# Study the Traffic Difference of Online Games Between GPRS/EGPRS and ADSL Networks

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**Abstract** - From network point of view, accurate traffic analysis of the online games is proved useful in the design of mechanisms for media access, resource management, admission control, etc. Furthermore, from application point of view, in order to properly design and evaluate performance of the online games, accurate traffic models are also highly required. Therefore, in this paper we focus on performance analysis and traffic modeling of the Massive Multiplayer Online Role Playing Game (MMORPG) in the presence of different access networks which include GPRS/EGPRS and ADSL. Our results show that being affected by network bandwidth and delay parameters, the statistic characteristics of the online game traffic behave differently in these heterogenous access networks, leading to different game performance and player experience.

## I. INTRODUCTION

Recently the global explosion of multiplayer online gaming has made it more important to investigate the network behavior and game performance in order to provide better networking supports. Among all the games in the world, the group loosely classified as "Massive Multiplayer Online Role Playing Games" (MMORPGs for short) has the most unexplored potential and gets a very quick increasing especially in Asia during these years [1]. MMORPGs are large-scale interactive online games, which aim to support a very large number of clients. Practically, MMORPG providers are often required to support tens of thousands of geographically distributed users simultaneously [2][3]. In this respect, the data traffic generated between the game server and the clients would impact the network behavior greatly because of the large number of online players.

With the fast development of wireless networks, the wired Internet has been expanded to more and more wireless clients, e.g. cell phones or wireless LAN. When playing games over a cell phone through the wireless Internet, most players have to tolerate problems of high latency and low bandwidth which are mainly caused by the wireless link nature. Therefore, to evaluate the online game performance in mobile environment and to understand different traffic behaviors in wired and wireless access networks are very practical and significant.

In the past, several network traffic models have been developed for different kind of multiplayer games. In [4] and [5], the traffic characterizations of the popular multi-player FPS (First Person Shoot) game *Quake* and *Counter Strike* are presented and analyzed. The game traffic is modeled by a special Extreme Value distribution both on the server end and the client end. Zander *et al.* [6] also use the Extreme Value distribution to fit the traffic for the *Xbox Game Halo*. In [7] the Gamma and Uniform distributions are used to model the Action and Strategy Internet-Games traffic. Feng *et al.*[8] analyze a 500-million-packet trace of a busy *Counter Strike* server. Their analysis shows that the network game traffic is highly predictable with periodic bursts of small packets. Chen *et al.* [9] have studied the traces of a typical TCP-based MMORPG captured in LAN, which is, so far as we know, the first formal analysis on MMORPG traffic.

This paper focuses on traffic analysis and modeling of the Massive Multiplayer Online Role Playing Game (MMORPG) in GPRS (General Packet Radio Service), EGPRS (Enhanced General Packet Radio Service) and ADSL (Asynchronous Digital Subscriber Line) access networks. The players access to the public game server in the Internet through different access networks, so that the impacts of various access network conditions on the online game traffic can be evaluated. In particular, we would like to find invariants of network gaming traffic, i.e. statistical characteristics of how a gaming client and a gaming server generate network traffic that can be parameterized for analysis and simulation. The traffic characteristics of the online game in different access networks are analyzed and modeled for better understanding of the MMORPG behavior. To the best of the authors' knowledge, there is no previous work on analysis and model comparison of the online game traffic in various wired and wireless access networks.

The rest of this paper is organized as follows. In Section II, the measurement environment and the method of data collection of our work are introduced. In Section III, the characteristics of game server-generated and client-generated traffic are analyzed respectively. In Section IV, source models for the network game traffic are derived. Finally, conclusions are presented in Section V.

## II. ENVIRONMENT SETUP AND GAME DATA COLLECTION

MMORPG, the abbreviation of Massive Multi-user Online Role Play Gaming, is a kind of online game, which means that players must have network connection to the game server in order to play games [2]. MMORPG enables players to live


Fig. 1. A screen shot of the game *World of Legend*

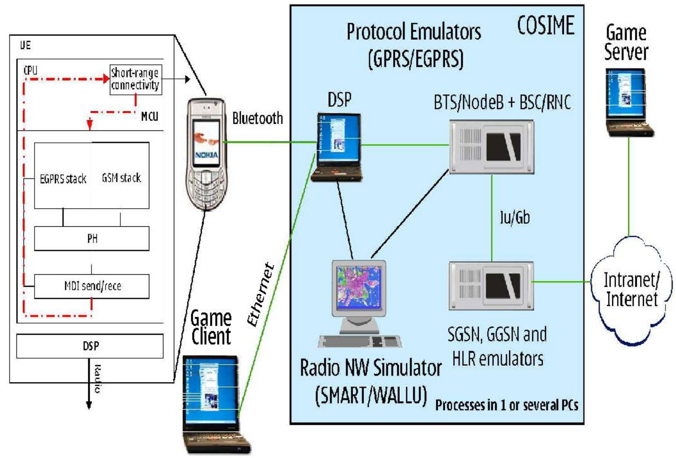


Fig. 2. Testbed illustration of the wireless emulator COSIME

TABLE I
TRAFFIC CHARACTERISTICS OF THE NETWORK GAME

| Item | Throughput (payload) | | RTT |
|---|---|---|---|
| | Server-generated | Client-generated | (Round Trip Time) |
| GPRS | 664 bit/s | 152 bit/s | 829.6 ms |
| EGPRS | 1336 bit/s | 168 bit/s | 442.8 ms |
| ADSL | 1448 bit/s | 200 bit/s | 53.9 ms |

and communicate in a virtual world. Players can act any roles that he/she wants. One could cooperate or fight with others to achieve targets. With growing of the virtual role, every player creates his/her own story/history in the virtual world. It enables players to try and to enjoy the lives that people could not try in the real world. It brings people interactive entertainment and achievement at the same time.

Logically, the whole game system includes game server, game client and the network that connects server and client. The game server is designed to support massive players playing games simultaneously. It accepts players' login/logout requests, receives user's actions, processes them and sends back the results. The game server also sends update messages to all relevant game clients with game progress. The game client is the software installed on player's game terminal. It provides the game voice/graphic/control interface to player and keeps communication with the game server. A game terminal might be a PC or laptop or cell phone whatever. The network is responsible for connecting game server and game client. It may vary from wire broadband (e.g. Ethernet, ADSL, etc.) to wireless narrow band (e.g. GPRS, CDMA 1x, EGPRS, etc.).

In this paper, we select one of the most popular MMORPG games in China - *World of Legend* from Shanda Networking, for our traffic measurement. It is reported [10] that the peak number of simultaneous online players of the *World of Legend* has reached 600,000 by August 2005. A screen shot of the *World of Legend* is shown in Fig.1. This is a very typical MMORPG in which the players can engage fights, chats and any other activities in the game world. Practically, since such kind of "role playing game" has large capability of supporting massively distributed online players, to investigate the impact of access network conditions on the game traffic is necessary and significant.

In our measurement environment, the game client is connected to the public game server through three different access networks: GPRS, EGPRS and ADSL. In the case of wired access network, an ADSL link with the maximum rate of 512Kbps is employed between the game client and server. In the case of wireless access network, the GPRS/EGPRS environments are emulated by a testbed of the Combined SIMulator and Emulator (COSIME) which is developed by Nokia. COSIME provides Linux based end-to-end testbeds for wireless cellular systems by combining the existing radio network simulators and protocol emulators in such a way that the best functionalities of each component will be utilized. It provides real world like conditions for different purposes in a desktop environment and offers predefined scenarios to make sure that the application behaves in a desired way in different radio conditions. The network topology of the testbed is shown in Fig.2, where the game client accesses to the public game server through the COSIME testbed which emulates the network conditions of GPRS/EGPRS. In the configuration of GPRS, the downlink/uplink channel of the game client occupies 3/1 timeslots with CS2 coding scheme [11] corresponding to an average bandwidth of about 36Kbps/12Kbps. In the configuration of EGPRS, the downlink/uplink channel of the game client occupies 3/1 timeslots with MCS5 coding scheme [11] corresponding to an average bandwidth of about 67.2Kbps/22.4Kbps. In the COSIME testbed, the game client is set to be moving within a cell at a speed of 10km/h and no handover scenario is included.

In order to get the general traffic characteristic of the online

TABLE II
STATISTICS OF THE GAME TRAFFIC

| Item | | Server-generated traffic | | Client-generated traffic | |
|---|---|---|---|---|---|
| | | Interarrival Time ($T_{IAT}$) | Packet Length ($L$) | Interarrival Time ($T_{IAT}$) | Packet Length ($L$) |
| GPRS | mean | 0.649 seconds | 102.75 bytes | 0.910 seconds | 18.96 bytes |
| | stdev | 0.663 seconds | 127.69 bytes | 1.208 seconds | 7.87 bytes |
| EGPRS | mean | 0.515 seconds | 87.52 bytes | 0.872 seconds | 19.61 (bytes) |
| | stdev | 0.706 seconds | 104.20 bytes | 1.536 seconds | 8.46 bytes |
| ADSL | mean | 0.317 seconds | 47.53 bytes | 0.787 seconds | 19.28 bytes |
| | stdev | 0.349 seconds | 63.23 bytes | 0.842 seconds | 12.27 bytes |

game, we have captured enough traffic traces on these selected access networks playing at different time during the months of May and June 2005. Volunteer players participated in this game data collection process with different access networks: the emulated GPRS/EGPRS networks or the real ADSL. As the playing continued, the sniffer program captured all the game data packets transmitted in the access link.

## III. TRAFFIC ANALYSIS

As most of the MMORPG games in China, the *World of Legend* uses TCP for reliable data transmission. The observed game traffic still follows the transmit cycle described in [4] and [5]: the server sends game state information to each client where packets are read and processed; the clients synchronize the server game state with their local game states, process player commands and return update packets with the players action and status information.

In our traffic measurement and analysis, we only focus on the particular packet stream between an individual client and the game server. The total traffic generated by game server can be separated into different streams belonging to different players because currently the broadcasting technique has not been applied in online games. Table I enumerates the average TCP throughput and round trip time (RTT) measured in three access networks. In this table the presented throughput only considers data payload excluding all protocol overheads. It is noted that even if all the overheads of packet headers are counted, the overall throughput of the server-generated traffic is still kept below 8Kbps in the ADSL access network with the most satisfactory performance. Therefore, the average bandwidth requirement per client of the MMORPG is low enough for mobile networks which generally agrees with findings in [9]. However, our results show that the transmission delay caused by the wireless cellular network (GPRS or EGPRS) leads to a long round trip time for game data transmission. Although the EGPRS network has achieved high enough data transmission rates by introducing new modulation techniques and new channel coding schemes, the long round trip delay still exists compared with that of the ADSL network (442.8ms vs. 53.9ms). Practically, this observed long delay will deteriorate the game performance very much. For example, during the game traffic test the players accessing through GPRS network often suffered a terrible lagging experience because of such kind of transmission delay.

Denoting by $T_{IAT}$ the packet interarrival time and by $L$ the packet length, Table II lists the statistics (mean and standard deviation) of the measured game traffic in different networks. Similar with the definition of throughput in this paper, here the packet length $L$ only contains the length of the data payload excluding all protocol overheads. The results have revealed the obvious asymmetry between the downlink and uplink traffic: larger packet length with smaller packet interarrival time for server-generated traffic. This can be roughly explained by the fact that the client-generated traffic mainly depends on individual player's behavior, while the server-generated traffic is affected by more factors of the holistic game state and information of other relative players.

When we are talking about the packet interarrival time and packet length in the discussion above, we have excluded all the pure TCP ACK packets. Actually, the observed traces have shown that in such kind of TCP-based game traffic, the influence of ACK packets is not negligible. In the traces of server-generated traffic about 20% of packets are pure TCP ACKs, while in the traces of client-generated traffic about 60% of packets are pure TCP ACKs. Disabling the delayed ACK option and frequent information updates between server and client are the major causes of this high ratio of pure ACKs. Therefore in the resource-limited mobile networks, how to improve the communication efficiency is a very important issue for further investigation.

### A. *Server-generated traffic*

Fig.3 and Fig.4 show the measured cumulative distribution function (CDF) curves of packet interarrival time and packet data length from server to client in the three access networks, respectively. Since most of the data traffic exists in the downlink direction from server to client, the packet interarrival time of the server-generated traffic is one of the key traffic

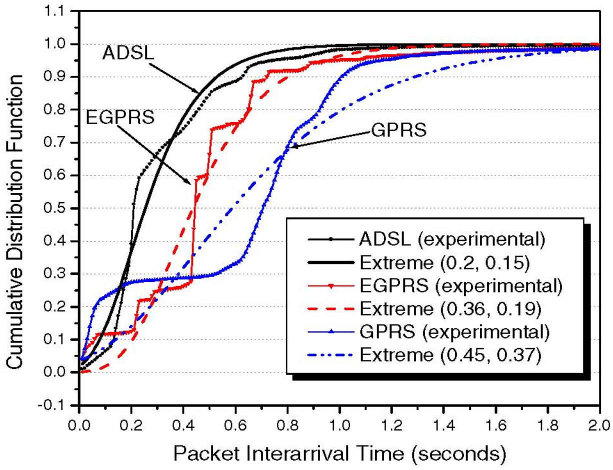


Fig. 3. Cumulative distribution function of packet interarrival time for server-generated traffic

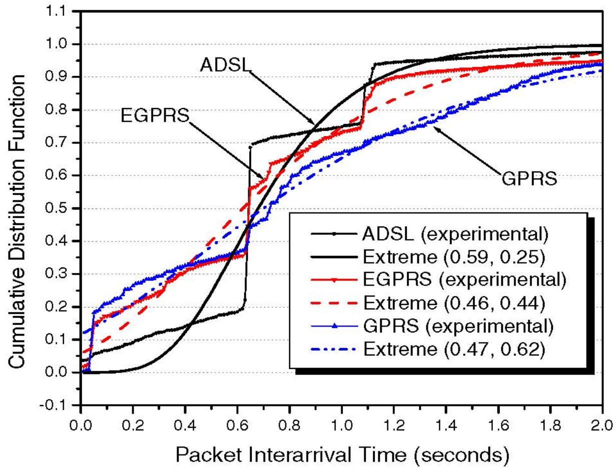


Fig. 5. Cumulative distribution function of packet interarrival time for client-generated traffic

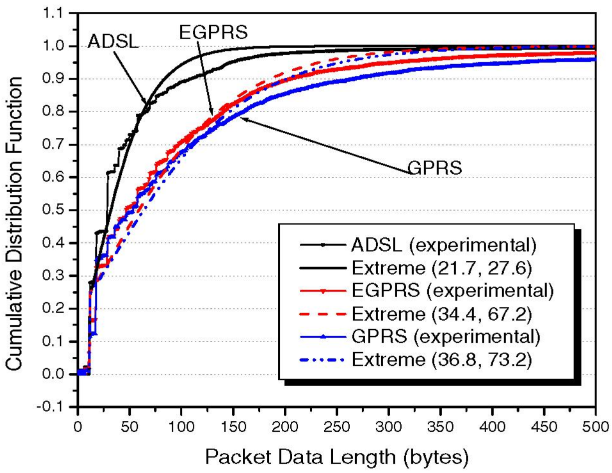


Fig. 4. Cumulative distribution function of packet data length for server-generated traffic

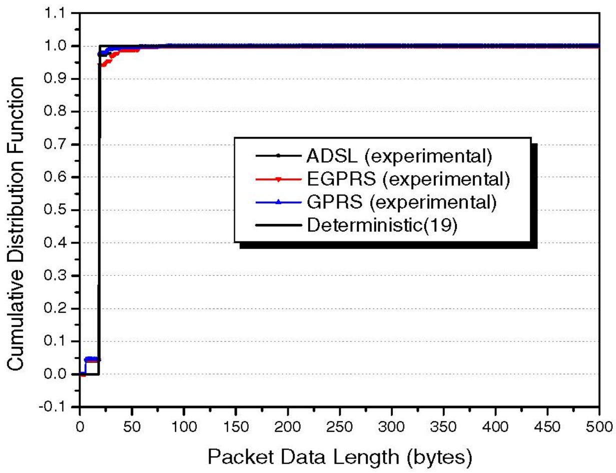


Fig. 6. Cumulative distribution function of packet data length for client-generated traffic

parameters which plays an important role in game performance. From the results of Fig.3, it is verified that the traffic statistics of the online game varies greatly with link conditions of the access networks. Practically the packet interarrival time is expanded with increasing end-to-end delay and diminishing link bandwidth of the access networks. From the point of view of the end-user, the increasing of packet interarrival time corresponds to performance deterioration of the network game: the responds from the game server become slower. Therefore, the wireless game designers need to consider more about processes of content generation and delay control from the application level in order to get a better support for the mobile networks.

Because the game contents which need to be transmitted has been determined by the game application layer, the statistics of packet length would have a tight relationship with that of the packet interarrival time in different access networks. Since the larger packet interarrival time means the smaller sending frequency of the game data, the packet length in each transmission turns to be larger in the mobile access networks. Therefore, as observed in Fig.4, the packet length of the server-generated traffic in GPRS/EGPRS networks is much larger than that in ADSL network.

The results have revealed that the traffic statistics of server-generated packets vary depending on the access network conditions which lead to different game performance and player experience. According to the results in Table II and Fig.3, 4, the *World of Legend* game in EGPRS access network has a relatively intermediate performance between that in ADSL and GPRS access networks. Actually from the point of view of user experience, the practical feeling of game playing in EGPRS is acceptable. It was reported that the detected performance difference between ADSL and EGPRS access networks is slight during our test.

TABLE III
MATHEMATIC APPROACH TO CUMULATIVE DISTRIBUTION FUNCTIONS FOR THE GAME TRAFFIC STATISTICS

| Item | Server traffic(per client) | | Client traffic | |
|---|---|---|---|---|
| | $T_{IAT}$ (sec) | $L$ (bytes) | $T_{IAT}$ (sec) | $L$ (bytes) |
| GPRS | Extreme(a=0.45, b=0.37) | Extreme(a=36.8, b=73.2) | Extreme(a=0.47, b=0.62) | Deterministic (19) |
| EGPRS | Extreme(a=0.36, b=0.19) | Extreme(a=34.4, b=67.2) | Extreme(a=0.46, b=0.44) | Deterministic (19) |
| ADSL | Extreme(a=0.2, b=0.15) | Extreme(a=21.7, b=27.6) | Extreme(a=0.59, b=0.25) | Deterministic (19) |

### B. Client-generated traffic

Fig.5 and Fig.6 show the obtained cumulative distribution function (CDF) curves of packet interarrival time and packet data length from client to server, respectively. As most of the massive multiplayer online games, the client-generated traffic is much simpler compared with the server-generated traffic because of the game communication requirements. Furthermore, the client-generated traffic is also affected greatly by the individual player behavior. Consequently, one can conclude that the statistics of client-generated traffic would not change too much with varying access networks, which has been verified by the results in Fig.5 and Fig.6.

In order to increase the server processing efficiency, the game clients use a uniform format for general information submission to the server. Therefore, a fixed data format is used for information submission of the player and hence the payload length of the client-generated packet is almost constant. It is noted that the client-generated packet length distribution has a tight relation with the specific game design in practice. In the measured MMORPG - *World of Legend*, the payload length of a uniform uplink packet is 19 bytes as shown in Fig.6. The results clearly show that most of the packets are small enough in the uplink direction. However, if all the overheads of packet headers are included, the total packet length still reaches over 73 bytes. This suggests that the network overhead has occupied most of the client-generated traffic and some possible technologies of header compression would be helpful for performance improvement especially in wireless access networks.

## IV. GAME TRAFFIC MODELING

In a massive multiplayer online role playing game such as the *World of Legend*, every player can log in and join the game immediately at any time and hence there is almost no special duration for game session setup. Therefore, from the point of view of an arbitrary player, the impact of login or logout behavior of all the other players can be ignored because of the extremely large number of online players. In this way the traffic between game server and client is regarded as stable in a long term.

Our source model consists of two independent modules: server traffic model and client traffic model. The server traffic model is responsible for data generation of the game server and similarly, the client traffic model is responsible for data generation of an online player. Specifically, the source model needs to control the packet generation process by two independent stochastic processes: packet interarrival time $T_{IAT}$ and packet data length $L$. When a data flow is started, the source model at the node is triggered to generate a new packet whose length is determined by the stochastic process $L$. At the same time, a random period is generated according to the stochastic process $T_{IAT}$ so that the schedule time of the next packet generation can be determined. In this way, the source model succeeds in reproducing the network game traffic.

For a mathematical description of the distribution functions for packet interarrival time and packet data length, we need to select a function of similar shape and fit its parameters to the empirical data. As the previous works in [4][5][7] have identified the Extreme Value distribution to fit best for the network game traffic, we also choose this function for better comparison. Actually, other similar functions such as shifted Lognormal or Laplace, Weibull and Exponential distributions could also result in acceptable fits as well.

The Extreme Value distribution is well suited to modeling data sets with significant modes. The Extreme cumulative distribution function (CDF) is given by [13]:

$$F(x) = exp\{-exp\{-\frac{x-a}{b}\}\} \tag{1}$$

For finding the best parameter values $a$ and $b$ of the selected expression, we perform a least square fitting (LSF) [14] to the cumulative distribution function.

The achieved mathematic approaches to cumulative functions for the game traffic statistics are illustrated in Table III. The test results in Fig.3-6 have shown that although the game traffic statistics varies among different access networks, the outlines of the CDF curves are always similar for the same traffic parameter. Therefore, we employ the Extreme Value distribution to approach the CDF curves of packet interarrival time and packet data length of the server-generated traffic. As for the client-generated traffic, the Extreme Value distribution is also employed for the CDF approximation of packet interarrival time, while the Deterministic distribution is used for the CDF approximation of packet data length. The

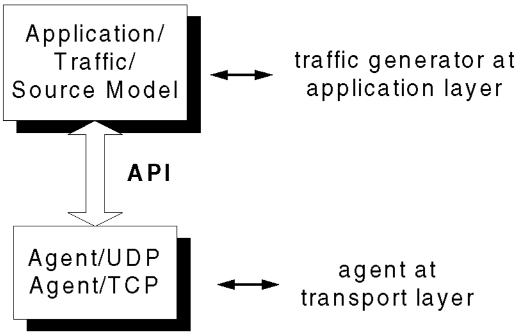


Fig. 7. Illustration of traffic generation procedure in simulation environment

approach lines are also presented in Fig.3-6 together with the test results.

Our approximation shows that by simply changing parameters of the distribution functions, different statistical processes can be approached so that the impacts from various access network conditions can be included. The simplicity of the presented source models makes it possible to simulate the MMORPG game traffic on each link from client to server as well as the traffic on each link from server to client. In the simulation environment, the game source model should be implemented in a high model level. Considering the particular traffic generation procedure, the presented source models need to be implemented at the application layer. Fig.7 illustrates an example of how traffic generation procedures are composed and attached to transport agents. By determining the packet interarrival time and packet length based on the achieved CDF expressions during every invoking time, the source model succeeds in regenerating the game traffic in simulation environment.

## V. Conclusions

In this paper, We have presented a traffic analysis of the MMORPG game and investigated the pattern difference for game traffic in various access networks. In our research we selected a popular MMORPG in China - *World of Legend* as the testing example and collected sufficient data from emulated GPRS/EGPRS networks and real ADSL network. Based on the statistic analyzing, we built the particular source models for game server and client independently which can be implemented directly in the simulation environment. The major findings are summarized as follows:

- The average bandwidth requirement per client of the MMORPG is low enough for mobile networks. However, the transmission delay caused by the wireless cellular network (GPRS or EGPRS) leads to a long round trip time which finally deteriorates the game performance.
- The access network conditions have a larger impact on the server-generated traffic compared with that on the client-generated traffic. The packet interarrival time and packet data length of the server-generated traffic are observed both decreasing with the increasing bandwidth of access networks. On the other hand, the client-generated traffic is not affected so much by the access network conditions.
- Although the game traffic statistics vary among different access networks, the outlines of the CDF curves are always similar so that by simply changing parameters of the distribution functions of the model parameters, different impacts from various access network conditions can be included.
- The overheads of packet headers and pure ACKs have occupied quite a lot of bandwidth in such kind of TCP-based online games. Therefore, how to improve the communication efficiency is an important issue in the resource-limited mobile networks.

Our results have verified that the practical feeling of game playing in the emulated EGPRS access network is acceptable from the point of view of user experience. However, this conclusion is based on the assumption that the cellular system capacity is not saturated and no handover occurs. The impact of system capacity and scheduling schemes of the cellular networks on the online game performance is yet to be explored in the future.

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