Traffic Characteristics of a Massively Multi-player Online Role Playing Game

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ABSTRACT

This paper presents traffic measurement of a Massively Multi-player On-line Role Playing Game (MMORPG). This analysis characterizes the MMORPG traffic and shows its implications for future research issues. The target game is 'Lineage II' developed by NCsoft, which is one of the world's largest MMORPGs in terms of the number of concurrent users. We collected about 1 tera bytes of packets for four consecutive days including a weekend. The MMORPG traffic consists of two kinds of packets: client-generated packets and server-generated packets. We observe that the client packet has an average of 19 bytes payload size, while the average payload size of server packets is about 318 bytes. This asymmetry is due to the fact that the server transmits all the information to construct the visual environment for the clients in the same region. Likewise, the bandwidth usage of the server traffic is about ten times larger than that of the client traffic. The analysis of RTT reveals that client packets and server packets are transmitted mostly at the interval of 200 milliseconds due to TCP's delayed ACK. We find that there is a linear relationship between the number of users and the bandwidth usage except when the number of users is around 5000.

Categories and Subject Descriptors

H.4.3 [**Communications Applications**]: Traffic Measurement

General Terms

Measurement

Keywords

MMORPG, 3D, traffic characteristic.

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1. INTRODUCTION

As the Internet grows, a number of new applications are emerging. Online game application is one of the most proliferated ones. Especially, online games among a myriad of users are gaining more and more attention since they not only pose challenging issues on game developers, but also boost up the game industry revenue.

Online games can be categorized as shown in Table 1 in terms of the number of concurrent users and game playing methods [1].

Table 1. Online game categories

Category	Number of concurrent users	Definition
MMORPG	Over 1,000	Game software company manages its server and massively multi players participate in the game.
Network game	1 ~ 40	Run on PCs in LAN environments. A small group of users participate.
Internet game	1	Run normally on web browser. Anybody connected to Internet can play the game.

Massively Multiplayer Online Role Playing Games (MMORPG) are getting popular because of their well structured scenarios and the realization of human interactions such as ally, community, territory, war, and merchandising. They provide spaces for creating virtual human society based on various backgrounds. Counter-strike games are good examples of the network game category. They are usually operating on PCs, and a small group of users participates in the games. Internet games are not so popular partly because interfaces of web browsers provide limited game playing environments.

Among the above online game categories, MMORPG is most bandwidth-intensive due to a large number of participants, which draws our focus on its traffic. In this paper we measure the traffic of 'Lineage II', which is one of the world's largest MMORPGs.

The original ‘Lineage’ is a 2D game and will be called ‘Lineage I’ hereafter. The number of concurrent participants in ‘Lineage I’ exceeds 300 thousands. It has over 2 million registered users around the world. ‘Lineage II’ is the successor of ‘Lineage I’, and it has the features of full-3D graphics, enhanced realization of virtual political and economic systems, and more intuitive interfaces. In Korea, the concurrent number of users who play ‘Lineage II’ has recently exceeded 150 thousands.

‘Lineage II’ is serviced by 30 servers. Our measurements show that bandwidth used by each server ranges between 20 Mbps and 140 Mbps depending on the number of concurrent users. Considering the increasing trend of the volume of MMORPGs traffic, our measurement of ‘Lineage II’ traffic might be a good reference for understanding MMORPG traffic characteristics. We believe that our work will help Internet service providers (ISPs) to provision network resources for MMORPG traffic and game developers to design an MMORPG server in a network efficient fashion.

Each server in ‘Lineage II’ administers its own world (in cyber space); that is, 30 servers correspond to 30 different worlds. To administer its world, the server keeps track of all the clients who are playing in that world. In other words, it deals with data regarding all actions of users such as location movement, cloth change, weapon acquirement and so on. These data with regard to a user will be sent to other users who are in the same region, which is a unit area and constitutes the world.

We measure ‘Lineage II’ traffic for 4 consecutive days including a weekend and the collected data size is about 1 tera bytes. Understanding the characteristics of MMORPG traffic is important for anticipating future demand on game servers and network capacity.

The rest of this paper is organized as follows. In Section 2, we consider the related work on game traffic measurements. Our measurement environments including measuring tools are shown in Section 3. Section 4 details the analysis of the measurements and the conclusion is given in Section 5.

2. RELATED WORK

On-line game traffic measurements are initially done on Counter-Strike games [4][5]. Counter-Strike game is a geographically small network game in which up to 40 game players participate. Counter-Strike games are commonly characterized by short latency, point-to-point communications, and small periodic UDP packets [4]. The average size of client packets is about 80 bytes and that of server packets is 127 bytes. Especially, [5] tries to model inter-arrival times of packets mathematically. However, they measure the traffic in LAN environments, which are dominant. Hence, the influence of the traffic on backbone networks is marginal.

To the best of our knowledge, the first MMORPG traffic measurement is performed on ‘Lineage I’ [2]. About 280 GB of data is traced for 8 days. There are 40 servers for ‘Lineage I’. They measure one of the 40 servers by the software tool, ‘tcpdump’. The metrics measured at server side are packet sizes, inter-arrival times, inter-departure times, and bandwidth usage. The peak number of concurrent users is around 2000, who are located nationwide in Korea.

Recently, K. Chen et al. measured an MMORPG, ‘ShenZhou Online’, serviced in Taiwan [9]. This game is based on 2D environment, which is the same case as ‘Lineage I’. Traffic characteristics are also similar with those of ‘Lineage I’.

3. MEASUREMENT ENVIRONMENT

To measure the ‘Lineage II’ traffic, we deploy our measurement system on the same link as the target server. The measurement system (PC) uses a software tool, ‘tcpdump’. This tool shows timestamp, IP address, port number, payload size, TCP flag of a packet and so on. It is operating on top of ‘Libpcap (Protocol Capture Library)’ and its timestamp resolution is microseconds in our system [6][7]. Figure 1 depicts the measurement setup based on port mirroring. The game server, the measurement system and the switching hub have gigabit Ethernet interfaces.

Our measurement system is LINUX-based and has 2 GB RAM. The system has dual CPU of Intel Xeon with 2.4 Ghz clock speed. Storage capacity of RAID structured hard disk is 1.2 tera bytes.

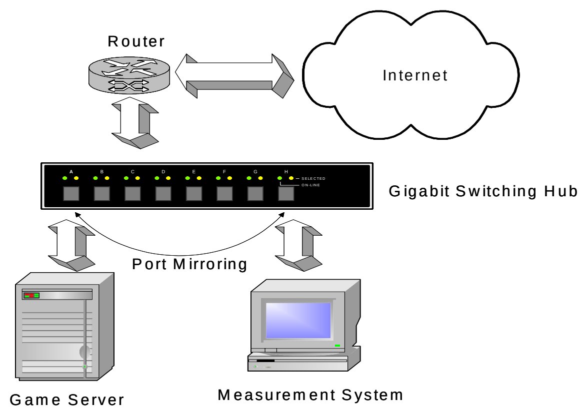

Figure. 1 Schematic of measurement setup.

4. ANALYSIS

We analyze the traffic on two aspects: (a) aggregate traffic and (b) per session traffic. Here, a session is a connection between a client and the server. With the server’s address and port number given, we identify a session by the IP address and port number of a client.

4.1 Aggregate Traffic

4.1.1 Overview

Aggregate statistics of the number of packets are presented in Table 2. About twelve billion packets are traced and 7.7 billion packets of them are data packets. The remaining packets are ACK, SYN, and FIN packets for TCP session control. Note that in the case of upstream packets (generated by clients), 22.9 percent are data packets, while 97.6 percent of downstream packets (generated by the server) are data packets. Most of non-data upstream packets (77.1 percent) are pure ACK packets because each client's TCP should reply with ACK packet on receipt of the server's data packets. Here, the server's data packets are generated by any user's action in the same region. On the downstream side, since the aggregate behavior of multiple users in the same region is frequently changed, the server can almost always reply with data packets (97.6 percent).

Table. 2 Overview of measurement data.

Measurement Period	Thursday 2004.12.9 12:02 PM ~ Monday 2004.12.13 8:24 AM		92 hours and 22 minutes
Captured log generated by 'tcpdump'			About 1 tera bytes
Concurrent Users			2000 ~ 5140
Packet Count	Total Packet Count		12,723,507,137
	Upstream	Total Packet Count	6,288,990,481
		Data Packet Count	1,443,289,225
	Downstream	Total Packet Count	6,434,516,656
		Data Packet Count	6,280,005,461

We trace the number of concurrent users, and each user is identified by the pair of a unique IP address and a port number, as time goes by for 4 days. The target game server is one of 30 servers of 'Lineage II', among which users are evenly distributed and hence total number of concurrent users can be estimated by simple multiplication.

Figure 2 shows the number of concurrent users from Thursday 12:02 PM to Monday 8:24 AM. The number of concurrent users varies between about 2000 and 5000; therefore, the total concurrent users of 30 servers can be estimated between 60,000 and 150,000. We guess that the two down-peaks are due to system or network failure.

4.1.2 Packet Size

We first exclude non-data packets such as ACK, SYN, and FIN packets in our analysis. Here, we count the payload size as the packet size, which means the pure data size without TCP/IP header.

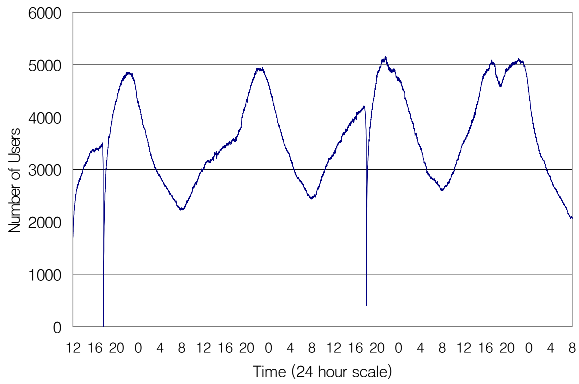

Figure. 2 Number of concurrent users connected to the server.

The average size of upstream packets is 19.06 bytes, which is relatively larger than that of 'Lineage I', 9.03 bytes [2]. This is due to the 3D feature of 'Lineage II' compared to the 2D feature of 'Lineage I'. The size of 19.06 bytes is however still a very small value. As shown in Figure 3, most of the upstream packets are less than a few tens of bytes.

Figure 4 shows the cumulative distribution of the upstream packet size. Half of all client packets are less than 20 bytes and 99 percent of packets are smaller than 50 bytes. However, the maximum TCP/IP packet size (1460 bytes) also exists.

The distribution of the downstream packet size shows a different curve. It is much larger than that of upstream packets. The average size of the downstream packets is 318.39 bytes. This is about 15 times larger than that of the upstream packets and 9 times larger than the downstream packet size of 'Lineage I', 36.74 bytes [2]. Not only the average size is larger but also the distribution of the long downstream packets is denser than that of the long upstream packets. Especially, the portion of 1460 bytes long packets is not marginal; about 5 percent of the total downstream packets are 1460 bytes or maximum transfer unit (MTU). These MTU packets are the result of segmentation over TCP/IP socket interface because some downstream packets have long application data that cannot fit in a single packet.

The increase of the average downstream packet size comes mainly from the 3D feature of 'Lineage II', which features much more personal items, textures (clothes of game character), and login data (user's initial status) than 2D-based 'Lineage I'. In addition, because each downstream data packet includes every user's information in the same visual display region, the downstream packet size increases accordingly.

Figure 6 shows the cumulative distribution of the downstream packet size. In this graph, we also find that the distribution of the downstream packet size shows a different curve from that of the upstream packet size; the slope is relatively gradual and thus reveals heavy-tailed characteristic.

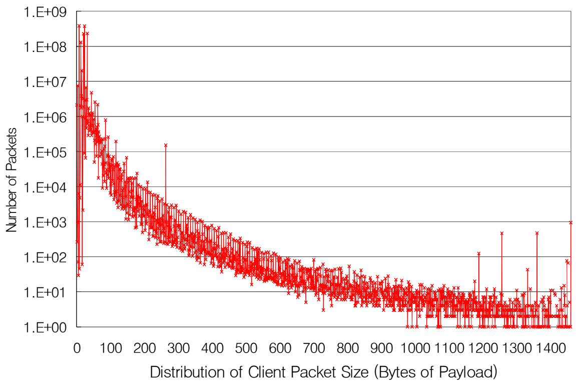

Figure. 3 Distribution of client packet size.

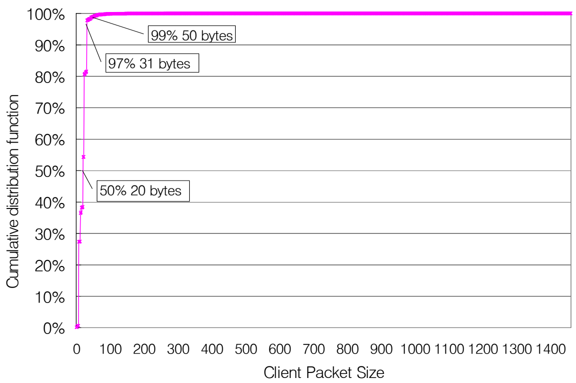

Figure. 4 Cumulative distribution of client packet size.

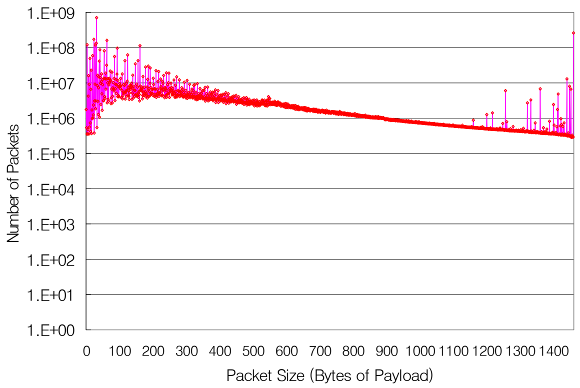

Figure. 5 Distribution of server packet size

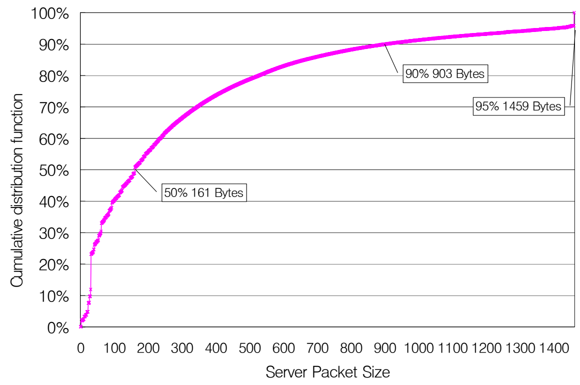

Figure. 6 Cumulative distribution of server packet size.

4.1.3 Packet Inter-arrival Times

The distribution of the aggregate packet inter-arrival time is shown in Figure 7. Aggregate packet inter-arrival times are dependent on the number of concurrent users. Figure 8 shows the relation between the number of concurrent users and packet inter-arrival time, which exhibits the property of inverse proportion whose correlation coefficient is -0.95, very highly reverse-correlated. Total average is 58.08 microseconds.

Figure 9 shows that 99 percent of packets arrive in 270 microseconds, which is far shorter than that of 'Lineage I', 2 milliseconds. This difference is caused by the concurrent user number and game structure. Because 'Lineage I' was measured on a test server, the concurrent user number was between 500 and 1200, but 'Lineage II' is played by 2000 to 5000 concurrent users in our target server. 'Lineage II' sends and receives much more packets for the same action than its predecessor because 'Lineage II' provides 3D gaming environments. For example, in 'Lineage I', a player's position is expressed by 2-dimensional X-Y coordinates but in 'Lineage II' not only 3-dimensional coordinates are needed but also the environment around the user should reflect 3-dimensional viewpoint. Therefore, a simple movement in 'Lineage II' incurs multiple packet transfer carrying information of user locations, environment items, 3D viewpoint, angle, and so on.

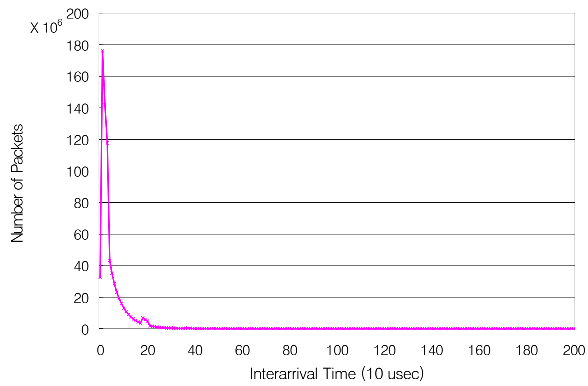

Figure. 7 Distribution of packet inter-arrival time.

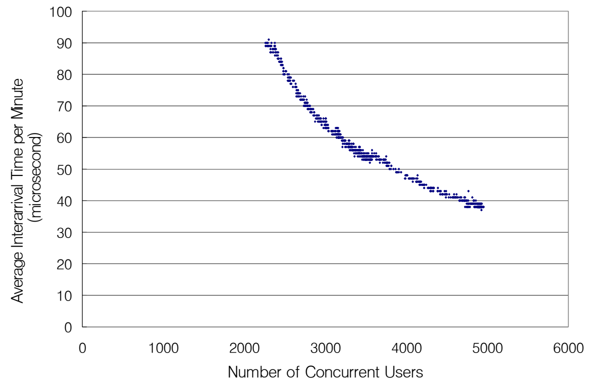

Figure. 8 Number of concurrent users v.s. inter-arrival time .

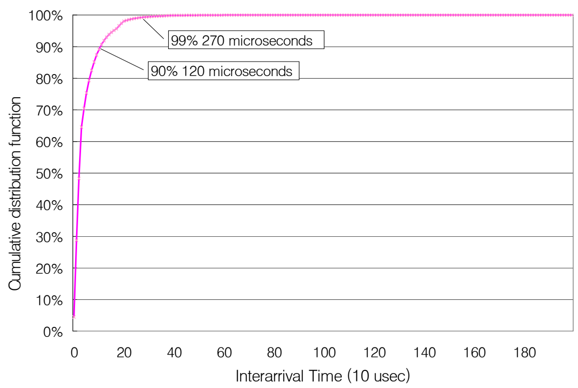

Figure. 9 Cumulative distribution of packet inter-arrival time.

4.1.4 Bandwidth

Trace of bandwidth usage by upstream and downstream packets is shown in Figure 10, which exhibits the diurnal property of 24 hour period. Note that the solid line and the dashed line show the bandwidth used by downstream packets and upstream packets, respectively. During weekdays, the bandwidth oscillates between 20 Mbps and 100 Mbps but on Saturday it soars up to more than 140 Mbps. In Figure 10, we find that the asymmetry between upstream and downstream traffic is substantial; bandwidth of downstream packets is more than 10 times larger than that of upstream packets. This disparity is much bigger than that of ‘Lineage I’, where downstream bandwidth is about 2 times larger than upstream bandwidth. We believe that this asymmetry will be more notable as a server should deliver much more complicated information (e.g. 3D image compared to 2D image). ISPs may be able to utilize this ever increasing asymmetry in provisioning Internet service to game servers.

4.1.5 Number of Users and Bandwidth

The number of the concurrent users is traced in section *4.1.1*, and here we analyze the relation between the number of users and bandwidth usage. Figure 11 plots the bandwidth used by downstream packets versus the number of concurrent users. Figure 12 shows the same relation in the upstream case. These two curves reveal different phenomena; the upstream bandwidth is linearly correlated with the number of concurrent users but the downstream bandwidth shows a little anomaly with the peak number of concurrent users. This anomaly comes from the packet segmentations because more users per region will make the downstream payload size larger than MTU, which incurs more TCP/IP header overhead. Correlation coefficients of Figures 11 and 12 are 0.95 and 0.99, respectively. A high correlation coefficient means that the linear relation is dominating.

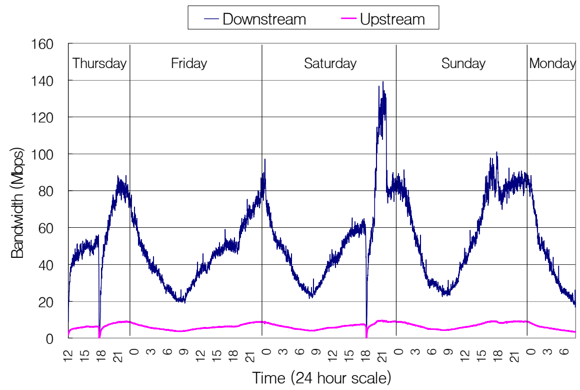

Figure. 10 Trace of bandwidth usage.

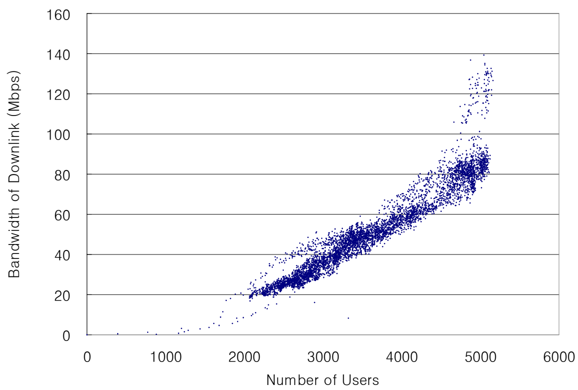

Figure. 11 Correlation between the number of users and downstream bandwidth.

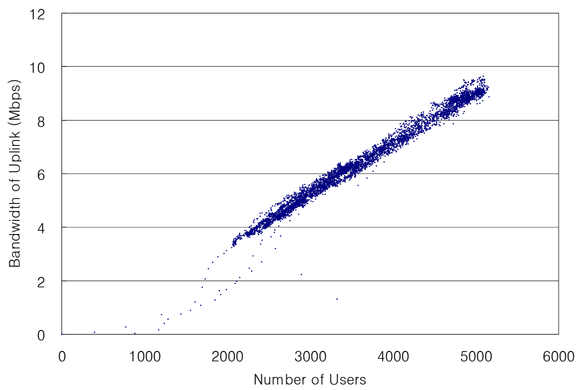

Figure. 12 Correlation between the number of users and upstream bandwidth.

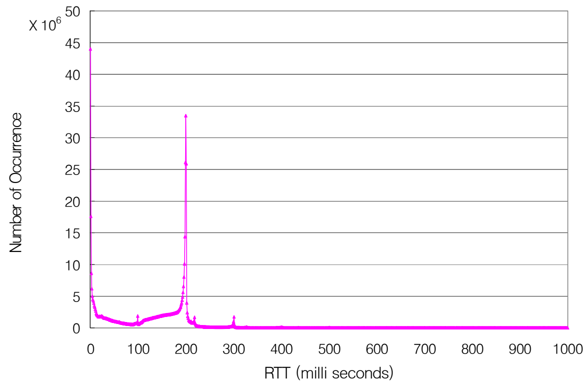

Figure. 13 Round trip times (RTT) of packets in milliseconds scale.

4.1.6 Round Trip Time (RTT)

Round Trip Time (RTT) is analyzed to characterize the server-client connections. Due to the large volume of RTT data, we sample three periods of the total trace, each of which belongs to Thursday 13:00~16:00, Saturday 20:00~22:00, and Sunday 15:00~17:00. As there is no significant difference in those three data sets, we calculated the average of all RTT data in those data sets. The average value of RTTs of these three periods is about 126 milliseconds and Figures 13 shows the distribution of RTTs. Peak points stand at 0 millisecond and around 200 millisecond, and 90 percent of RTTs are distributed less than 200 milliseconds.

Those peak points are related to TCP's delayed ACK mechanism implemented in the Windows TCP/IP stack. 'Lineage II' is running on Windows operating system that adopts the delayed ACK feature [8].

In Figure 13, about 11 percent of analyzed RTTs are less than 1 millisecond and about 15 percent fall within 200±1 milliseconds. Note that the default delayed ACK value in Windows TCP protocol stack is 200 milliseconds. That is, in normal cases, about 11 percent of sent packets from the server are acknowledged almost instantly but if the client has no data packet for piggybacking the ACK, it waits until delayed ACK timer expires (200 milliseconds). If shorter RTT is needed for game's real time interactivity, then the 'Lineage II' client software may have to turn off the delayed ACK feature.

4.2 Per Session Traffic

4.2.1 Packet Inter-arrival Time within Sessions

We identify a session by the pair of client's IP address and port number and select three sampling periods due to the large volume: two and half hours on Thursday, four hours on Friday, and two hours on Saturday. Each period represents weekday peak time, weekday not busy time, and weekend peak time, respectively.

We find no substantial difference between the distributions of packet inter-arrival times per session of each period and Figure 14 shows the distribution of packet inter-arrival times per session of those sampling periods. In the graph, we observe that high density probability around the 200 millisecond which is also found in RTT analysis (Section *4.1.6*). This phenomenon is due to TCP's delayed ACK mechanism in Windows operating system of clients' computers.

The average inter-arrival time of each period is 180.41 milliseconds, 191.98 milliseconds, and 174.87 milliseconds, respectively. As expected, these average values show that busy periods have shorter inter-arrival time and vice versa, but the difference is marginal. The average inter-arrival time of total samples is 182.24 milliseconds, which means about 5.5 packets per second are transmitted to the server from each client.

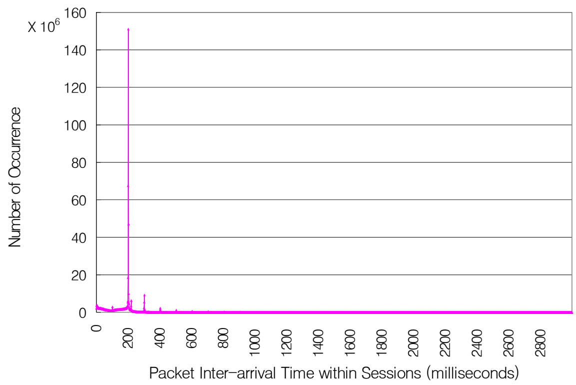

Figure. 14 Packet inter-arrival time within sessions.

4.2.2 Session Inter-arrival Time

Figure 15 shows the distribution of session inter-arrival times whose average value is 401.77 milliseconds. At peak time about 2.5 new sessions arrive every second, which sets up about 9000 new sessions per hour.

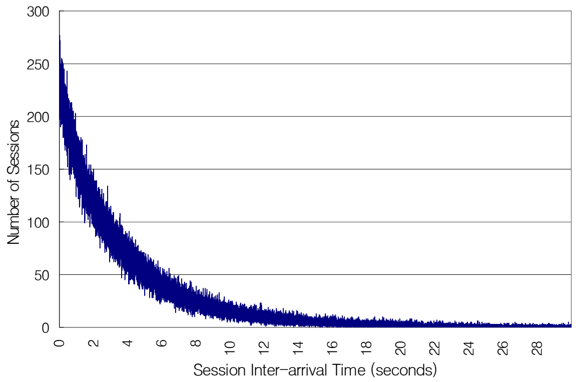

Figure. 15 Distribution of session inter-arrival time.

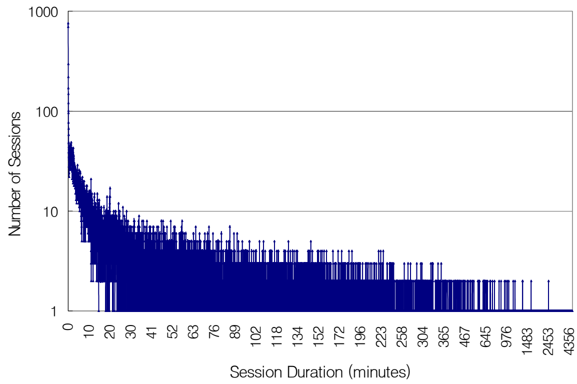

Figure. 16 Distribution of session duration.

4.2.3 Session Duration

A session duration means how long a user keeps on playing 'Lineage II'. We measure a session duration by tracking the pair of TCP SYN-FIN packets of the same client. The number of total identified sessions is 39858 when we exclude sessions with less than 1 second duration.

The average value of session durations is 183 minutes, which is much longer than that of 'Lineage I', 50 minutes. Though the average is about 3 hours, Figure 17 shows that 50 percent of total sessions last less than 26 minutes and 80 percent last less than 156 minutes. Thus the distribution of session durations exhibits heavy-tailed characteristics. It means that some addicted users are connected to the game for a very long time; there are even a few users who play more than 80 hours during our measurement period.

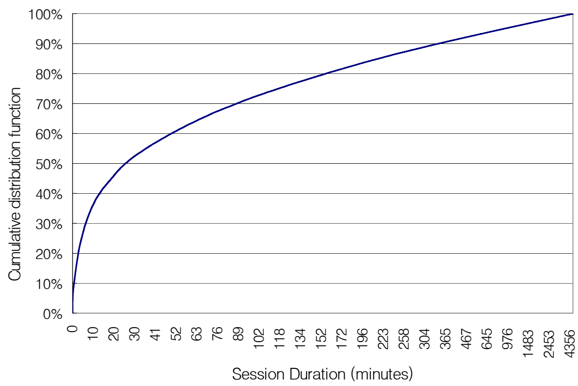

Figure. 17 Cumulative distribution of session duration.

4.3 Discussion

The most significant feature of 3D-based MMORPG is asymmetry between upstream and downstream traffic in terms of packet size distribution, the ratio of the number of data packets to total number of packets, and bandwidth usage.

Table. 3 Asymmetry between upstream and downstream traffic.

	Upstream	Downstream
Average Packet Size of Payload	19.06 Bytes	318.39 Bytes
Ratio of data packets	22.9 %	97.6 %
Bandwidth	Up to 9 Mbps	Up to 140 Mbps

Table 3 summarizes this asymmetry. ISPs who provide Internet service to MMORPG game servers can utilize these characteristics for efficient resource provisioning. For example, asymmetric bandwidth allocation between upstream and downstream traffic may be an efficient network solution.

The relation between the number of concurrent users and bandwidth usage is highly correlated, which is linear. As the numbers of MMORPG games and users are expected to ever increase, backbone networks and/or access networks should be designed by taking into account the traffic characteristics analyzed in this paper. RTTs and packet inter-arrival times per session are affected by TCP's delayed ACK mechanism.

Considering today's MMORPG interactivity requirements, 200 milliseconds is not unbearable. However, next generation MMORPGs may require faster response time, which will require that RTTs and packet inter-arrival times per session be reduced. Therefore, TCP delayed ACK may have to be modified.

5. CONCLUSION

On-line games in the Internet are getting popular, and, game traffic is increasing on the Internet at rapid pace. Especially, MMORPG is characterized by a large number of concurrent participants and its upstream-downstream traffic asymmetry. We measured and analyzed the traffic of 'Lineage II', which is one of the world's largest MMORPGs in terms of the number of concurrent users.

Our analysis is performed on two bases: (a) aggregate traffic and (b) per session traffic. The aggregate traffic characteristics show that there is a significant asymmetry between upstream and downstream traffic. The average packet size of downstream was about 15 times larger than that of upstream. While the ratio of data packets of downstream traffic is 97.6 %, that of upstream is 22.9 %. The bandwidth usage of upstream and downstream traffic also shows a large gap, i.e. 10 times. This asymmetry should be taken into account in two aspects. Game developers should design a game server considering this asymmetry; for example, mitigating traffic burden by optimizing downstream data packet size. ISPs can efficiently provision network resources to game servers; for example, allocating more bandwidth to downstream traffic.

The correlation between the number of users and bandwidth usage shows strong linearity. However, on peak time, downstream packets are segmented because more users per region make the downstream payload size larger than MTU, which incurs more TCP/IP header overhead. This phenomenon makes a small anomaly in the linear relation between the number of users and bandwidth usage. For per session traffic, we analyzed RTTs and packet inter-arrival times per session, which are characterized by TCP delayed ACK, 200 milliseconds. If faster response time is required by MMORPGs, the delayed ACK timer should be reduced. The distribution of session durations exhibits heavy-tailed characteristics, which should be taken into account by game server architects. There are even users who played more than 80 hours nonstop. Eighty percent of the users play less than two and half hours.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] White Paper, *The Rise of Korean Games*, Korea Game Development & Promotion Institute (KGDI), 2004, http://www.gameinfinity.or.kr/en/sub2_1_04.php .

[2] Kim, J., Hong, E., and Choi, Y. Measurement and Analysis of a Massively Multiplayer Online Role Playing Game Traffic, In *Proceedings of Advanced Network Conference (Network Research Workshop)*, Busan, Korea, August, 2003.

[3] Yu, S., Designing Fast-Action Games For The Internet, In *proceedings of Gamasutra*, Sep. 5, 1997.

[4] Feng, W. et al. Provisioning On-line Games: A Traffic Analysis of a Busy Counter-Strike Server, In *proceedings of IMW2002*, 2002.

[5] Farber, J. Network Game Traffic Modelling, In *prodeedings of NetGames2002*, April, 2002.

[6] Jacobson, V., Leres, C., and McCanne, S. *The pcap(3) Manual Page*. Lawrence Berkeley Laboratory, Berkeley, CA, October 1997.

[7] McCanne, S. and Jacobson., V. The BSD packet filter: A new architecture for user-level packet capture. In *Proceedings of the 1993 Winter USENIX Technical Conference*, San Diego, CA, January 1993. USENIX.

[8] Fout, T. and Shelest, A. *Common Performance Issues in Network Applications*, http://msdn.microsoft.com/library/default.asp?url=/library/en-us/dnwxp/html/comperfnetapppt1.asp .

[9] Chen, K., Huang, P., Huang, C. and Lei, C. Game Traffic Analysis: An MMORPG Perspective, In *proceeding of NOSDAV'05*, June, 2005.