

**Technische Universität Berlin**



Forschungsberichte der Fakultät IV  
Elektrotechnik und Informatik

**Tigers vs Lions: Towards Characterizing  
Solitary and Group User Behavior in MMORPG**

Juhoon Kim <sup>1,2</sup>  
Nikolaos Chatzis <sup>1,2</sup>  
Matthias Siebke <sup>1</sup>  
Anja Feldmann <sup>1,2</sup>

<sup>1</sup> Technische Universität Berlin  
<sup>2</sup> Telekom Innovation Laboratories

**Technical Report**

Bericht-Nummer: 2013-01  
ISSN: 1436-9915

Februar 2013



# Tigers vs Lions: Towards Characterizing Solitary and Group User Behavior in MMORPG

Juhoon Kim<sup>\*†</sup>, Nikolaos Chatzis<sup>\*†</sup>, Matthias Siebke<sup>†</sup>, Anja Feldmann<sup>\*†</sup>

<sup>†</sup>Technische Universität Berlin, <sup>\*</sup>Telekom Innovation Laboratories

{jkim,nikolaos,anja}@net.t-labs.tu-berlin.de<sup>\*†</sup>, siebke.matthias@gmail.com<sup>†</sup>

**Abstract**—The development of Internet technologies enables software developers to build virtual worlds such as Massively Multi-Player Online Role-Playing Games (MMORPGs). The population of such games shows super-linear growing tendency. It is estimated that the number of Internet users subscribed in MMORPGs is more than 22 million worldwide [1]. However, only little is known about the characteristics of traffic generated by such games as well as the behavior of their subscribers. In this paper, we characterize the traffic behavior of World of Warcraft, the most subscribed MMORPG in the world, by analyzing Internet traffic data sets collected from a European tier-1 ISP in two different time periods. We find that World of Warcraft is an influential application regarding the time spent by users (1.76 and 4.17 Hours/day on average in our measurement), while its traffic share is comparatively low ( $< 1\%$ ). In this respect, we look at the World of Warcraft subscriber’s gaming behavior by categorizing them into two different types of users (solitary users and group users) and compare these two groups in relation to the playing behavior (duration as the metric) and the in-game behavior (distance as the metric).

## I. INTRODUCTION

Ever since the personal computer was introduced game developers have been building virtual worlds. While the hardware resources, e. g., CPU/GPU power and memory capacity, have been the key constraints on developing such games in the past, network resources and properties, e. g., bandwidth and latency, play an important role in today’s online games. Given the fact that the number of Massively Multi-player Online Role Playing Game (MMORPG) subscribers rapidly increases every year and that it reached 22 million in 2011 [1], it is crucial for ISPs to understand characteristics of Internet traffic generated by MMORPGs and the playing behavior of their users.

According to several reports (see for instance [2], [1]), World of Warcraft (a.k.a. WoW) alone accounts for more than 50% of the total MMORPG subscriptions. Thereby, this particular online game has attracted much attention of academia and industry.

In this paper, we present the analysis of MMORPG traffic and users’ gaming behavior focusing on World of Warcraft as a representative game. The contributions of our paper are mainly three-fold. First, we reveal the characteristics of World of Warcraft game traffic by thoroughly analyzing Internet traffic collected from a European tier-1 ISP. Second, we present changes of traffic behavior by observing two data sets collected in different time periods. Third, we compare the gaming behavior of users who play the game alone and users who play the game together with other users behind the same middle

box. As far as we know, none of the previous studies [3], [4], [5], [6], [7] questioned on the theme (the user behavior of MMORPGs) from this perspective.

The remainder of this paper is structured as follows. Section II provides the necessary background for understanding World of Warcraft. We discuss related work in Section III. The implementation of our protocol analyzer is discussed in Section IV and traffic traces used for this study are described in Section V. Section VI and Section VII explore characteristics of World of Warcraft traffic and World of Warcraft subscriber’s gaming patterns, respectively. Finally, we conclude the paper in Section VIII.

## II. OVERVIEW OF WORLD OF WARCRAFT

World of Warcraft was first introduced in the market by Blizzard Entertainment in 2004 and soon became one of the most subscribed (the number of its worldwide subscriptions reached 12 million in October 2010 [2]) online games. A user<sup>1</sup> within World of Warcraft is represented as a graphical form, which is often called the avatar, whose identity (name, gender etc.) is usually different from the user’s real world identity. This type of game is commonly referred to as a Massively Multi-player Online Role Playing Game (MMORPG).

Unlike traditional computer games, in which the user plays as the only intellectual game entity and the other entities act based on the story line programmed by the game developers, MMORPGs provide their subscribers virtual worlds in which users meet and communicate with other users. This makes interactions among users to play more important role than the story line. For MMORPGs, more than a thousand users play the game at the same time and they build the real-world-like society in the game world. Moreover, users own private possessions and even trade them with other users in virtual world currency. These sorts of social features allow MMORPG providers to introduce a different business model from that of traditional games. While users pay for the purchase of traditional computer games, MMORPG users pay fee based on time they play.

Although World of Warcraft is designed to accommodate a massive number of players, it needs a certain level of load balancing. To this end, Blizzard Entertainment provides multiple copies of the virtual world for their users, which are

<sup>1</sup>The term “user”, “subscriber”, and “player” are interchangeably used in this paper.

called realms. Thus, avatars are only able to interact with the other avatars which are within the same realm.

### III. RELATED WORK

Previous studies in MMORPGs have mainly focused either on characterizing gaming traffic behavior [8], [9], [10] or on determining the users' playing patterns [3], [4], [5], [6], [7]. Although some of our findings overlap studies of the former category, we emphasize that our work falls more into the latter category as the novelty of our findings mainly lies on the gaming behavior analysis of solitary users and group users.

Szabó et al. [6] studies how gaming traffic is influenced by various in-game activities of game players by deeply inspecting MMORPG traffic. Suznjevic et al. [10] evaluates types of actions generated by players within the virtual world. Their work aims at determining activities of players within the game world, while our work examines properties such as the movement of avatars within the virtual world and the playing duration of users. Cevizci et al. [8] studies self-similarity of online game traffic, but they do not particularly focus on MMORPGs. Kihl et al. [3] reports that 20% of the households in their measurement environment (a Swedish broadband access network with 12K users) has active World of Warcraft players and that their average playing duration is 2.3 hours per day. Our work is complementary to their work since we perform our measurement based on the traffic traces collected from the topologically similar network in 2008 and 2010, while they conduct the measurement on traffic collected in 2009.

Chen et al. [9] analyzes ShenZhou online game traffic collected at the server side and reports that MMORPG traffic shows irregularities due to the players' drastically diverse gaming behaviors. However, our results suggest that there is a high level of similarity when grouping players by the number of co-players behind the same middle box (i.e., residential gateways). Varvello et al. [7] studies avatars' social behavior in Second Life. They find that approximately 0.3% of the total subscribers are playing the game concurrently at any point of time and that they do not move 90% of the connected time. They also find that avatars in Second Life tend to organize small groups (2 to 10 avatars). Some of these numbers are noticeably different in our study. This is likely due to the different gaming nature between Second Life and World of Warcraft. Pittman et al. [5] studies the population dynamics of virtual worlds over time and the players' movement patterns in the virtual world. Miller et al. [4] analyzes the avatars' movements within the virtual world and they find that 5% of visited territory accounts for 30% of all time spent. We also consider the movement as an important metric for characterizing the player's in-game behavior, but we focus rather on the distance avatars travel than on the pattern of the movement. Benevenuto et al. [11] studies the user's interaction with other online users within various social networks (i.e., Orkut, MySpace, Hi5, LinkedIn). Although their study is based on online social networks, the key question asked in their work and the one in our work are similar to each other.

### IV. METHODOLOGY

In this section, we describe the implementation of the analysis tool and the classification method used to perform our measurement. Note that we are willing to offer our analysis tool to other researchers for further studies on this subject (see also Section V).

#### A. Analysis Tool

For our analysis, we implement the World of Warcraft protocol analyzer with Bro NIDS [12] as the code base. The reason why we choose Bro as the basis of our analysis tool is mainly due to three unique features of Bro. First, Bro is designed in such a way that the transport layer protocol analyzers are hierarchically separated from the higher layer protocol analyzers, so that developers do not need to deal with the complexity that transport layer protocols have (e.g., TCP stream re-assembly). Second, Bro supports a specialized protocol analyzer development framework which can be translated by the BinPac protocol parser generator [13]. The development process is greatly eased due to the framework. Third, Bro provides an indigenous protocol identification mechanism, namely the Dynamic Protocol Detection (DPD) [14], which allows the analyzer to identify the protocol in the semantic manner. More precisely, the analyzer identifies a potential protocol in the beginning of the connection based on various classification methods (e.g., signature or well-known network ports) then confirms or denies the decision depending on the connection's further behavior. This unique feature of Bro improves the accuracy of the traffic classification.

#### B. Classification Method

In order to illustrate our classification method in detail, we first provide some level of technical information about the World of Warcraft protocol. The World of Warcraft protocol uses TCP as its transport protocol and a client typically opens two connections towards different servers. One connection is established between the client and the logon server in order to authenticate the subscriber and to update relevant server/client information such as the list of game servers and the status of the subscriber's avatar. The other connection is established between the client and the game server in which actual gaming information, e.g., coordinates of the avatar and chat messages, is exchanged.

Our analyzer is implemented to detect the protocol in two steps. The initial step of the protocol identification is based on examining the protocol's unique byte pattern (signature) of the first packet of the connection. We use `^x00...WoW` and `^...\xed\x01` as regular expression signatures of the logon connection and the game connection, respectively. However, due to the short signature length, relying only on this step yields a high false-positive rate. Thus, the next step verifies if the connection responder replies with the expected signatures. In this step, we use `^x00` (logon connection) and `^...\xec\x01` (game connection) as signatures.

Even after the protocol classification, the nature of the proprietary software that the World of Warcraft programs have and

partly encrypted protocol messages make the deep inspection of World of Warcraft traffic extremely difficult. Thus, we use unencrypted part of protocol messages for our analysis. As we will show in Section VI, more than 60% of the World of Warcraft packets are coordinate information which can be translated into human readable text.

## V. DATA SETS

We use two anonymized 24-hour packet-level traffic data sets (ISP08 and ISP10) for our study. These two traces are collected at the same aggregation point within a European tier-1 ISP in 2008 and in 2010. The monitor, using Endace monitoring cards, operates at the broadband access router connecting customers to the ISP's backbone. We count more than 20K DSL lines behind our vantage point. All confidential information such as IP address and user identification are anonymized by Bro's integrated encryption feature. The relevant information of our traffic data sets and the number of identified World of Warcraft subscribers are summarized in Table I.

In the light of the fact that World of Warcraft traffic is pure controlling traffic generated by users (e.g., by mouse button clicking and/or by key pressing), as opposed to the media content delivery, we believe that 0.48% and 0.72% (see Table I) of traffic contributions are worthwhile to study. Note that traffic generated by software updates is not included.

Although our traffic data is highly anonymized, we cannot make it publicly available since the content of messages encrypted by the World of Warcraft application is unknown to us and may include personal information. However, the measurement can be conducted by using any such traces since our analysis tool is available<sup>2</sup> to public under the same license that Bro NIDS follows (BSD).

## VI. TRAFFIC CHARACTERISTICS

In this section, we first illustrate the general characteristics of World of Warcraft traffic. Then, we present that the majority of the World of Warcraft traffic is movement messages in which coordinates of avatars and nearby objects (e.g., non-player characters or game items) are delivered.

### A. General Characteristics

Figure 1, Figure 2, and Figure 3 respectively depict the distributions of packet size (payload only), packet sending rate, and throughput. We report results of logon connections separately from those of data connections since those two types of connections show clearly different behavior in terms of packet count, traffic volume, and duration of connections. Interestingly, we observe that the line shape of server-to-client packet streams of ISP10 is significantly different from that of ISP08 in all logon plots, while the change of client-to-server packet streams is not remarkable. Furthermore, the lines representing data packet streams of ISP10 ((b) of all three

figures) have drastically shifted compared to those of ISP08. We draw the conclusion that the protocol has been modified during the two years in such ways that a server delivers logon information in a more compressed or more distributed manner and delivers gaming information more frequently.

Comparing the throughput statistics of the two traces shown in Figure 3, the later version of World of Warcraft protocol tends to need more bandwidth than the earlier one. Yet, its bandwidth utilization is relatively low considering the network bandwidth provided by today's ISPs. This means, unlike popular belief among users, upgrading the link capacity may not be the solution for a better gaming experience.

### B. Movement Messages

Regarding the peak of client-to-server packet streams observed in Figure 1 (b), 43 bytes (ISP08) and 51 bytes (ISP10) are typical sizes identified from packets which deliver avatar's coordinates within the virtual world to the server. The reason why the size of the movement message differs in two traces is that the object's ID is embedded in a different way in different versions of the protocol. This phenomenon leads us to the conclusion that more than 60% of the total packets delivered from clients to servers is the avatar's coordinate information.

By deeply inspecting server-to-client messages, we find that the majority of messages sent from servers to clients are movement messages for updating the client on coordinates of its nearby players and objects. However, we do not observe the peak which is shown in client-to-server packet streams since a server sends coordinates of various numbers of objects within one packet.

## VII. TIGERS VS LIONS

MMORPG subscriber's gaming behavior is an often addressed research topic in online game traffic measurement. Such studies are especially important for ISPs in order to understand user's increasing demand for a good gaming experience. Assuming MMORPG users as a homogeneous group, previous studies [9], [3], [4], [10], [6] focus either on characterizing the overall gaming behavior of users or on comparing the user behavior in different virtual worlds. However, towards gaining a more complete insight into the gaming behavior of MMORPG subscribers we take a different approach to those of earlier work.

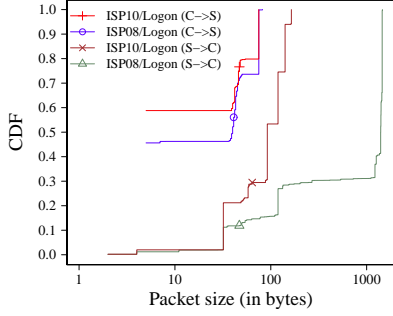
### A. Playing Behavior

We first classify World of Warcraft players into two groups. The first group consists of users who is the only player behind an IP address. The other group consists of users whose IP addresses are shared with other World of Warcraft users. We refer to the former as Tigers and to the latter as Lions according to their hunting behaviors (tigers hunt individually, while lions hunt in a pride). One must note that players may be included in both groups multiple times due to the change of their playing locations or the reallocation of IP addresses, thus the number of users reported in Table II is greater than the one in Table I. It is crucial to mention that we do not focus on characteristics

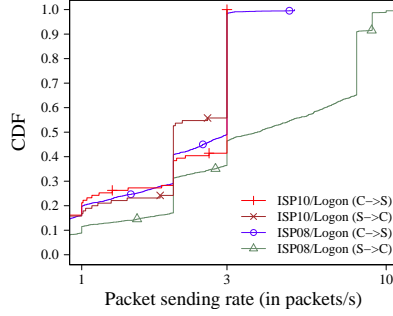
<sup>2</sup>The base code can be downloaded from <http://www.bro-ids.org/> and our analysis tool can be obtained by contacting the corresponding author of this paper.

TABLE I: Overview of anonymized packet traces.

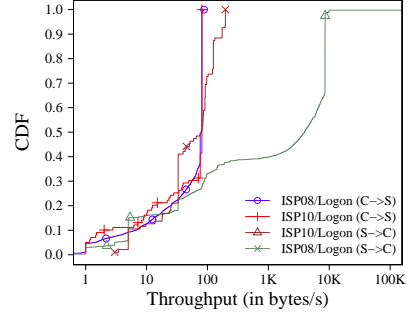
Name	Overall Traffic			World of Warcraft				
	Mon. Year	Duration	Volume	packets	Volume	Version	Users	Avg. Playing
ISP08	Aug. 2008	12:00 – 12:00	> 4TB	0.91 %	0.48 %	2.4.3	3.0 % (599)	1.76 Hours
ISP10	Mar. 2010	02:00 – 02:00	> 4TB	0.83 %	0.72 %	3.x.y	1.4 % (280)	4.17 Hours



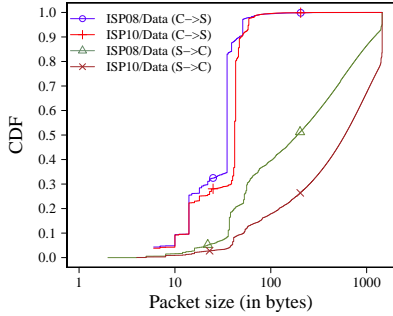
(a) Logon connections



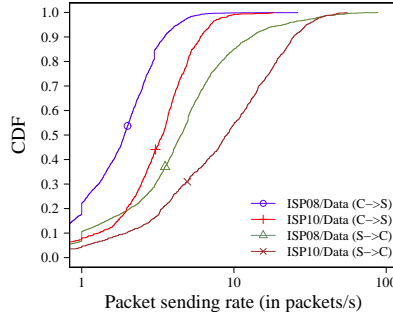
(a) Logon connections



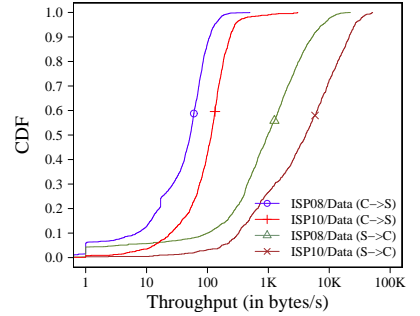
(a) Logon connections



(b) Data connections



(b) Data connections



(b) Data connections

Fig. 1: Packet size

Fig. 2: Packet rate

Fig. 3: Throughput

TABLE II: Categorization of users according to the number of locally grouped co-players

Group size (in players)	ISP08			ISP10			
	# of IPs.	# of users	volume	# of IPs	# of users	volume	
Tigers	1	487 (75 %)	487 (54 %)	53 %	257 (82 %)	257 (68 %)	65 %
Lions	2	118 (18 %)	236 (26 %)	28 %	46 (15 %)	92 (24 %)	30 %
	3	26 (4 %)	78 (9 %)	10 %	8 (3 %)	24 (6 %)	> 4 %
	4	11 (2 %)	44 (5 %)	< 6 %	1 (<1 %)	4 (1 %)	< 1 %
	> 4 *	7 (<2 %)	55 (6 %)	< 4 %	0 (0 %)	0 (0 %)	0 %
total	649 (100 %)	900 (100 %)	100 %	312 (100 %)	377 (100 %)	100 %	

\* Maximum number of users behind a single IP address is 14

of individual users, but intend to study general differences between locally grouped players and solitary players in terms of playing time, traffic volume, and distance their avatars move within the virtual world. We summarize relevant statistics in Table II.

With few exceptions in ISP08, we find that the number of users per group of Lions is less than 4 which is a common maximum number of physical network ports on home networking devices. The table explains that the fraction of Tigers increases in ISP10.

Figure 4 illustrates the subscriber’s playing time in different

perspectives. While Figure 4 (a) depicts duration of connections, the result shown in Figure 4 (b) is aggregated with the user. We infer two observations from the figures. First, while the number of identified game users decreases during the two years, the playing duration tends to increase. Taking a deeper look, we find that the fraction of users who play the game shorter than 0.28 hours in a day decreases from 40 % to 20 %, while the fraction of users who play the game longer than 2.8 hours in a day increases from 20 % to 40 %. Second, considering that the y-axis of Figure 4 (b) is in

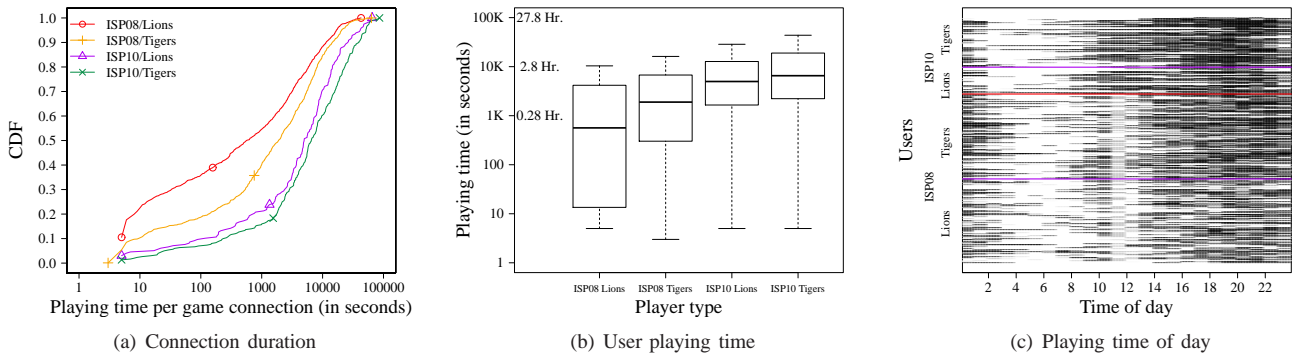


Fig. 4: Playing time distributions

a logarithmic scale, solitary users (Tigers) are playing notably longer than users playing together behind the same middle box (Lions).

In Figure 4 (c), we illustrate the time of day that users play the game. Note that the y-axis of this figure represents World of Warcraft users and x-axis time of day. Each time slot is filled with various depth of gray color depending on the minutes played in the time slot. Thus, a time slot is fully used when it is black and it is not used when it is white. The x-axis is wrapped around the beginning time of the measurements. It is crucial to illustrate the results in this manner in order to make the results comparable. Indeed, the two traces do not begin at the same time of day and also do not begin at mid night (see Table I). The sudden bright cells observed between 11 a.m. and 1 p.m. in ISP10 is due to the fact that the connections established before the beginning of the measurement cannot be recognized by the analyzer. The figure suggests that there is only a negligible difference between Tigers and Lions when considering the time of day they play. Unsurprisingly, popular time slots of a day are identified between 7 p.m. and 11 p.m.

### B. In-game Behavior

Next, we analyze the distance that avatars move in the virtual world during the game play. Figure 5 illustrates the distance distribution of the avatar’s movement. As there is no way to map the distance in the virtual world to the real world’s metric, we invent an imaginary metric  $W_m$  for measuring the distance in World of Warcraft. In order to provide readers with the intuitional hint of this virtual metric, we illustrate the distribution of the speed at which avatars move in the virtual world in Figure 6. In this analysis, we find that about 0.8% of the identified avatars has unrealistic movement speeds (two to three orders of magnitude higher speed than the average speed). We assume that these are mainly due to the usage of long distance transportation systems such as the teleport. We, thus, ignore such extremely high movements from the result. From this evaluation, it is calculated that average speeds of avatars are 4.25  $W_m/s$  (ISP08) and 6.39  $W_m/s$  (ISP10). Figure 5 illustrates that Lions show more itinerant behavior than Tigers. This is likely due to the fact that Tigers spend more time for communicating with other avatars in the virtual world,

whereas Lions focus more on hunting in the battle field. This is a reasonable inference because, for Lions, a communication with other users does not interfere in the movement in the virtual world as their in-game friends are within the talking distance.

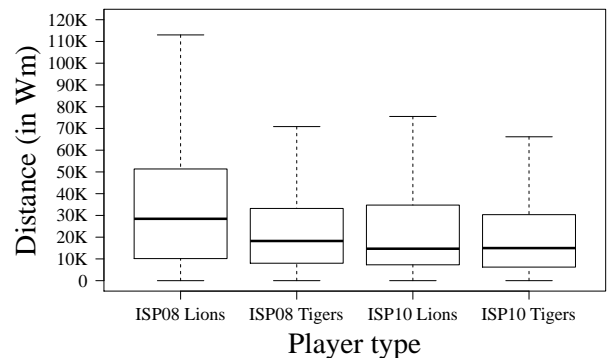


Fig. 5: Movement distances of avatars

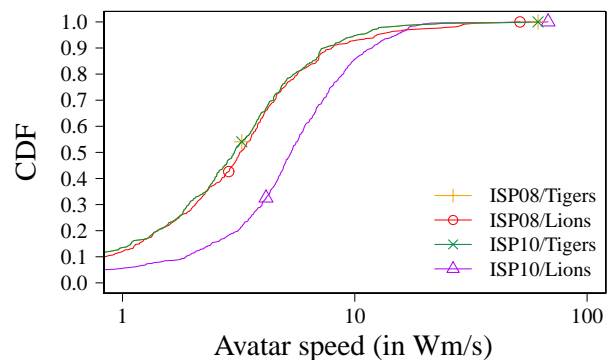


Fig. 6: Speeds of avatars

## VIII. CONCLUSIONS

In this paper, we have presented a thorough analysis of World of Warcraft game traffic based on two sets of anonymized packet-level traces collected from a European tier-1 ISP in two

different time periods. This study is intended to provide ISPs and academia for a better understanding of MMORPG user behavior and characteristics of network traffic generated by such games. For this study, we developed the protocol analyzer designed to identify World of Warcraft traffic from the overall Internet traffic and to extract unencrypted messages, i. e., logon messages and movement messages, from the classified World of Warcraft traffic.

From this analysis, we uncover general trends and characteristics of World of Warcraft traffic. More precisely, we find that the protocol is modified during the two years (2008 to 2010) in such a way that servers send less information or more compressed information to clients through the logon connections, and servers and clients send more information or more detailed information to each other through game connections. We also report that the bandwidth utilization of such games is comparatively low and more than 60% of the total packets that clients send to the server are for updating the avatar's coordinates. Then, we examine differences between solitary users (Tigers) and users who play the game together with other users behind the same middle box (Lions). We find that Tigers tend to play the game longer than Lions, while Lions travel longer distance in the virtual world than Tigers.

The major restriction we have encountered during this study is highly encrypted part of the payload. We are of the belief that we can find similarities among the same type of users if we examine social interactions, e. g., chatting and trading, between users. However, we do not intend to violate the privacy of World of Warcraft subscribers. Thus, our future work includes the development of the message classification method that identifies messages without the payload inspection. Furthermore, we plan to carry out a survey in the user community for finding out reasons of such differences between the two groups.

#### REFERENCES

- [1] "Total mmorpg subscriptions and active accounts," <http://users.telenet.be/mmodata/Charts/TotalSubs.png>, Oct 2010.
- [2] "World of warcraft surpasses 11 million subscribers worldwide," <http://us.blizzard.com/en-us/company/press/pressreleases.html?id=2847881>, Dec 2011.
- [3] M. Kihl, A. Aurelius, and C. Lagerstedt, "Analysis of world of warcraft traffic patterns and user behavior," in *ICUMT*. IEEE, 2010, pp. 218–223. [Online]. Available: <http://dblp.uni-trier.de/db/conf/icumt/icumt2010.html#KihlAL10>
- [4] J. L. Miller and J. Crowcroft, "Avatar movement in world of warcraft battlegrounds," in *Proceedings of the 8th Annual Workshop on Network and Systems Support for Games*, ser. NetGames '09. Piscataway, NJ, USA: IEEE Press, 2009, pp. 1:1–1:6. [Online]. Available: <http://portal.acm.org/citation.cfm?id=1837164.1837166>
- [5] D. Pittman and C. GauthierDickey, "A measurement study of virtual populations in massively multiplayer online games," in *Proceedings of the 6th ACM SIGCOMM workshop on Network and system support for games*, ser. NetGames '07. New York, NY, USA: ACM, 2007, pp. 25–30. [Online]. Available: <http://doi.acm.org/10.1145/1326257.1326262>
- [6] G. Szabó, A. Veres, and S. Molnár, "On the impacts of human interactions in mmorpg traffic," *Multimedia Tools Appl.*, vol. 45, pp. 133–161, Oct 2009. [Online]. Available: <http://dl.acm.org/citation.cfm?id=1613012.1613044>
- [7] M. Varvello, F. Picconi, C. Diot, and E. W. Biersack, "Is there life in second life?" in *CoNEXT 2008, 4th ACM International Conference on emerging Networking Experiments and Technologies, December 9, 2008, Madrid, Spain*, Madrid, ESPAGNE, Dec 2008.
- [8] I. Cevizci, M. Erol, and S. F. Oktug, "Analysis of multi-player online game traffic based on self-similarity," in *Proceedings of 5th ACM SIGCOMM workshop on Network and system support for games*, ser. NetGames '06. New York, NY, USA: ACM, 2006. [Online]. Available: <http://doi.acm.org/10.1145/1230040.1230093>
- [9] K.-T. Chen, P. Huang, C.-Y. Huang, and C.-L. Lei, "Game traffic analysis: an mmorpg perspective," in *Proceedings of the international workshop on Network and operating systems support for digital audio and video*, ser. NOSSDAV '05. New York, NY, USA: ACM, 2005, pp. 19–24. [Online]. Available: <http://doi.acm.org/10.1145/1065983.1065988>
- [10] M. Suznjevic, O. Dobrijevic, and M. Matijasevic, "Mmorpg player actions: Network performance, session patterns and latency requirements analysis," *Multimedia Tools Appl.*, vol. 45, pp. 191–214, Oct 2009. [Online]. Available: <http://dl.acm.org/citation.cfm?id=1613012.1613039>
- [11] F. Benevenuto, T. Rodrigues, M. Cha, and V. Almeida, "Characterizing user behavior in online social networks," in *Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference*, ser. IMC '09. New York, NY, USA: ACM, 2009, pp. 49–62. [Online]. Available: <http://doi.acm.org/10.1145/1644893.1644900>
- [12] V. Paxson, "Bro: A system for detecting network intruders in real-time," *Computer Networks*, vol. 31, no. 23–24, 1999.
- [13] R. Pang, V. Paxson, R. Sommer, and L. Peterson, "binpac: A yacc for writing application protocol parsers," in *Proc. ACM Internet Measurement Conference*, 2006, pp. 289–300.
- [14] H. Dreger, A. Feldmann, M. Mai, V. Paxson, and R. Sommer, "Dynamic application-layer protocol analysis for network intrusion detection," in *Proc. Usenix Security Symp.*, 2006.