Trends in evolution of the network traffic of Massively Multiplayer Online Role-Playing Games

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***Abstract*—The history of online video games spans over 30 years, with Massively Multiplayer Online Role-Playing Games (MMORPG) being one of the most popular genres. Constant evolution of MMORPGs has also brought along the need to understand how emerging game mechanisms and design choices affect the game data traffic characteristics. This paper presents a network data traffic analysis of *Guild Wars 2* (GW2), an MMORPG released in 2012, with the idea to draw a comparison between GW2 and older MMORPGs, the characteristics of which are already known from previous studies, and to provide insight into the network traffic trends in this genre. For GW2 analysis, we use game data traffic collected over five weeks' time in an Internet Service Provider core network. The dataset consists of anonymized packet traces corresponding to 19 players who agreed to their network traffic being captured during gameplay. We analyze traffic characteristics, such as packet size, packet inter-arrival times, throughput, and duration of the playing sessions, along with the participants' basic demographic information and their use of voice communication during game play.**

I. Introduction

Massively Multiplayer Online Role-Playing Games (MMORPG) have been one of the most commercially successful genres of online video games, attracting millions of players across the world. While the first commercial MMORG *Island of Kesmai* appeared in 1985, the largest commercial success came with the *World of Warcraft* (WoW), released in 2004 by Blizzard Entertainment. Even now, more than 10 years after its release, WoW is still one of the most popular games for the personal computer (PC) platform, according to NewZoo [1]. Recently, there has also been a growing interest in Multiplayer Online Battle Arenas (MOBAs), like *League of Legends* and *Defense of the Ancients* (DotA), which represent a "fusion" of action games and real-time strategy games. Interestingly, although MOBAs involve more players than MMORPGs [2], and are hence considered their biggest competitors, MMORPGs still perform better on the market, as indicated by digital game market research data from February 2015. According to analyst company SuperData, estimated earnings of MMORPGs in January 2015 were 65 million USD, compared to 54 million USD earned by MOBAs [3]. Therefore, understanding the game traffic requirements to provide and/or to improve the networking support for MMORPGs is still very relevant, not just for the game market, but also for telecoms and data networking in general.

MMORPG are based on persistent, real-time virtual worlds to which players need to have "instant" access. Internet Service Providers (ISPs) catering to gamers need to constantly monitor and analyse MMORPG network traffic to ensure that the user perceived quality remains high. Some ISPs have also recognized a market potential for new business models, based on prioritizing game data traffic [4]. On the other hand, game designers and developers are also constantly changing and improving their products, which sometimes leads to unpredictable and undesired outcomes for ISPs, as clearly demonstrated by a case in the UK [5], where a newly released version of the game changed the network traffic properties so that the ISP's traffic management system did not correctly label the game traffic as gaming class. Marking the game traffic as non-real time traffic class resulted in significantly lower Quality of Experience (QoE) than usual for players, who reportedly responded by switching to other ISPs.

As a popular online video game genre, MMORPGs have been subject to a number of studies focusing on the network traffic properties, for example [6], [7], [8], [9]. In this paper we focus on the effects of (selected) more recently introduced game mechanisms onto MMORPG network traffic, taking as an example a relatively newly released game with significant market success, namely, *Guild Wars 2* (GW2) published by ArenaNet. According to a core PC games top-list by *NewZoo* (a game market research company), as of May 2015, GW2 was ranked 6th, just one position below WoW [1].

The "popularity" of individual MMORPGs should also be observed in light of respective business models. Presently dominant business models in the MMORPG market are: 1) *free-to-play*, in which the game itself is free, but is financed through micro-transactions in the virtual world; 2) *subscription based*, in which players pay monthly subscription, and 3) *buy-to play*, in which the game needs to be purchased, and while there is no subscription, there are micro-transactions in the virtual world. GW2 employs the buy-to-play model, and has sold over 3.5 million copies in its first year on the market [10]. While GW2 may never reach such a numerous fan base as some free-to-play MMORPGs (e.g., *Age of Wushu*), the game is considered a market success, because each player of GW2 has, at least, purchased a copy of the game.

Another reason for studying GW2 lies in several game mechanisms, which may be considered "unorthodox" in the "classical" MMORPG genre, and which may affect the properties of network traffic. One of them is the *targeting system*, which relies on precise positioning of entities in the virtual world. Formerly, when a player had a target "selected" (like in WoW), and then activated an "attacking" skill, that skill would surely hit the target, regardless of its movement at the time. In GW2, targeting is dynamic and based on the position of both the player and the target (e.g., another player). Thus, in GW2 it is possible to avoid the attack by evasive movement, which is not the case in majority of earlier MMORPGs (some notable exceptions include *Darkfall* and *TERA*). Another recently introduced mechanism includes *World versus World versus World* (WvWvW) battles, in which several hundreds of players fight against other players in a single map. Dynamic targeting and WvWvW battles are expected to increase the bandwidth requirements of GW2. In general, when a player is fighting a single hostile entity, more information needs to be transmitted because the positioning information needs to be more precise and more frequently updated, so as to be able to determine whether a given attack is a hit, or a miss, with sufficient accuracy. In WvWvW battles, a large number of players is typically present in the same Area of Interest (AoI), so the amount of information to be transferred is multiplied, since each player needs information on movement and actions of all other players in that AoI. GW2 also introduced *enemy scaling* mechanism, which changes the strength of hostile Non-Player Characters (NPCs) based on the number of (human) players who they are fighting against at a given time. Dynamic events or "quests" (i.e., tasks which yield rewards in terms of experience, money and virtual items) enable all the players who participate in the event to get the reward, based on respective amount of participation. Enemy scaling and quests have both been designed to encourage grouping of players when questing, which used to be a mainly solitary activity in earlier MMORPGs [11]. Even if the players are not acting as a group, just the fact that there are more players simultaneously present in the same AoI, increases the amount of information that needs to be sent by the server, thus also increasing the average use of network bandwidth.

The data analysed in this paper has been captured in cooperation with an ISP in France, in the ISP's core network. The dataset size comprises 6 GB of game data traces belonging to 19 players, collected over a timeframe of five weeks. We analyse this dataset and present selected network traffic properties at an aggregated, and at a single flow level. The properties of interest include: packet size, packet inter-arrival times, and throughput at the network layer, and gaming session duration and behaviour patterns of the players at the application layer.

The remainder of the paper is organized as follows: Section 2 provides an overview of related work, focusing on MMORPG-related network traffic measurement studies. Section 3 presents the methodology of data collection and analysis. Section 4 describes the results of the network traffic analysis, as well as the results of the player survey. Finally, Section 5 concludes the paper.

II. Related work

In network data traffic studies, traffic can, in general, be monitored and/or captured at three locations: 1) at the server side, 2) at the client side, and 3) at various points in the network. We describe related work in these categories next, together with main results and findings.

Traffic capture at the server side is particularly interesting for MMORPG studies, however, as game servers are usually hosted by the game providers, they are usually inaccessible for independent study. Server-side captures usually involve large quantities of data, as the data is captured in a live network and at a very high bitrate. During the traffic capture, especially on the server side, it is essential to ensure that the capturing process does not interfere with, or change the observed traffic characteristics, or, otherwise affect the player QoE. In cooperation with game providers, several research groups have reported measurement results on the server side. Kim, Chong and Hoi studied the Lineage saga – *Lineage* and *Lineage II* by *NCsoft* – which was a huge market success in Korea and Taiwan. They analysed a 281 GB trace captured over an 8-day span on the server side of *Lineage* [12], as well as the traffic of the sequel, *Lineage II* [9]. They noted an interesting and significant increase in size of the server packets in the sequel (packet size was around 15 times larger). This result suggested that MMORPG traffic may increase in volume as the genre evolves. Authors confirmed the linear correlation between the number of active users and the client traffic (correlation coefficient 0.99), as well as the server traffic (correlation coefficient 0.95). Server side traffic measurements and analysis have been also been performed on other games, such as by K.-T. Chen et al. for *ShenZhou Online* [6], [13], and by Griwodz and Halorsen for *Anarchy Online* [14].

Client side traffic is easier to capture, but it requires player cooperation. The amount of data captured at a single client is usually small, but this can also change if a larger number of players become involved in a "crowd-sourcing capture". Datasets captured on the client side have been analysed by several research groups, using a variety of online games, including *World of Legend* [15], *Ragnarok Online* [16], *Silkroad Online* [17][18], *Guild Wars, Star Wars Galaxies* and *EvE Online* [19]. Many studies use WoW as a case study, because of its popularity [20], [21].

When it comes to measurements in the network, few studies refer to MMORPG network flows captured within ISPs. Han and Park used the captured dataset to develop and test an alternative decision tree (ADT) method for classifying the network traffic flows of multiple games, including two MMORPGs: *WoW* and *Lineage II* [22]. They captured their traffic trace on the border router of a campus network with average utilization of 120 Mbps. They captured 562 million packets with total volume of 282 GB, and used this data to demonstrate that their algorithm had high precision and recall. They examined various traffic characteristics: packet size, packet rate, bandwidth usage, and correlation of packet size distributions between different flows of the same application. The ADT algorithm is based on a simple decision tree, with critical discriminators being packet size statistics (i.e., minimum, maximum, mode, mean, distribution), transport behaviours (i.e., mean bytes per second, mean packet rate) and flow information.
Svoboda, Karner and Rupp analysed a traffic trace captured within a 3G mobile core network in Austria [7]. They noted that a significant part of the traffic is coming through the port TCP:3724, a well-known port for WoW. In their dataset, WoW was among top-10 TCP-based services in the monitored network, and it consumed 1% of all TCP-based traffic. Additionally, they captured traffic of two groups of five WoW clients connected through the ADSL line. Analysis at the packet level demonstrated that the packet size in the downlink

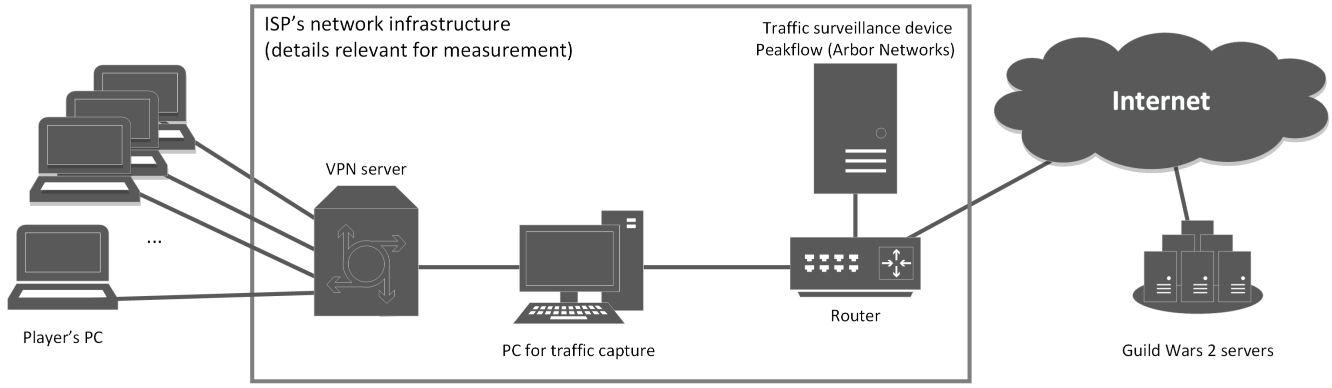

Fig. 1. Measurement setup

direction was quite even, and could be modelled by a Weibull distribution, while in the uplink direction, the packet sizes had large, discrete steps. They also found out that a large number of transmitted packets were TCP ACK packets, carrying no application data.
Kihl, Aurelius and Lagerstedt studied municipal broadband access network in Sweden [23]. The measurement point was the Internet Edge aggregation point, where the service providers of optical network were connected to the network. The dataset comprised data traces from 435 households with active WoW players. Significant differences in traffic patterns were established throughout the week. From Monday to Thursday, the total WoW traffic volume was about 3 Gb per day. On Fridays and Saturdays, the total volume was about 2.5 Gb per day. On Sundays, there was a slightly larger traffic volume of 3.3 Gb per day.
Packet level analysis of MMORPG traffic was performed by Szabo, Veres and Molnar [17], [18]. Authors claimed that the nature of human behaviour had high impact on traffic characteristics and that it influenced the traffic both at the macroscopic level (e.g., traffic rate) and at the microscopic (e.g., payload content) level. They measured and analysed the traffic of WoW and *Silk Road Online*, and examined the server generated traffic. They defined the states of the virtual world across two axes, namely: a) the movement of the player, and b) the number of surrounding players (inside, or outside of cities, i.e., densely populated areas). This resulted in four possible states: *Moving in the city*, *Moving outside the city*, *Stalling in the city*, and *Stalling outside the city*, which significantly differ in traffic characteristics.

Finally, our survey paper on network traffic characteristics of MMORPGs [24] summarized the properties of the network traffic of MMORPGs across multiple studies:

- Bandwidth consumption of MMORPGs is very low compared to other action paced games, such as First Person Shooter (FPS) games (e.g., 7 Kbps for *ShenZhou Online* compared to 40 Kbps for *Counter Strike*).
- Packet payload sizes vary significantly across the whole set of possible values – from zero to maximum size determined by the Maximum Transmission Unit (MTU).
- Packet inter-arrival times vary, but in general they are much longer (200 ms or even up to 400 ms) than in more dynamic games, such as FPS.
- Traffic characteristics vary significantly depending on the state of the virtual world and player actions (e.g., server bandwidth consumption can use up to six times more bandwidth for cooperative group actions compared to solitary actions [20]).
- The amount of data traffic between the server and the client is strongly asymmetrical.
- TCP is often used for MMORPGs, despite of a fairly large protocol overhead, as well as some mechanisms of TCP having deteriorating effect on QoE (Nagle's algorithm, Delayed acknowledgement), and some being ineffective for MMORPG traffic (Fast retransmit).

In this work, we study evolution trends in network traffic generated by MMORPGs, focusing on GW2 as a fairly recent MMORPG, which implements game mechanisms typically not found in older MMORPGs. A similar "evolutionary approach" was adopted by Kim et al. [9] for *Lineage* saga, as already mentioned, but our study is different in that it aims to relate and compare the characteristics of GW2 to previous, generalised findings about the whole genre. We also examine how new mechanisms impact the network traffic properties. To the best of our knowledge, this is the first study to focus on GW2, and especially traffic patterns of massive battles enabled by WvWvW system in GW2.

III. Traffic Recording Methodology

Network traffic was captured in the core network of an ISP in France. A group of 19 players were involved, who belonged to the same player group, playing on a GW2 server also located in France. The players were given fast access through a Virtual Private Network (VPN) server and agreed to their traffic being captured. A high-level illustration of the measurement setup is shown in the Figure 1:

1) Each player connects to the Internet from his/her PC through a VPN server.
2) Once connected to the VPN, each player's traffic is recorded on another PC ("traffic capture") in the core network.
3) Traffic is further routed through the core network as usual, passing along the way through the router with

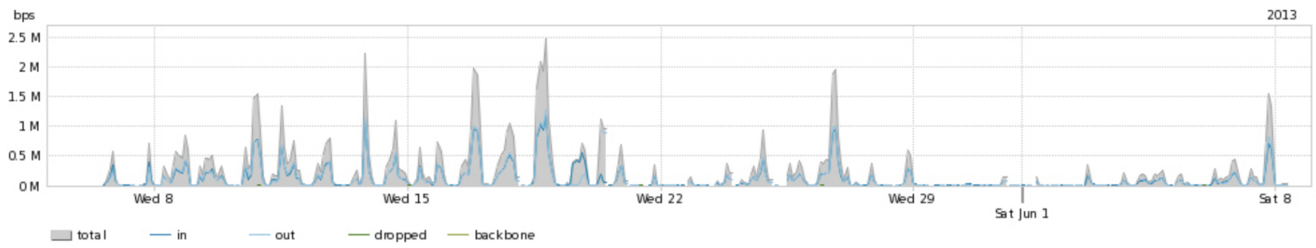

Fig. 2. Aggregate traffic pattern for whole recorded period

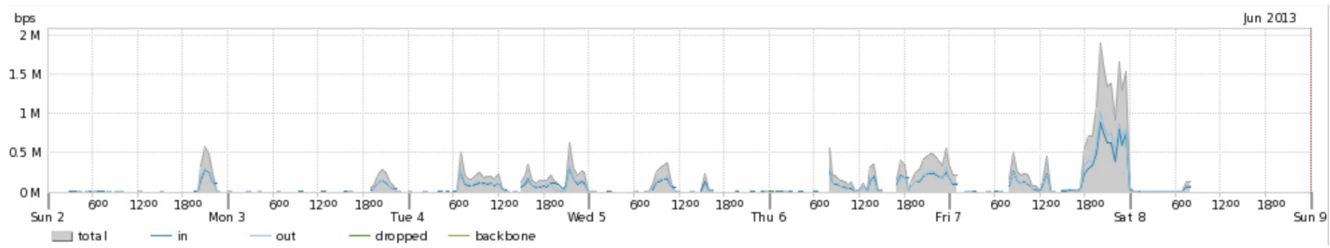

Fig. 3. Aggregate traffic pattern for the (zoomed-in) fifth week of the measurements

Arbor Peakflow network traffic surveillance device attached.

4) Traffic is further routed past the border router (through the Internet) towards GW2 servers.

To record traffic, we used TCPDump, installed on a dedicated PC for traffic capture (Figure 1). Multi-link PPP implementation of Point to Point Protocol (PPP) on FreeBSD was used to track exactly which players are connected to the VPN server. Multi-link PPP is capable of handing of over several Gbps of network traffic and it was also installed on the PC running the traffic capture.

During the traffic recording we recorded only GW2-related traffic. GW2 uses the following ports:

- TCP port 80: HTTP,
- TCP port 443: HTTPS,
- TCP port 6112: main game related data,
- TCP port 6600: background music during game play.

The measurement procedure resulted in about 6 GB data trace, comprising 18,405,463 packets. The captured trace was saved in 596 (.pcap) files of 10 MB each, for easier handling and analysis. Information regarding session lengths has been extracted from TCP flow duration, using the data collected on port 6112. This information was extracted from the trace by using Wireshark, after which it was post-processed to reconstruct individual flows and respective data. Throughput data for each flow was also extracted by using Wireshark.

For further analysis, we created a virtual server using Dell Poweredge R610 with the following configuration: Intel Xeon 5500 processor, 24 GB RAM, 146 GB of disk space, and a 64-bit operating system Linux Debian 6.0. For obtaining the average packet size, we used Tshark. Inter-arrival time data was obtained by first extracting the data into text files, and then processing the files by using custom-built programs, written in C programming language.

Finally, to obtain a basic notion of the participating players' demographics, we created a brief online survey to collect the following characteristics:

- Gender,
- Age,
- Use of voice communication during play, and
- Preferred tool for voice communication.

More details regarding the measurement procedure can be found in [25].

IV. Results

We now present the results for 1) aggregate traffic throughput, 2) packet size, 3) packet inter-arrival time, 4) variation of throughput, 5) session length, and 6) player survey.

A. Aggregate traffic throughput

Figure 2, taken directly from the Arbor Peakflow tool, represents the aggregated traffic pattern over the whole 5-week measurement period. Average aggregate throughput is 197.35 Kbps, and maximal observed value is 2.47Mbps. It should be noted that Arbor Peakflow device uses the GMT time zone, so two hours should be added to the timeline displayed in Figure 2 to obtain the actual local time values (e.g., the label 18:00 means it is actually 20:00 local time).
It may also be noted that every Saturday morning at 1:00 a.m. GW2 servers reset the states of the WvWvW battles (23:00 Friday in the figures), which results in a spike in activity on every Saturday around that time. This trend is even more visible in Figure 3. It may also be noted that players tend to play more in the evening, and there are also increased levels of traffic on Friday and Saturday evenings. This is in contrast with findings of Kihl et al. [23], who observed an overall lower traffic load on Fridays and Saturdays. This difference is not significant, as it can easily be attributed to player age group and playing habits, as will be explained later in this paper in more detail.

B. Packet size

The packet size distribution of client traffic (i.e., traffic originated on the client side) is heavily inclined towards smaller packets, which is in line with the results of older MMORPGs. Over 90% of the packets are sized between 64 bytes and 127 bytes in size, as shown in Figure 4 (note the logarithmic scale). The maximum packet size is 1420 bytes, while the minimum is 64 bytes (IP packet with no payload and a 20 byte Ethernet header, a 20 byte IP header and a 20 byte TCP header and 4 byte of Frame check sequence). The mean value is 81.55 bytes, which means that, on average, client side packets carries only 17.55 bytes of game related information, which means that this "signalling" overhead is quite high.

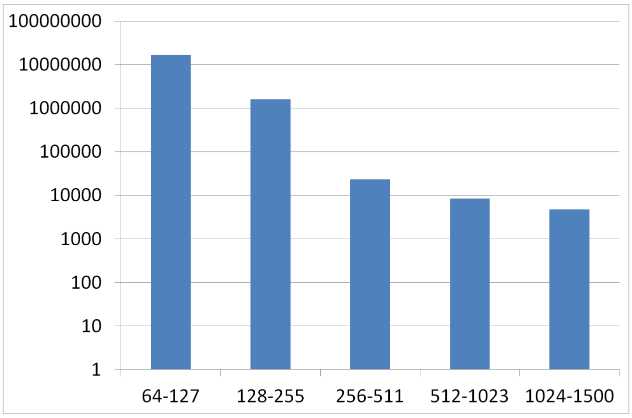

Fig. 4. Histogram of the packet size of client traffic for the whole dataset

The server side packet size distribution is much more evenly distributed, as presented in Figure 5. It should be noted that the scale in Figure 5 is not logarithmic.

For further, detailed inspection we have isolated one, randomly chosen flow from the trace comprising over 120,000 packets. Figure 6 illustrates both the server and the client traffic Cumulative Distribution Function (CDF). For this particular selected flow, packet sizes are quite similarly distributed, although the CDF of the server flow is growing more slowly (i.e., there are many more packets with larger sizes). More than 99% of client packets are smaller than 116 bytes, while 80% of server packets are smaller than 200 bytes. These results show a discrepancy with respect to the general results obtained for the whole dataset. We explain this phenomenon later in the paper.

C. Packet Inter-Arrival Time (IAT)

Since IAT of aggregated traffic does not yield any relevant new information, because it directly depends on the number of active flows, we only report IATs of a single randomly chosen flow, as discussed in the previous subsection. The characteristics of the IAT distribution are depicted in Figure 7. The IATs are very similarly distributed, and fairly regular, and the majority of both server and client IAT fall between 20 ms and 60 ms. Such temporal regularity, and very small values of IAT are not characteristical for MMORPGs, such as *WoW* [20] or *ShenZhou Online* [6], where IAT values are often over 200 ms range, and can reach up to 1 second, in rare cases. Such temporal regularity and small IAT values are characteristical

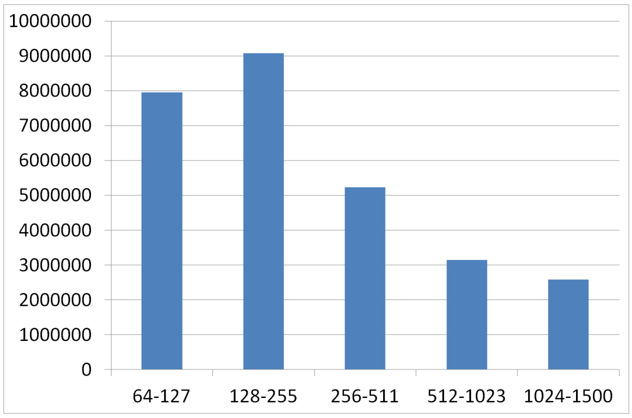

Fig. 5. Histogram of the packet size of server traffic for the whole dataset

for FPS games such as *Halo 2* [26]. In FPS games, the packet rate is dependent of update rate (also known as "tick") of the network engine (i.e., the number of times per second that the client sends an update to the server). For example, in Source network engine used by *Counterstrike GO*, update rate can be configured in the game to 64 or 128 Hz. Sadly, there is no available public information on the internals of the network engine employed in GW2, but Figure 7 shows that a majority of IAT times are concentrated around 40 ms (corresponding to update rate of 25 Hz), which is still much lower than in FPS games. It can thus be assumed that a relatively high packet rate stems from the dynamic targeting system applied in the game. Since the user positioning information is crucial for outcome of every attack (unlike in previous MMORPGs, but similarly to FPSs), this information must be delivered more precisely and more frequently, resulting in a higher packet rate and smaller IAT values.

D. Variability of throughput

Figure 8 shows the GW2 throughput distribution per flow. The client side traffic throughput is always below 20 kbps, while the mean value is 6.3 kbps, and the median is 6 kbps. On the other hand, the server throughput is much more variable, with values going up to 262 kbps, with a mean of 26.8 kbps. The median value of server throughput is 19.5 kbps, which is

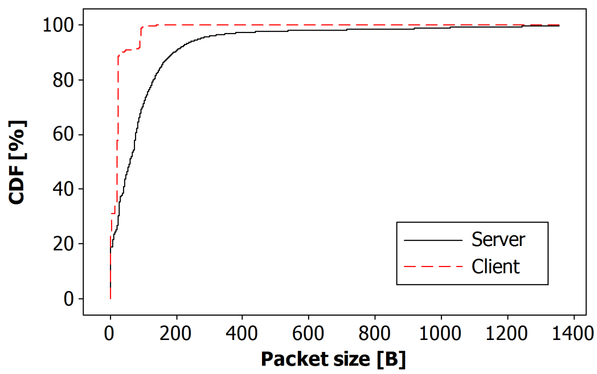

Fig. 6. Cumulative distribution function of packet sizes for a single GW2 flow

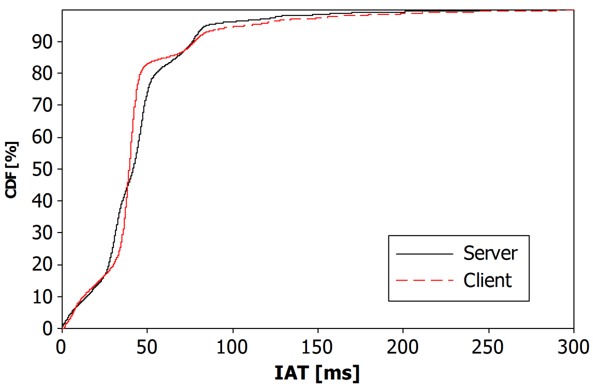

Fig. 7. Cumulative distribution function of packet IATs for a single GW2 flow

almost three times higher than in WoW, where median value is 6.9 kbps [7]. This increase may be attributed to new game mechanisms, especially the space based combat and stronger incentives for grouping of the players.

It should, however, be noted that the presented information is averaged over the whole flow. We did not examine specific context situations within a specific flow, like what the user is doing in the virtual world [20]. Therefore, we expect time intervals in the traffic pattern that exhibit traffic bursts in specific situations, such as WvWvW combat in GW2. We confirm this by using a random example where we observed spikes of server side throughput up to 500 kbps which is, for an online game, a very high value. The time series of a burst in throughput is presented in Figure 9. The high variability of flow throughput explains why the characteristics of a randomly chosen flow in Section IV.B and IV.C do not comply with the average characteristics of the dataset. Probably the player which generated that particular flow performed actions which were less demanding than the behaviour of the average player (e.g., performing quests alone, crafting etc.).

E. Session length

The CDF of session lengths in the dataset is depicted in Figure 10. Besides session lengths captured in our measurement, we also show the session lengths resulting from independent measurements taken for WoW [23], [7]. In comparison to these results, session lengths in our dataset are significantly shorter, with the mean of 48.3 minutes, and the median of only 10.1 minutes, which suggests that short sessions are prevalent in our dataset. The discrepancy in session lengths might be attributed to design differences in the games (WoW vs GW2,) although WoW and GW2 have similar game concepts. Also, as our survey revealed that the average age of our player sample was higher than in other surveys, which might also explain their (on average) shorter gaming sessions.

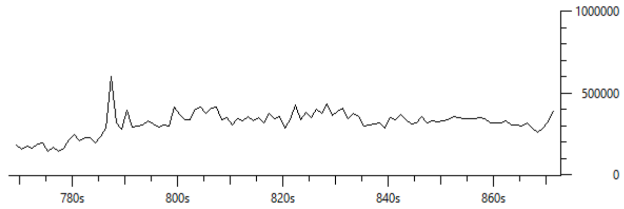

Fig. 9. Time series of a burst in one aggregated (both server and client) GW2 flow

F. Player survey

We conducted a brief player survey, consisting of 4 questions, related to the players' age, gender, and using voice communication during gameplay. The goal was to gain basic information regarding player demographics and their gaming habits. The results of the survey are presented in Figure 11. As mentioned earlier, our sample consisted of 19 players. Majority of them turned out to be male, and over 18 years old. Age-wise, most players were between 30 and 39 years old. The age of the players might explain the observed discrepancies in session length and in traffic patterns. People in that age group typically have less time to play due to work and family obligations, which results in shorter sessions. They also tend to play more often on Fridays and Saturdays. These results differ from those reported for student players (average age 22), where session lengths were longer on average, and there was less activity on Fridays and Saturdays [27]. It was also shown that group activities, in which large groups of organized players engage in battles with monsters, usually do not happen on Fridays and

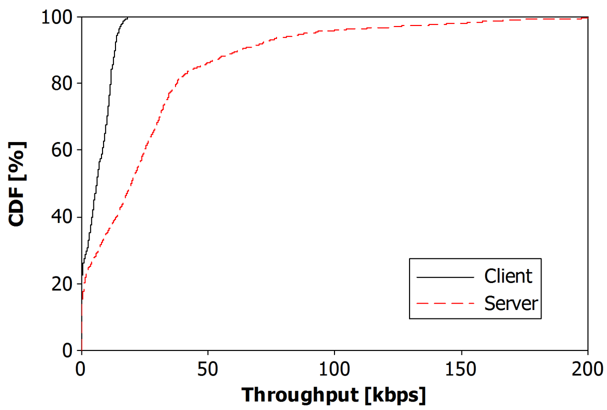

Fig. 8. Cumulative distribution function of throughput per flow

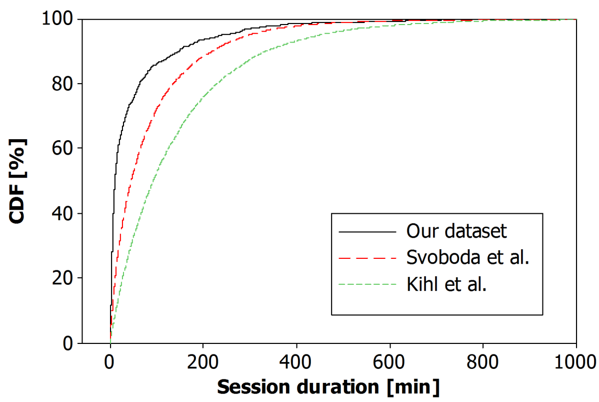

Fig. 10. Cumulative distribution function of session lengths from several MMORPG datasets

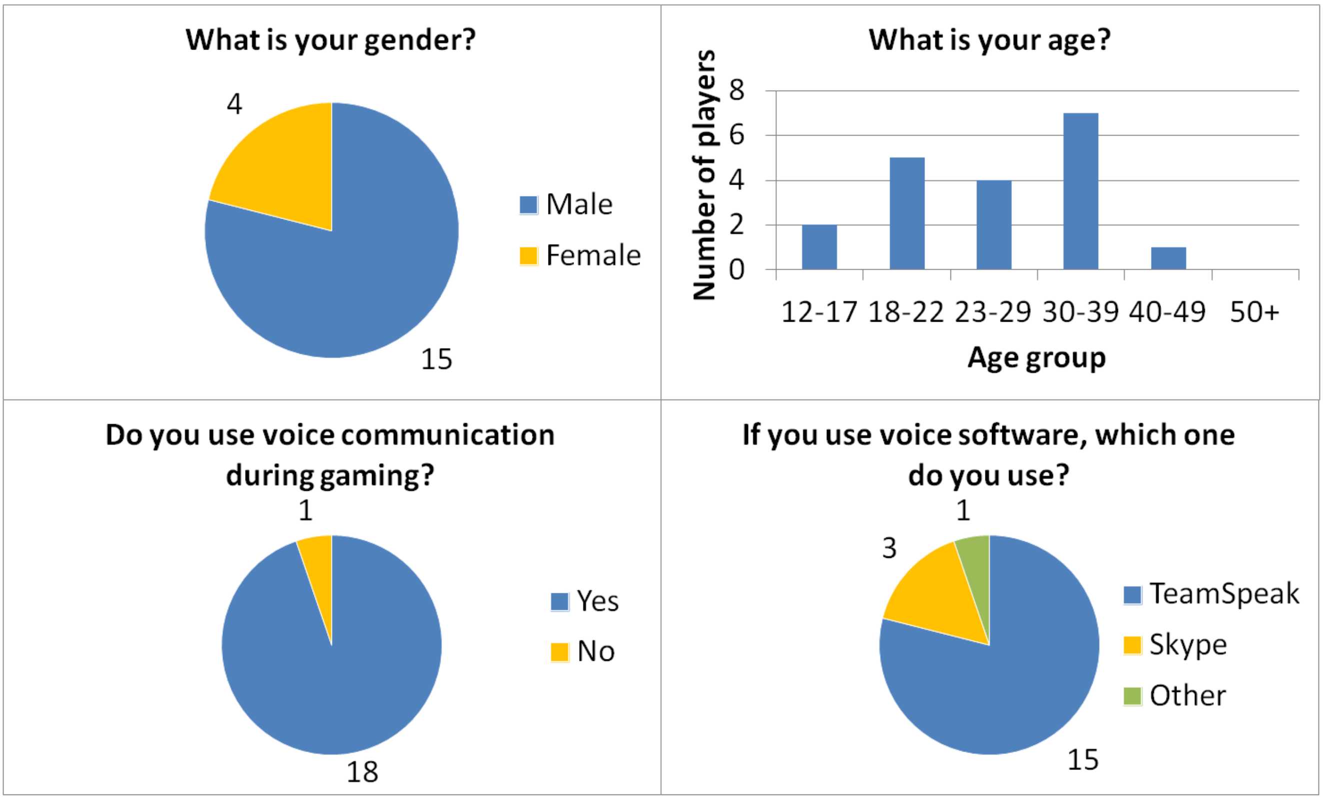

Fig. 11. Results of the survey for gender, age, usage of voice communication, and software for voice communication

Saturdays, when young people tend to engage in real-life social activities. These assumptions could be confirmed through a large scale user behaviour study, or, through cooperation with game developers, who have the whole set of information regarding their clients and their behaviour at their disposal.

To summarize, our player sample comprises mainly experienced gamers, not only by the age, but also based on the statistics regarding use of voice communications (which almost all players use). Previous work [28] showed that voice communication is mostly used in "late game" activities, involving players with significant experience in the game. Regarding voice communication, unlike some other MMORPGs, GW2 does not have an internal voice communication application, so all players use external applications, of which the most popular, in the surveyed group, was TeamSpeak. It should be noted that voice communication slightly increases bandwidth usage per player (e.g., TeamSpeak with Speex codec can use up to 44 kbps).

V. Conclusion and discussion

The comparison of GW2 data traffic with previously studied MMORPGs, with respect to characteristics common to the MMORPG genre [24], can be summarized as follows:

- Average throughput of GW2 is higher than in previously studied MMORPGs, especially in the server traffic, which is caused by higher packet rate.
- Packet sizes in GW2 are similar to other MMORPGs in both client and server traffic.
- GW2 packet IATs are shorter and very regular, which is otherwise typical for FPS games, rather than MMORPGs – this can be attributed to faster gameplay and dynamic targeting system, which requires much more frequent positional updates.
- Server side throughput for GW2 is more variable than in other MMORPGs (up to 20 times, compared to 5 times of WoW), possibly due to player grouping and WvWvW battles with large number of players.
- Client server traffic characteristics of GW2 are strongly asymmetrical, which in line with previous MMORPGs.
- GW2 uses TCP as a transport protocol, although gameplay is much faster and more dynamic than in (most) previous MMORPGs.

The analysis of traffic of GW2 indicates that the evolution of the network traffic of MMORPGs is indeed happening, and that both the data network traffic characteristics and data quantity are changing. Unlike in the case of *Lineage* and *Lineage II* [9], we found that for GW2 the increase in traffic can be attributed to higher packet rate, and not to larger packet size. Although GW2 traffic flows are still "thin" when compared to video, which is currently the prevalent type of traffic in the Internet, they are very sensitive to latency, which is a direct consequence of real-time nature of networked virtual worlds. Therefore, it is imperative that GW2 data traffic (as well as MMORPG traffic, in general) is properly identified and treated accordingly in the core network. ISPs need to be aware of the "behavioural profile" of networked games and adapt traffic

classification mechanisms as needed – especially those based on statistical properties of the game data traffic – to enable fair traffic shaping mechanisms to provide adequate QoE to end users. The game developers, on the other hand, should be aware that even small increases in the amount of information sent for a single entity in the virtual world, may quickly scale up in massive multiplayer scenarios.
To conclude, the analysis presented in this paper illustrates the existence of links between specific game mechanisms and their manifestation at the network traffic level, but cannot examine the exact relationships in more depth based on the analysis of aggregated network traffic alone. In future work, we would like to perform a study which would directly investigate the impact of described in-game mechanisms combined with user behavior onto network traffic, through supervised gaming sessions paired with traffic measurements.

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