Traffic Comparison of a Series of MMORPGs

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Abstract

This paper measures and compares the traffic of a series of Massively Multiplayer On-line Role Playing Games (MMORPG). The target games are 'Lineage' and 'Lineage II' developed by NCsoft, which are ones of the world's largest MMORPGs in terms of the number of concurrent users. We collected about 1 tera bytes of packets of 'Lineage II' for four days including a weekend. These packets are analyzed and compared with those of 'Lineage.' Packet size, packet inter-arrival time, and bandwidth usage are compared. The traffic of the two games shows much difference because original 'Lineage' is a kind of 2-D based MMORPG, while 'Lineage II' is 3-D based. By comparing the characteristics of the traffic of these games, we can anticipate future needs of network and game structure.

1. Introduction

As the Internet grows, a number of new applications are emerging. Online game application is one of the most proliferated ones, and is gaining more and more attention since it not only poses challenging issues on game developers, but also boosts up the game industry revenue.

Among many kinds of online games, 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.

Especially, MMORPG is 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 3D graphics, enhanced realization of 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. We measure 'Lineage II' traffic for 4 consecutive days including a weekend and the collected data size is about 1 tera bytes. The traffic of 'Lineage I' was measured, two years earlier than 'Lineage II' [2].

Our measurements show that bandwidth used by each 'Lineage II' server ranges between 20 Mbps and

140 Mbps depending on the number of concurrent users. Considering the increasing trend of MMORPGs and their traffic, our measurement of 'Lineage I' and 'Lineage II' traffic will be a good basis 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.

2. Measurement Environment

To measure the traffic, we deploy our measurement system on the same link as the target server. Our measurement methodology is the same in both the case of 'Lineage I' and 'Lineage II.' 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 method based on port mirroring. The game server, the measurement system and the switching hub have gigabit Ethernet interfaces.

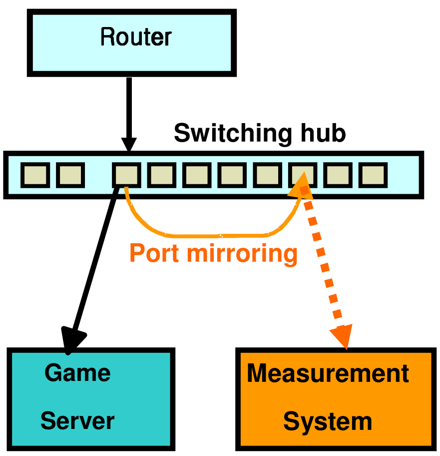

Figure 1 Schematic of measurement method

Our measurement system is LINUX-based and has 2 GB RAM. Our 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.

3. Analysis

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

3.1 Aggregate Traffic

3.1.1 Overview

Aggregate statistics of the number of packets are presented in Table 1. 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 of total upstream packets 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 %) are pure ACK packets because each client should reply with ACK packets 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 %).

Table 1 Overview of 'Lineage II' 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		About 1 tera bytes

generated by 'tcpdump'			
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, each of which 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,' whose users are evenly distributed among those servers 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, so 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.

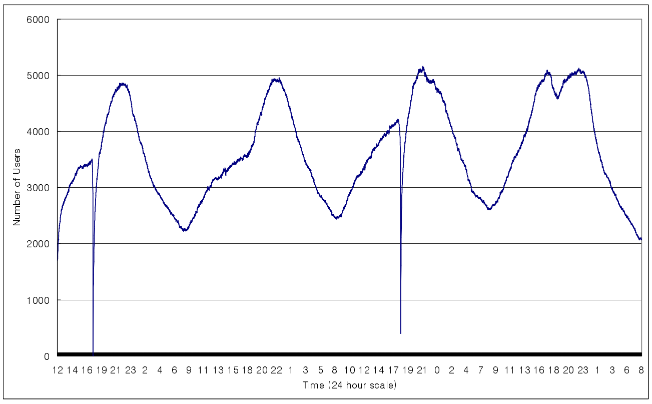

Figure 2 Number of concurrent users connected to the server

3.1.2 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. The average size of upstream packets is 19.06 bytes, which is relatively larger 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 is shown in Figure 3, most of the upstream packets are less than a few tens of bytes.

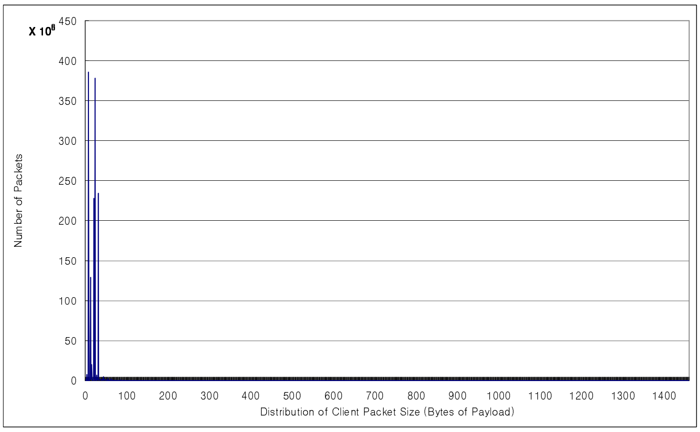

Figure 3 Distribution of client packet size

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.

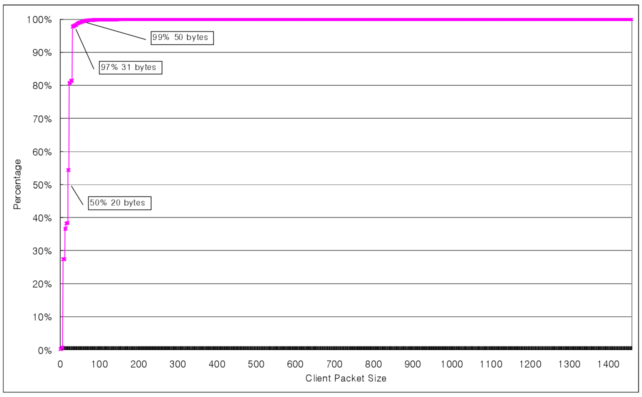

Figure 4 Cumulative distribution of client packet size

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]. The peak value stands at 31 bytes. 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 distribution of packets 1460 bytes long 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 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 incurs 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, 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 slow and thus reveals heavy-tailed characteristics.

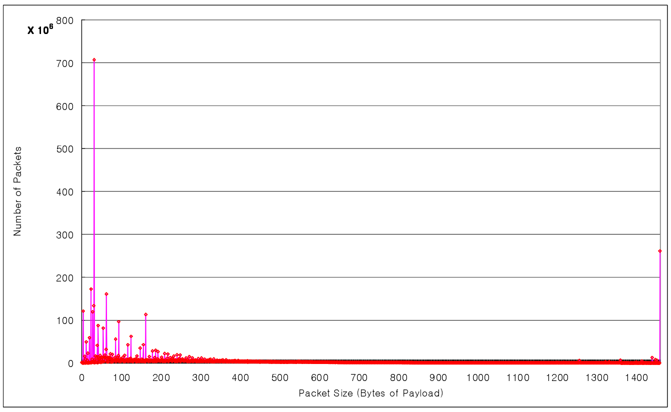

Figure 5 Distribution of downstream packet size

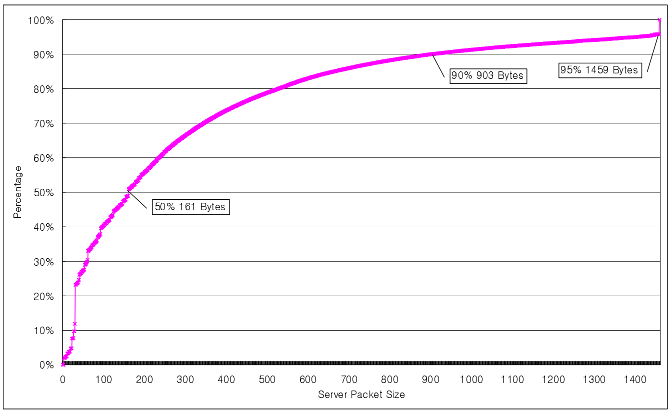

Figure 6 Cumulative distribution of the downstream packet size

3.1.3 Bandwidth

Trace of bandwidth usage by upstream and downstream packets is shown in Figure 7, which exhibits high periodicity of 24 hour intervals. 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 more than 140 Mbps.

In Figure 7, 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 for Internet service to game servers.

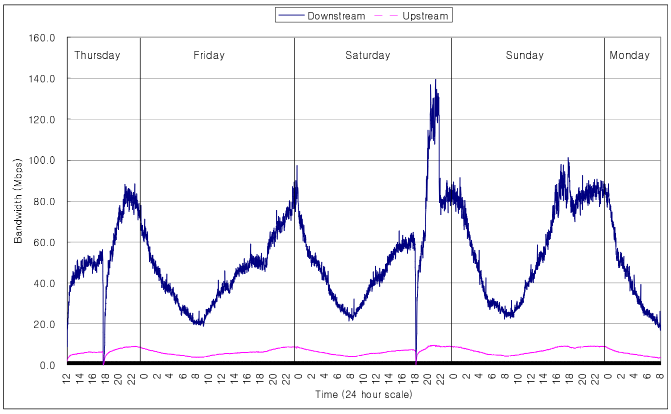

Figure 7 Trace of bandwidth usage

3.1.4 Number of Users and Bandwidth

The number of the concurrent users is traced in 3.1.1, and here we analyze the relation between the number of users and bandwidth usage. Figure 8 plots the bandwidth used by downstream packets versus the number of concurrent users. Figure 9 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 10 and 11 are 0.95 and 0.99, respectively. A high correlation coefficient means that the linear relation is dominating.

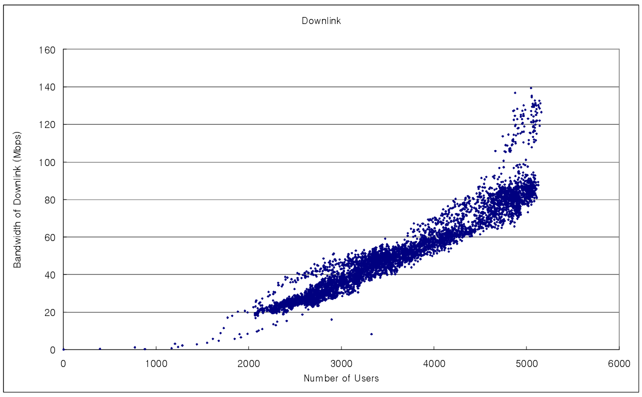

Figure 8 Correlation between the number of users and downstream bandwidth

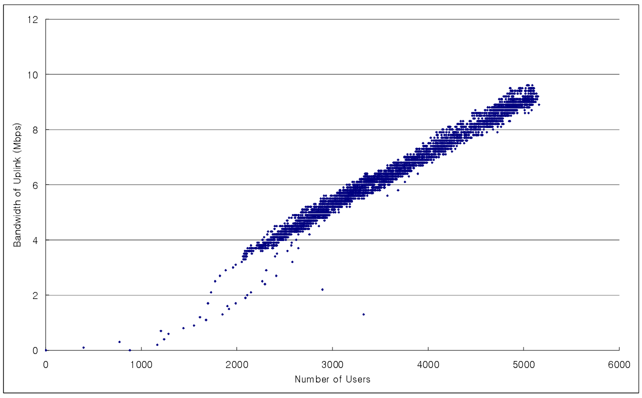

Figure 9 Correlation between the number of users and upstream bandwidth

3.1.5 Round Trip Time (RTT)

Roud 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 10 shows the distribution of RTTs.

Peak points stand at 0 millisecond and around 200 millisecond, and 90 % of RTTs are distributed less than 200 milliseconds. Those peak points are related to TCP 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 12, about 11% of analyzed RTTs are less than 1 millisecond and about 15% 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 % of sent packets from the server are acknowledged almost instantly but if the client has no data packet for piggybacking the ACK until delayed ACK timer expires (200 milliseconds). If shorter RTT is needed for game real time interactivity, then the 'Lineage II' client software may have to turn off the delayed ACK feature.

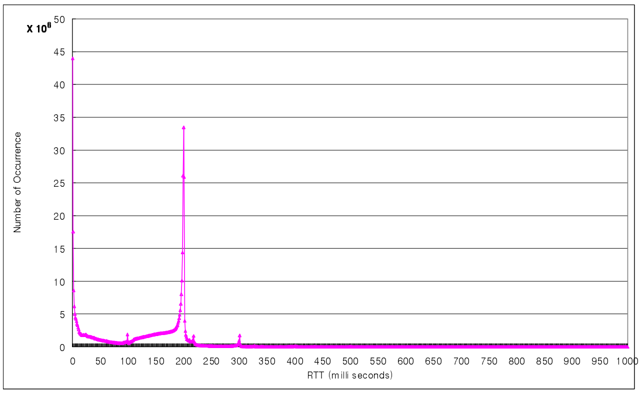

Figure 10 Round trip times (RTT) of packets in milliseconds scale

3.2 Per Session Analysis

3.2.1 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 the three periods and Figure 11 shows the distribution of packet inter-arrival times within a 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 D.1.6). This phenomenon is due to TCP 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.

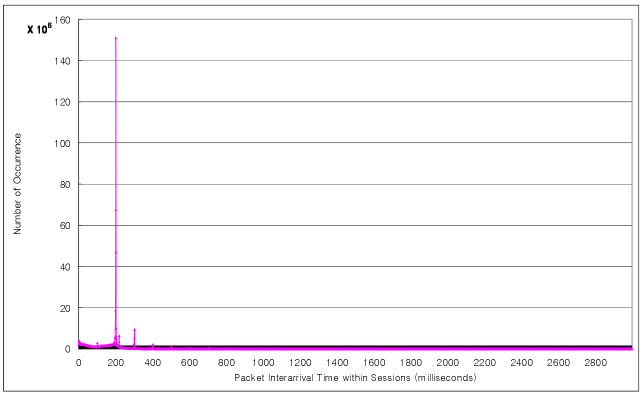

Figure 11 Packet inter-arrival time within sessions

3.2.2 Session Inter-arrival Time

Figure 12 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 make up about 9000 new sessions per hour.

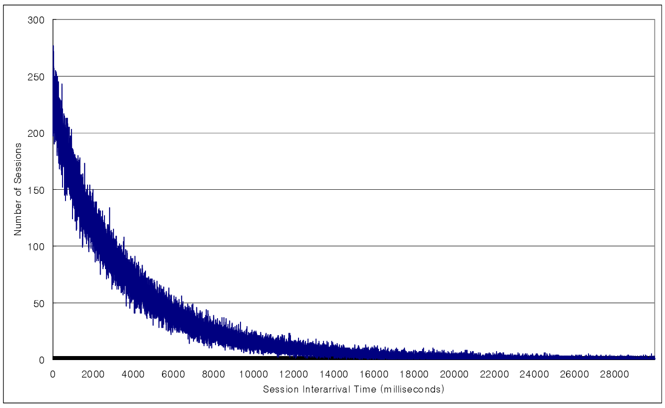

Figure 12 Distribution of session inter-arrival time

3.2.3 Session Duration

Session duration is how long a user will play 'Lineage II'. We measure 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 13 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 for a very long time; there are even a few users who play more than 80 hours during our measurement period.

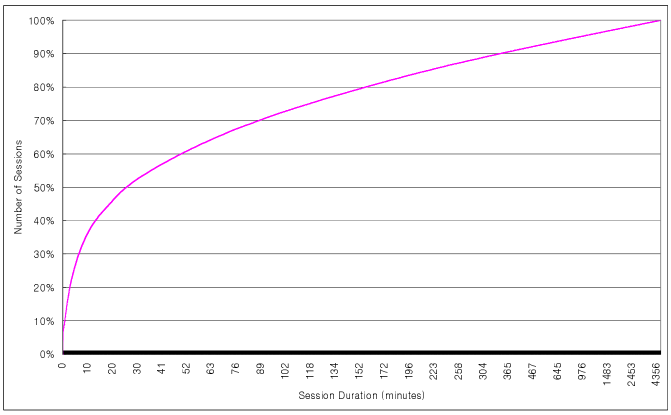

Figure 13 Cumulative distribution of session duration

3.3 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 2 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.

Table 2 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

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 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.

4. Conclusion

On-line games in the Internet are getting more and more popular, which imposes ever increasing game traffic on the Internet. 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 in 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, 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. Eighty percent of the users play less than two and half hours.

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