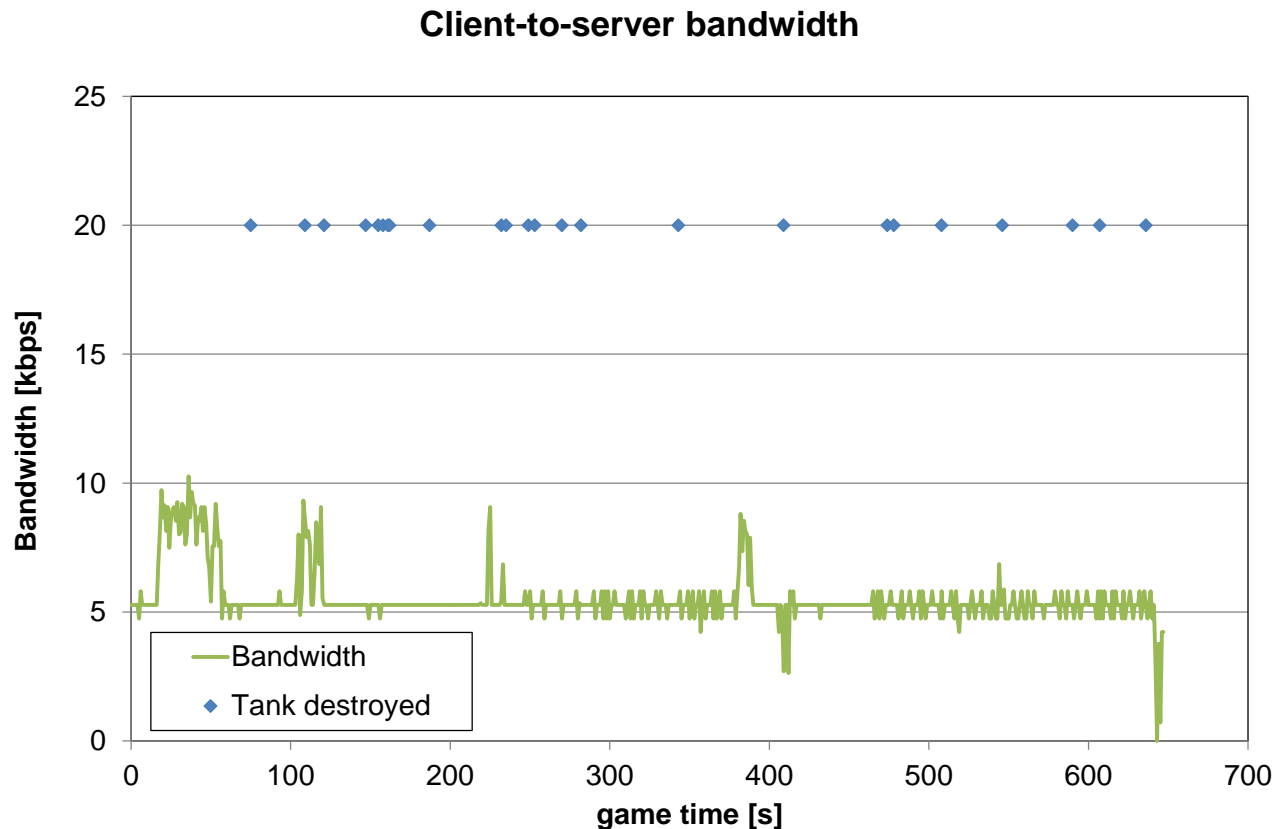
World of Tanks

- Effect of player's death on downlink



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



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)

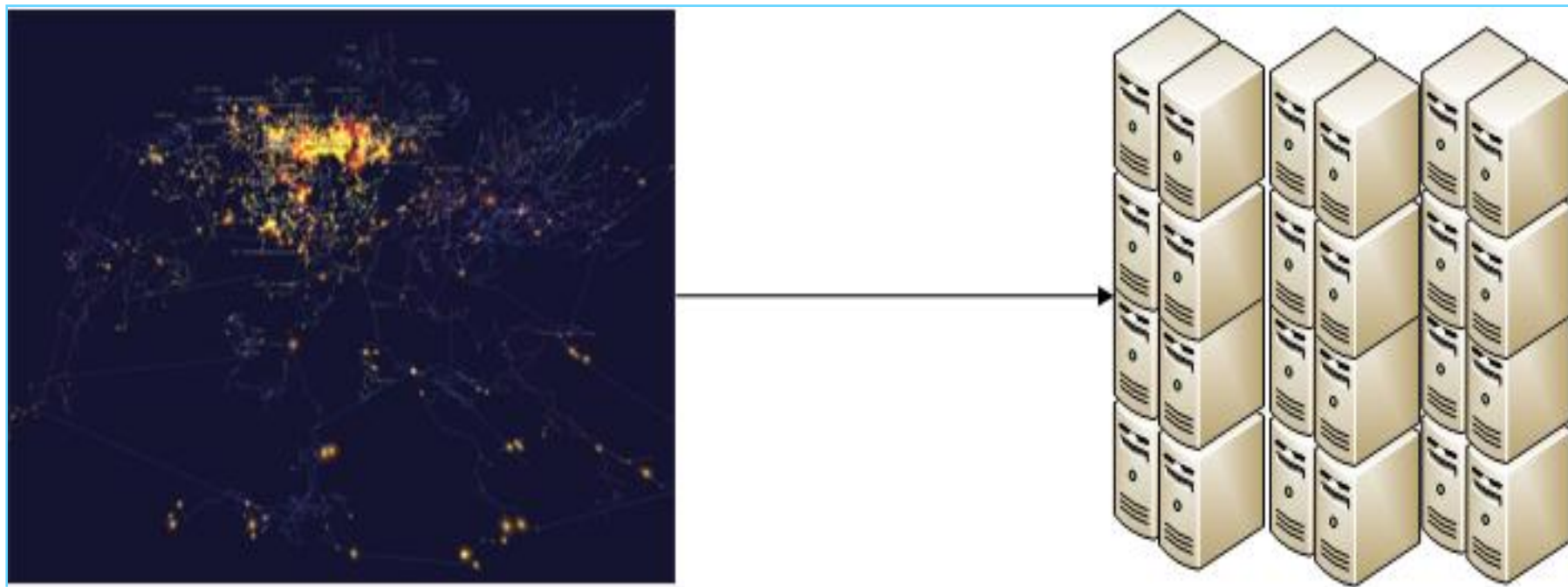


MMORPG architecture: challenges

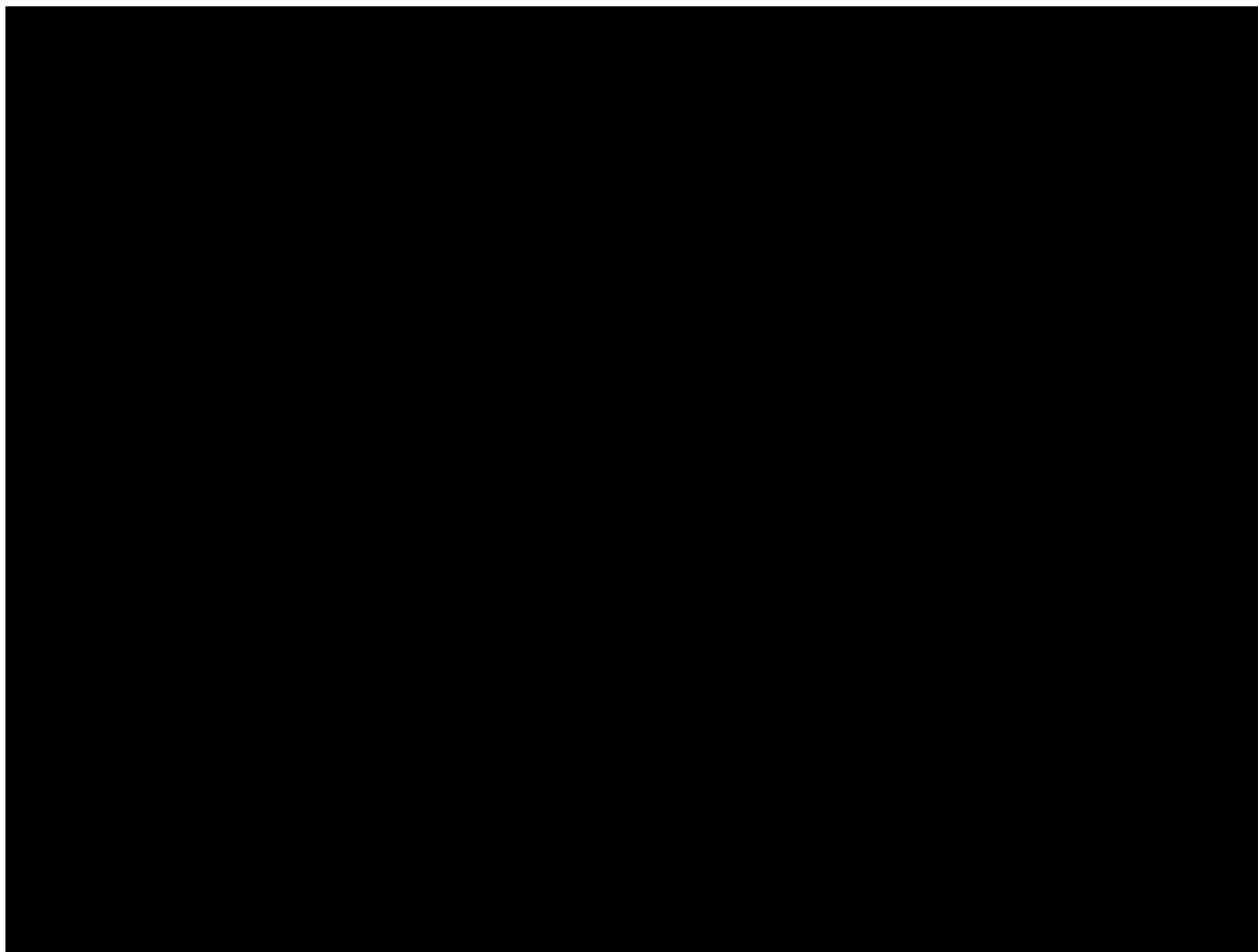
- **Massively** Multiplayer Online Role-Playing Games
 - A large number of players which share one virtual world
 - WoW – 12 million players (at the peak of popularity)
- Main issues:
 - Calculation of the virtual world state
 - Consistency
 - Cheating avoidance
 - Scalability (all servers need to be under control of the provider)
- Two solutions:
 - Single space worlds (using huge server farms e.g., EvE Online)
 - “Sharding” of virtual world 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??

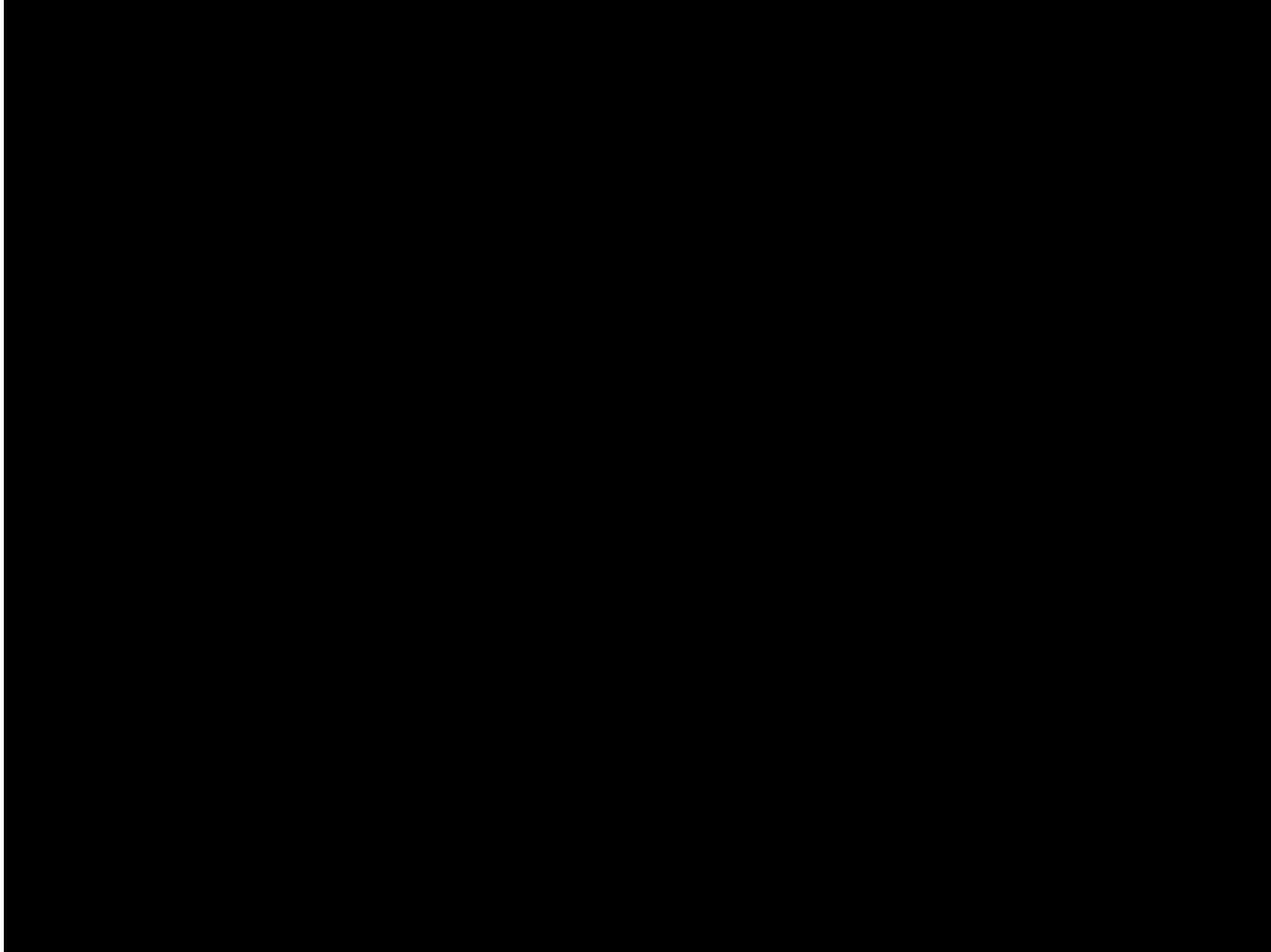


The Asakai incident



Youtube link: <http://www.youtube.com/watch?v=iQw3YcLoQU>

Integration of multiple games into one virtual world (Dust 514 and EvE Online)

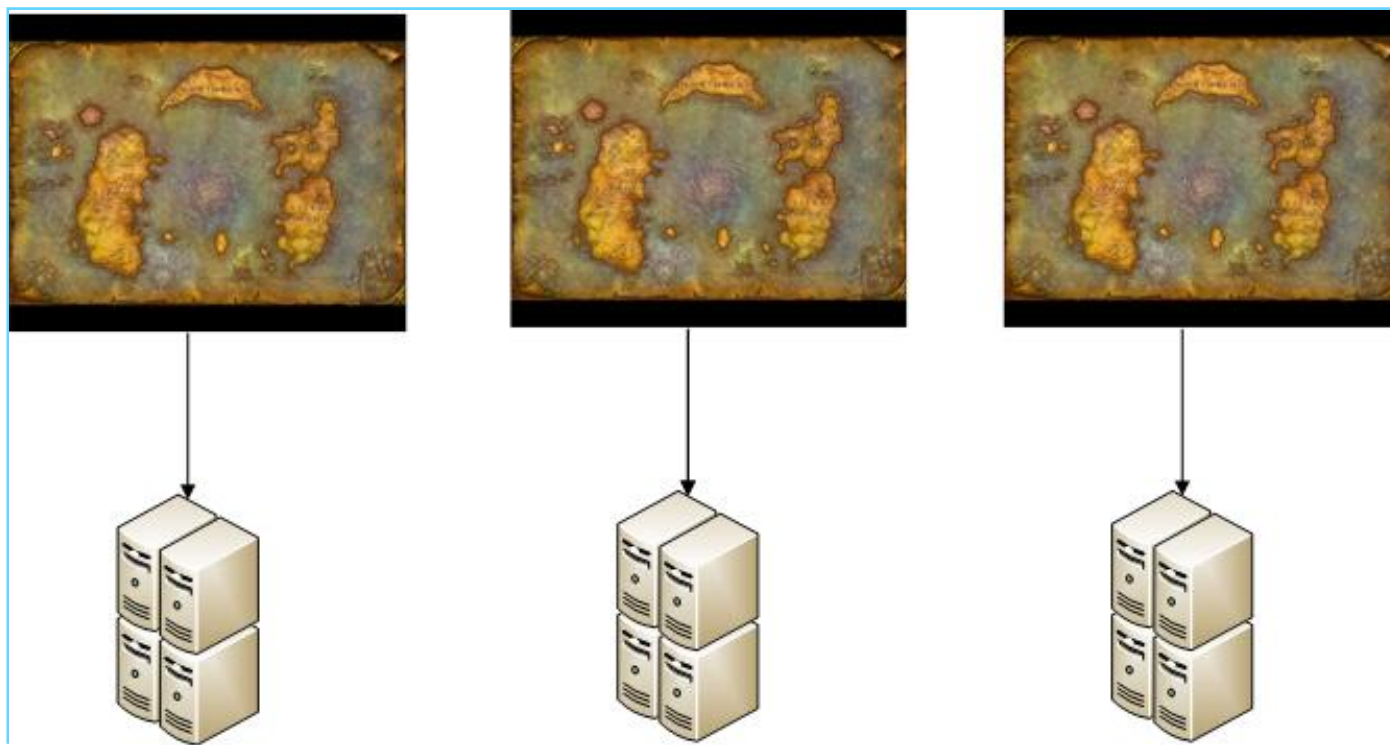


Youtube link: <http://www.youtube.com/watch?v=eS4rAYrRHWc>

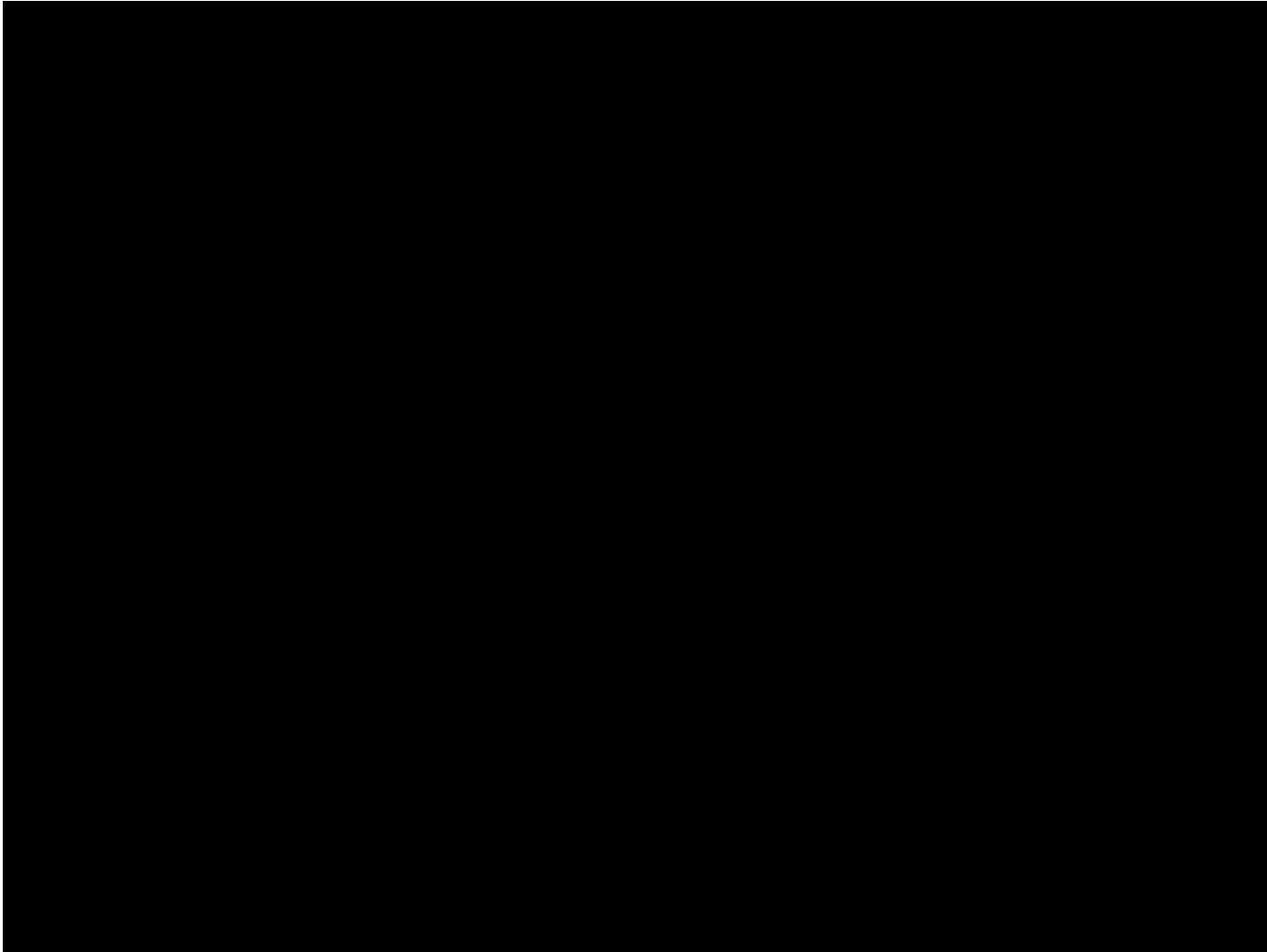
10.01.2014.

Shards

- Each shard holds a copy of the whole virtual world
- Players are divided on shards and can not interact or communicate (although this is changing)



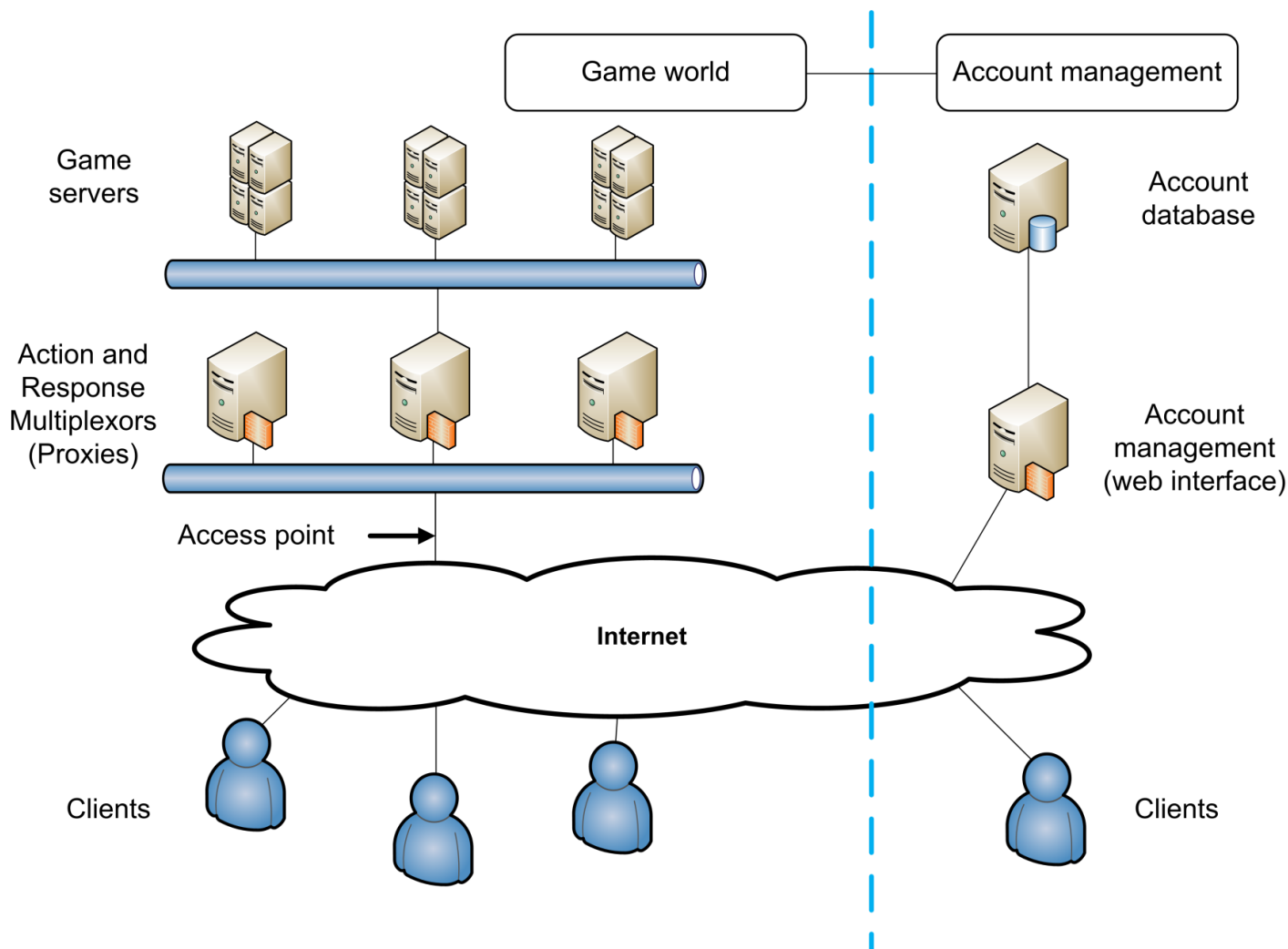
War without the warchief



Youtube link: <http://www.youtube.com/watch?v=ZzslISTnQfl>

10.06.2013.

Example of MMORPG architecture with multiple servers



Transport protocols

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

Protocol	MMORPGs
TCP	World of Warcraft, Lineage I/II, Guild Wars, Ragnarok Online, Anarchy Online, Mabinogi
UDP	EverQuest, City of Heroes, Star Wars Galaxies, Ultima Online, Asherons Call, Final Fantasy XI
TCP/ UDP	Dark Age of Camelot

MMORPGs and TCP

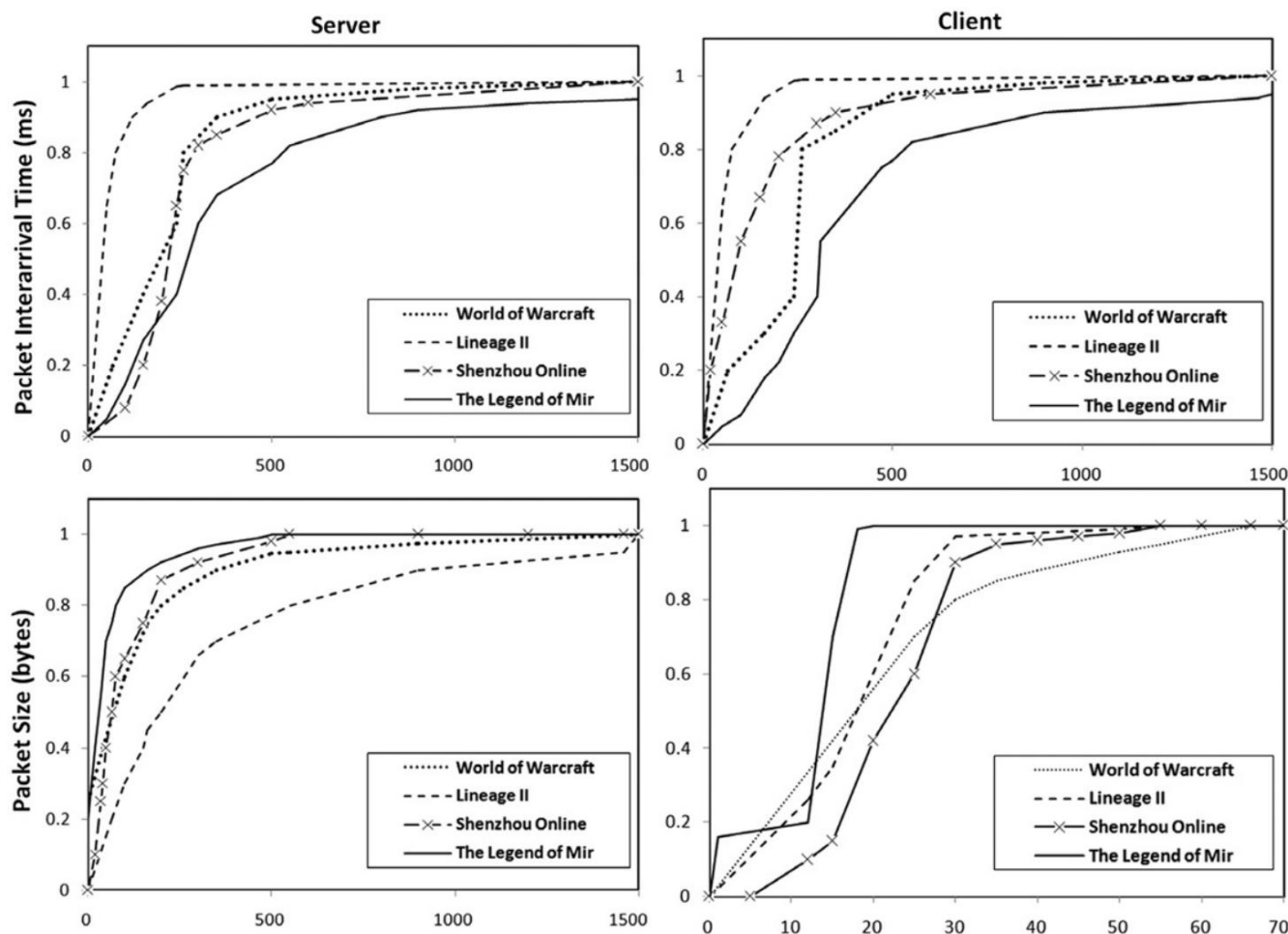
- TCP not designed for a real time interactive application!!! (yet it works)
- Application limited not network limited flows
- Multiple thin TCP flows behave unlike one fat TCP flow
- Mechanisms in TCP directly deteriorate the experience of the players (delayed ACK, Nagle algorithm)
- Mechanisms of TCP 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

S. Pack, E.Hong, Y. Choi, I.Park, J-S. Kim, and D. Ko, "Game Transport Protocol: A Reliable Lightweight Transport Protocol for Massively Multiplayer On-line Games (MMPOGs)", Multimedia Systems and Applications, Vol. 486 pp. 83-94, Oct, 2002)
C-C. Wu, K-T. Chen, C-M. Chen, P.Huang, and C-L. Lei , "On the Challenge and Design of Transport Protocols for MMORPGs", Multimedia Tools and Applications Vol. 45, No. 1, pp. 7--32, Oct, 2009.

CDF's of different MMORPGs

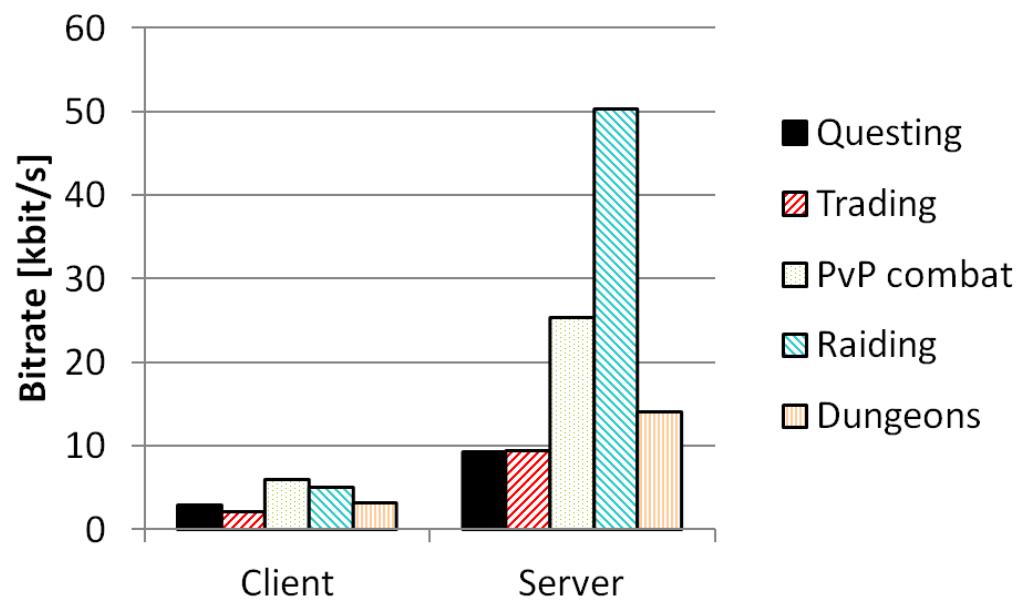
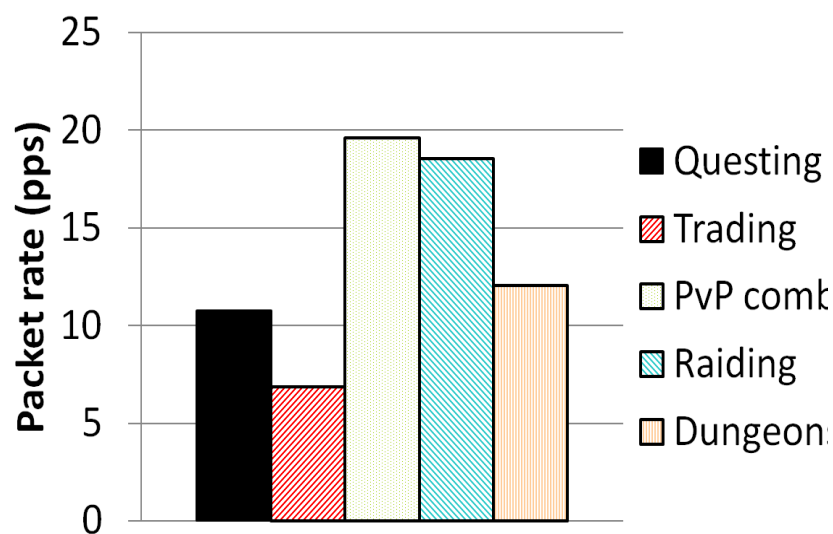


MMORPG action diversity



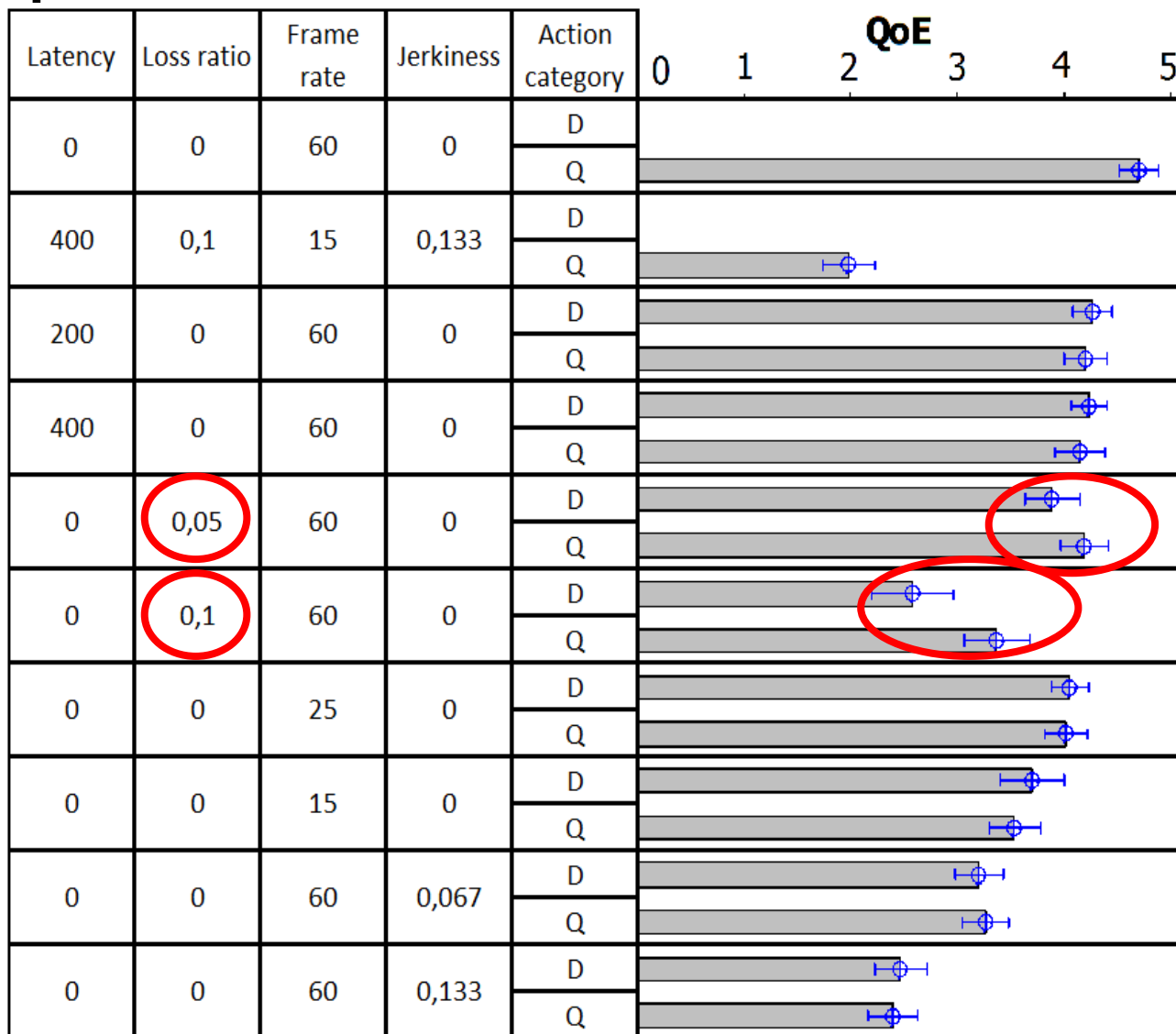
Impact of MMORPG actions on network traffic

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



M. Suznjevic, O. Dobrijevic, and M. Matijasevic, "MMORPG Player Actions: Network Performance, Session Patterns and Latency Requirements Analysis," Multimedia Tools and Applications, vol. 45 no. 1-3, pp. 191-214, 2009.

Impact of MMORPG actions on QoE



M. Suznjevic, L. Skorin-Kapov, M. Matijasevic. "The Impact of User, System, and Context factors on Gaming QoE: a Case Study Involving MMORPGs", Proc. of NetGames 2013, Denver, USA, Dec. 9-10, 2013.

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

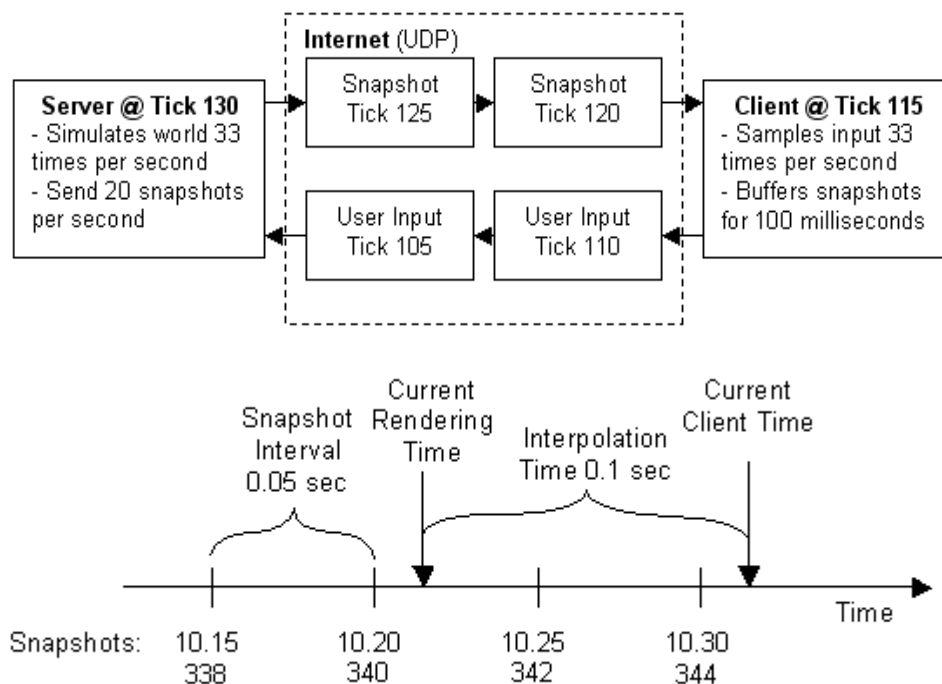
ARTS (MOBA)

- 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?

Date	Registered players	Monthly players	Daily players	Peak concurrent players	Daily hours of play
Jul. 11	15 million	4 million	1.4 million	0.5 million	3.7 million
Nov. 2011	32.5 million	11.5 million	4.2 million	1.3 million	10.5 million

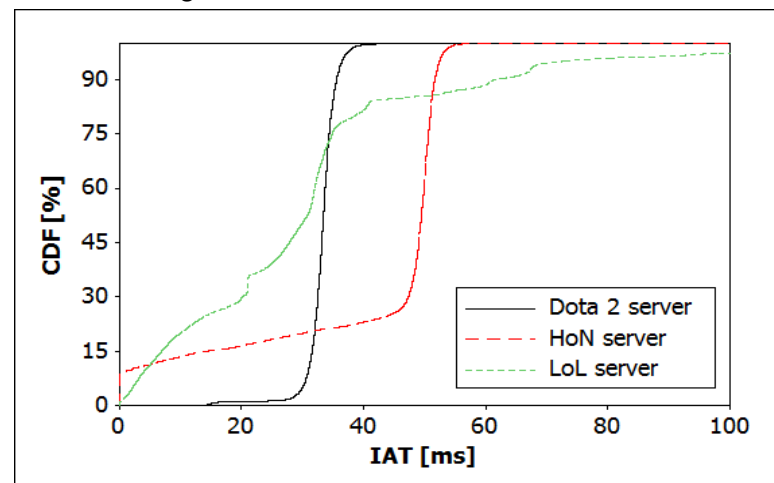
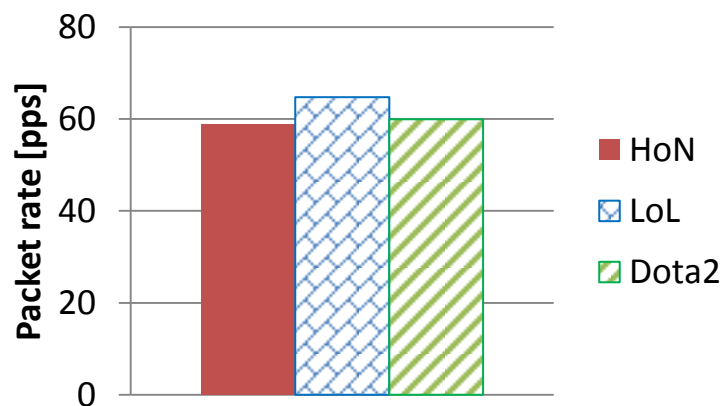
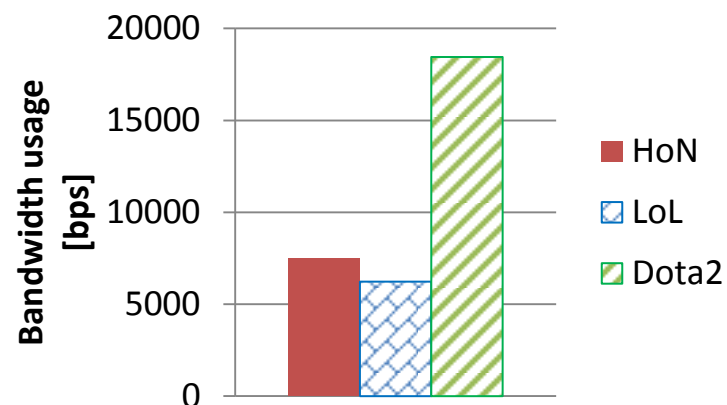
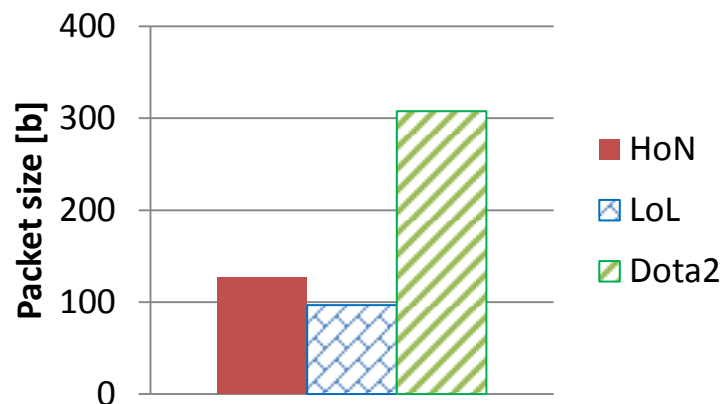
Networking model of the source engine (DOTA 2)

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



Source: Valve Developer Community

Traffic characteristics comparison



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!

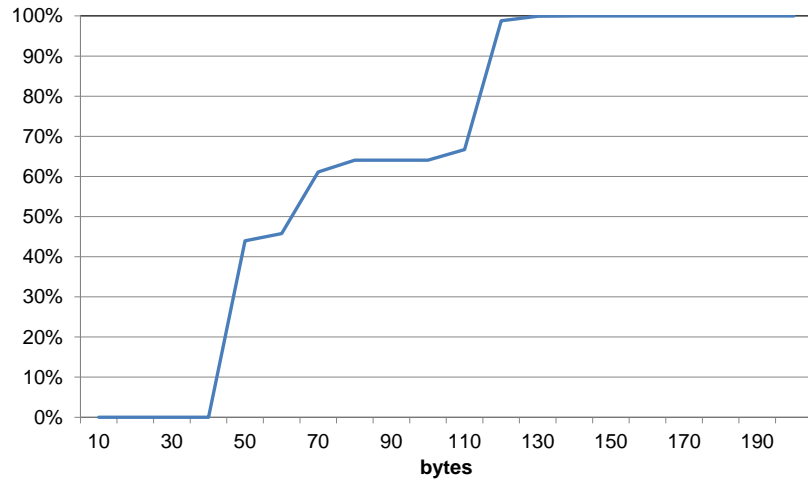
- The web page starts the game application
- One of the players acts as the server
 - It is not the one who creates the race
 - Perhaps the one with the best connection
- Scalability advantage
 - The game company does not have to set up a high number of servers
 - They only orchestrate the players

Let us play that online race!

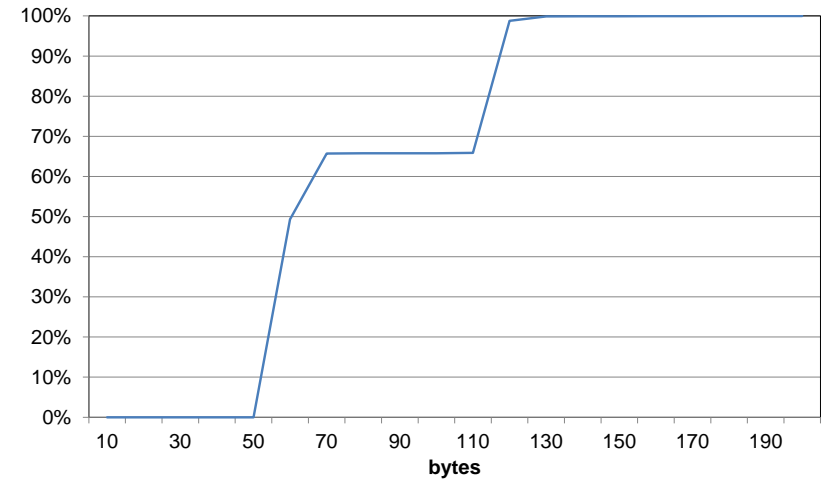
- Problems:
 - You have to deal with NAT, since a computer has to be the server
 - You have to download the characteristics of the other cars, since they are improved and painted
- Extra delay does not affect, since interaction between cars is not very significant (only at the beginning)

Traces with 8 players (myself+7)

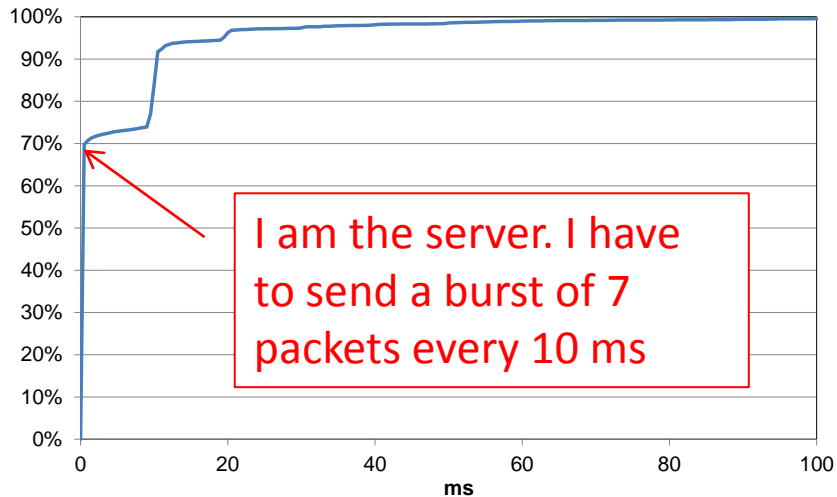
Packet size uplink (bytes)



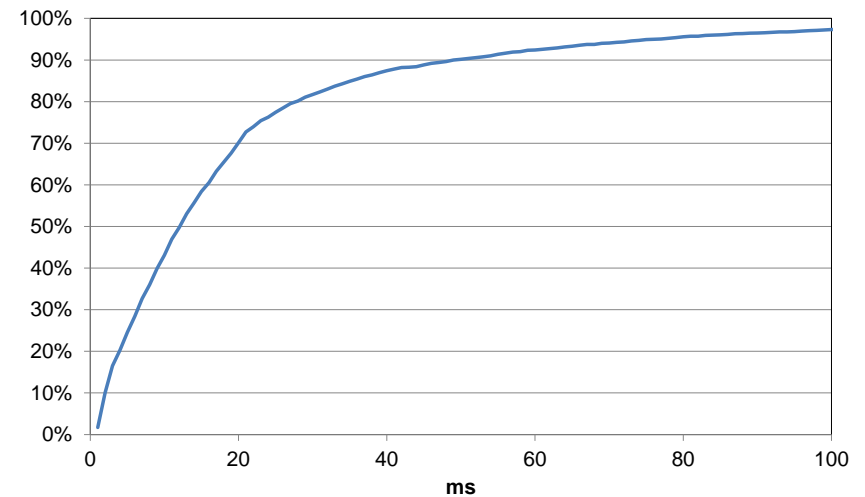
Packet size downlink (bytes)



Inter-packet time uplink (ms)



Inter-packet time downlink (ms)



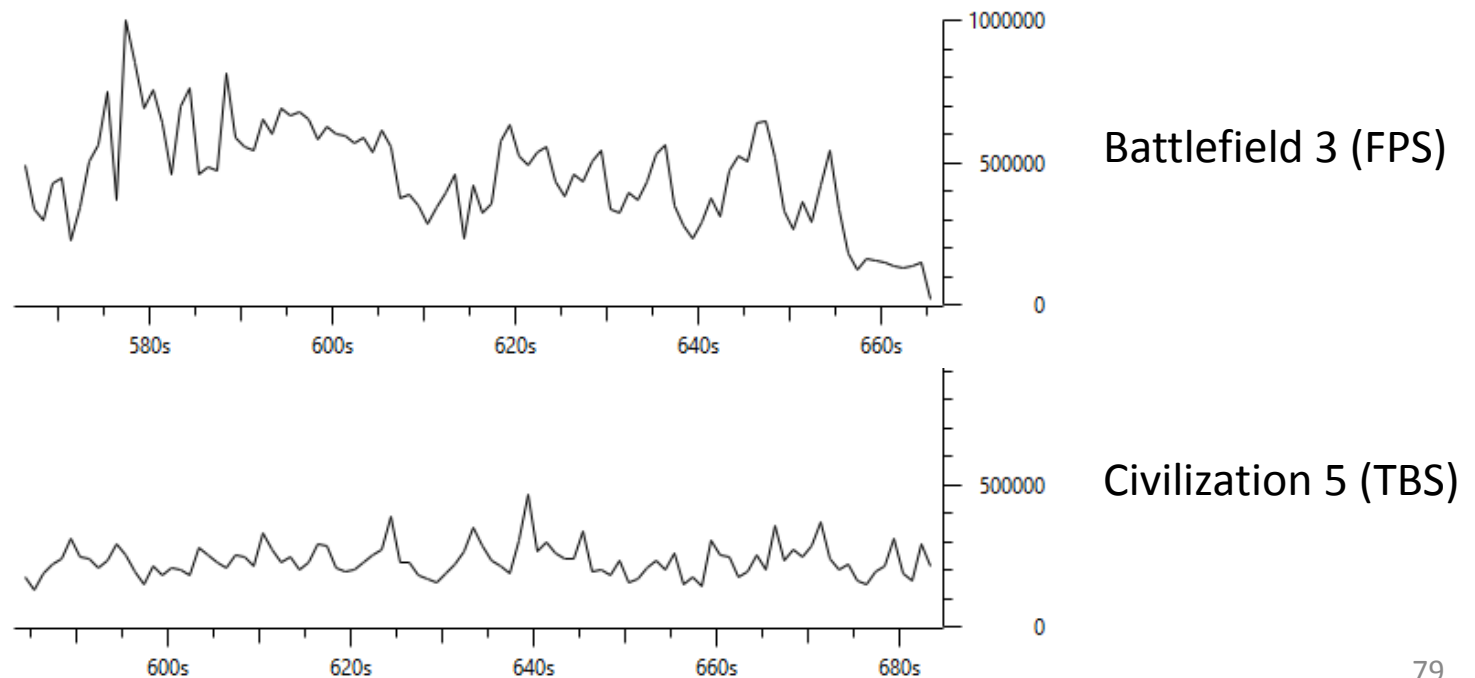
Genre differences in cloud games

- Differences due to game dynamics – different video characteristics

		<i>pes2012</i>	<i>unreal3</i>	<i>crazytaxi</i>	<i>aircombat</i>	<i>4elements</i>
Downstream	Total time (s)	249.41	261.16	200.56	239.68	236.59
	Number of packets	149004	174265	13867	153798	108619
	Avg. packets / sec	597.41	667.25	691.39	641.66	459.09
	Avg. packet size (B)	915.57	975.05	1014.99	955.65	722.58
	Bit rate (Mbps)	4.37	5.21	5.61	4.91	2.65
Upstream	Total time (s)	249.48	261.31	200.69	239.83	236.72
	Number of packets	8947	13943	6825	14677	14849
	Avg. packets / sec	35.86	53.35	34.01	61.19	62.72
	Avg. packet size (B)	168.49	157.8	170.08	154.81	154.91
	Bit rate (Mbps)	0.0048	0.067	0.046	0.075	0.077

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)

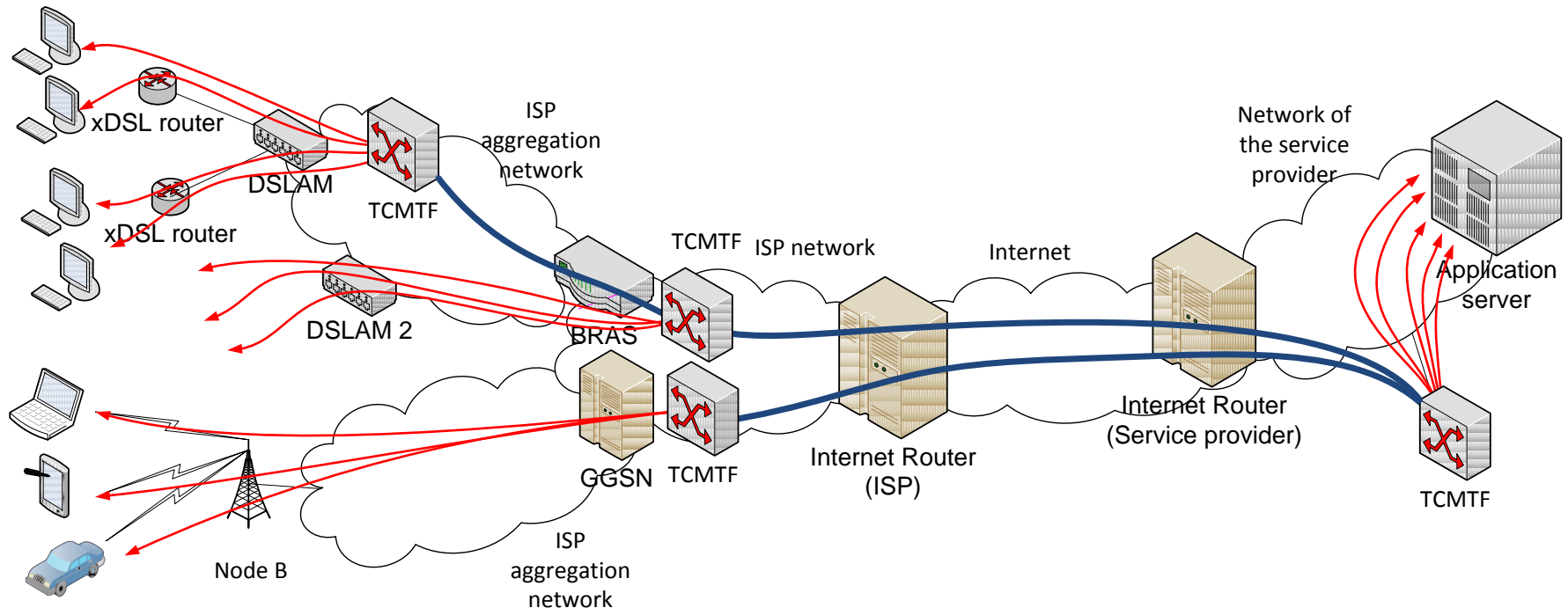


Summary of problems

- 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

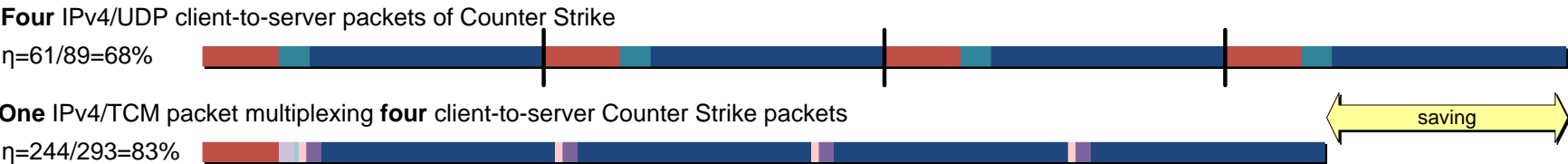
TCM-TF advertisement

- 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?

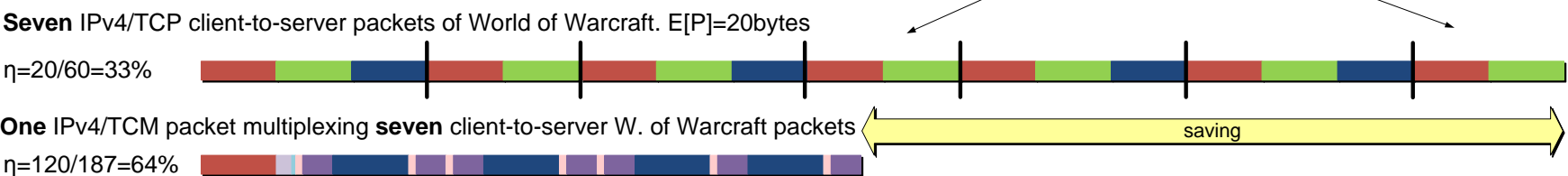


TCM-TF advertisement

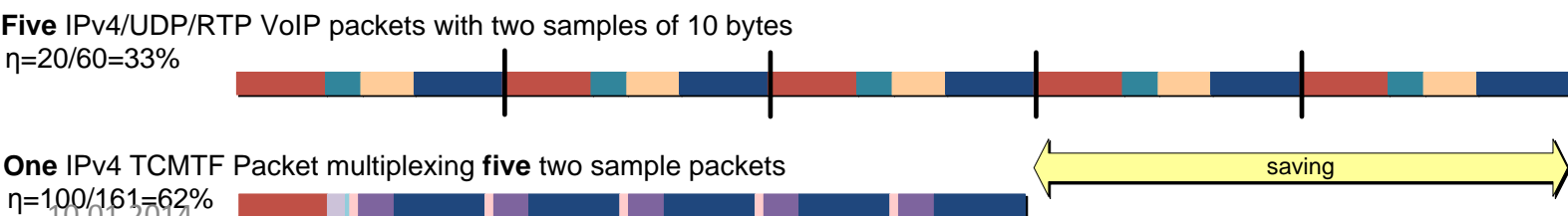
First Person Shooter game:



MMORPG:



VoIP (exactly like RFC4170):



Acknowledgments

- Projects that supported this work:
 - Content Delivery and Mobility of Users and Services in New Generation Networks,” by the Ministry of Science, Education, and Sports of the Republic of Croatia;
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Thank you!

