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MMOPRG Traffic Measurement, Modeling and Generator over WiFi and WiMax

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***Abstract*—Nowadays, online gaming is one of the emerging industry on the Internet. Massively Multiplayer Online Games (MMORPG) is one of the most important type of online games. Research on MMORPGs always pay attention to the network situations, such as flow imbalance, system optimization and traffic identification. The results help the game designers and network protocol engineers to improve user game experience. In this paper, we perform traffic analysis and modeling in three distinct game scenarios over two different wireless network connections in World of Warcraft(WoW), which is one of the most popular MMORPGs among the world. In addition, we contribute a random traffic generator base on ns-2 which could be a open development platform for the MMORPGs.**

I. Introduction

Online game industry has made substantial revenue in the entire Internet industry, and the number of online game users is significantly increasing every year. [1] In accordance to this, the volumn of online game traffic has been rapidly increased and the game traffic shares about 5% of Internet traffic [2]. Amongst many online games (*e.g.* casual games, board games, massively multiplayer online games, *etc*), Massively Multiplayer Online Role Playing Games (MMORPGs) are one of the most popular games and about millions of players enjoy these kinds of games simultaneously [3].

One of the representative characteristics of MMORPGs is the real-time interactive service. Network services oriented to real-time interaction, such as Internet telephony service, real-time multimedia streaming service, and online game, require sufficient network capacity for users to enjoy the services and the network capacity can be represented with respect to various performance metrics(*e.g.* bandwidth, jitter, and loss.) [4] For these reasons, to offer reliable MMORPGs to players, there are a few network measurement studies with MMORPGs.

The study [2] presented the result about generating MMORPG traffic with ns-2 simulator and the authors focused on the traffic patterns in World of Warcraft (WoW). They analyzed the information on the IP-layer (*e.g.* packet size and packet rate) and the user-level (*e.g.* session duration). The studies [4] [5] provided a synthetic traffic generator for WoW traffic clients.

It is observed that there are mainly three aspects missing in the existing work on the traffic in online games.

The first is the lack of analysis of the traffic characteristics with different wireless network connections. The current WiFi network enables users to play online games. Moreover, players can play online games even during movement with the emerging 3G network or WiMAX if they are within its coverage. Hence, it is really important to analyze game traffic generated from different network connections. The work [5] evaluated the game traffic generated from “The world of Legend” [6] over GPRS access network, but it considers GPRS network alone. To address this issue, in this paper we perform the analysis on the usage of different wireless network connections, including WiFi and WiBro [7][1] with different game scenarios in the game WoW.

Second, the existing work did not consider the impact of the user interactions on the traffics. [2] [3] [8] [9] [10] When analyzing the characteristics of game traffic, one should consider both the traffic itself and the user behaviors. In this paper we investigate three different scenarios: a) closed but crowd area, b) open area with many users, and c) battlefield area.

Finally, an open source traffic generator for MMORPG is not available. After the analysis and modeling of WoW traffic to identify the certain features of packet inter-arrival time and packet size, we designed a random traffic generator of WoW based on ns-2 to provide a platform for MMORPG research.

In this paper, we perform MMOPRG traffic modeling and analysis over WiFi and WiMax by analyzing, modeling, and generating the traffic. We collecte data traces of WoW by Wireshark. From the trace files we extract feature information to be used in traffic generation and later simulation. Based on the parameters, we design and implement the traffic generator. The ns-2 trace files generated in our simulation were used to compare with the original data, in order to verify the correctness of our generator.

In summary, our main contributions in this paper includes:

1) We measure the MMORPG traffic in three distinct scenarios,including City Environment, Player vs. Enemies and Player vs. Player, which will described in details in section II.
2) We compare the network capacity between WiFi and WiBro on real-time gaming support.
3) We create a random traffic generator based on ns-2 to simulate the packet transmission for MMORPG.

The remainder of the paper is organized as following: We perform the traffic measurement, analysis and modeling in

[1]WiBro is a successful commercial 802.16e network which provide metropoliatan area network access in the city of Seoul, Korea.

Section II, III and IV, individually. Then an random traffic generator based on ns-2 and its simulation analysis are described in Section V. Finally, Section VI concludes this paper.

II. Traffic Measurement

A. Environment

In order to collect our datasets, we played WoW on a MacBook Pro labtop with Intel Core 2 Duo T8300 CPU, 2GB RAM, and Nvidia 8800GT video card and we collected traffic packets with Wireshark[2]. We ensured that our hardware platform is enough to play WoW, so that it did not affect gaming performance. To connect to WiFi, we use a Realtek RTL8168C(P)/8111C(P) network card, which provide 802.11b access to the Access Point(AP). To connect to WiBro, we used Samsung SWT-H200K WiBro modem with dial client version 2001 and it provides 30Mbps to 50Mbps bandwidth connection to the Internet.

B. Scenarios

For our experiment, we connected to wireless network via WiFi and WiMax, specifically 802.11b and WiBro and we played WoW in three kinds of virtual gaming spaces, named `City`, `PvE`, and `PvP`. In `City` space, we controlled our game character, avatar, to walk around in a crowd city where many players chat and make deals with others. In `PvE`, our avatar killed constant monsters in open wild scenes in the virtual space. Finally in `PvP`, our avatar joined to a set of battles and made fights with others. On the other hand, we played WoW in three types of enviroment scenarios: subway, bus, and static access. 1)Subway: Line Number 2 in the city of Seoul. In the subway, Base Stations(BSs) are deployed inside station terminals, and several repeaters are set up in the tunnels to enhance the signal and relay data between subscriber stations(SSs) and BS at MAC layer. 2) Bus: Bus 501 from Seoul National University to Seoul Station, a typical route passing several campuses, residential areas, a tunnel, a bridge over the Han river. This route also passes near several electronics shopping malls.3) Static access: Seoul National University Kwanak Campus. There are WiBro stations in the campus which provide high quality of internet access.

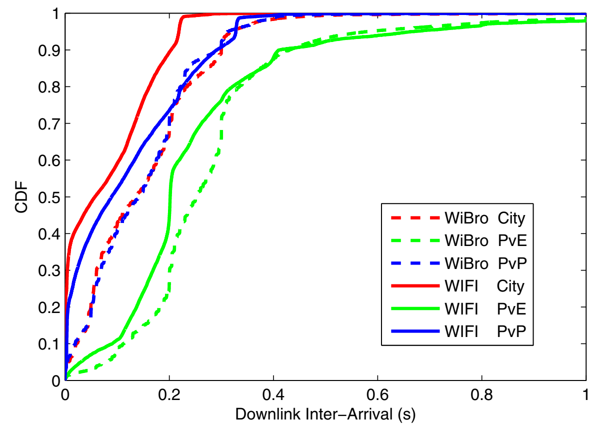
C. Data set

We capture the trace in different environment and gaming scenarios for a large number of times. All of the gaming trace files via WiFi[3] and WiBro[4] are shared in the Internet. It can be an open resource for the research community.

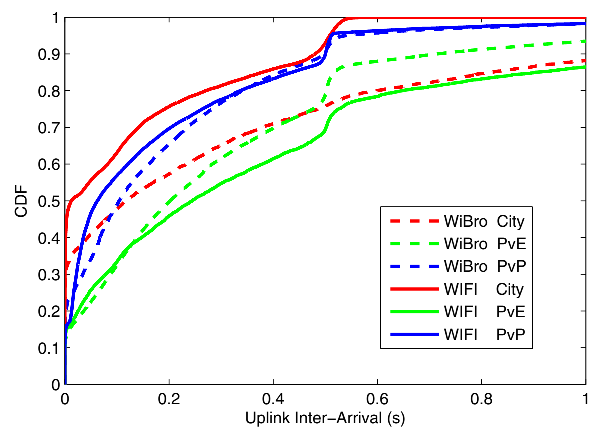
III. Traffic Analysis

With the dataset, we first study the packet inter-arrival time and the packet size to characterize WoW traffic. In our analysis, we ignore packets which do not have any payload because they are not related to the characteristics of WoW traffic. Throughout this paper, we call a flow from a WoW client to its server as an uplink flow and its reverse flow as a downlink flow. In addition, we use uplink and downlink to indicate uplink flows and downlink flows, respectively.

A. Packet Inter-Arrival Time



(a) Downlink Inter-Arrival CDF

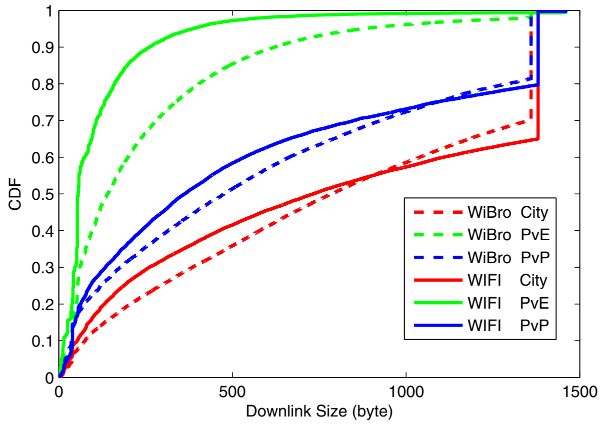


(b) Uplink Inter-Arrival CDF

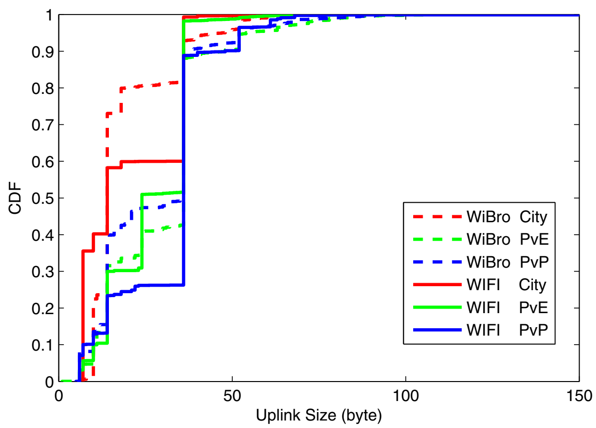
Fig. 1. Packet Inter-Arrival Time Analysis

In Figure 1, we plot the packet inter-arrival time for uplink and downlink. Figure 1(a) shows the Cumulative Density Function (CDF) of packet inter-arrival times for downlink. It is observed that WiFi has smaller latency than WiBro for all game scenarios. It is caused because the network capacity provided by WiFi is always beyond the one offered by WiBro. Interestingly, we observe that the packet frequencies in `PvP` and `City` are much higher than in `PvE`. One of the possible reasons for this is that there are more players around in `PvP` and `City` scenarios where much more information should be exchanged among servers and clients. Another interesting observation is that there are more packets arrival at client during the inter-arrival time of 0.2s and 0.3s than other periods. We expect a mechanism in a server-side insisting a client to upload the parameters of its gaming world within a certain period of time.

[2]http://www.wireshark.com/
[3]http://mmlab.snu.ac.kr/c̃aiwei/resource.html
[4]http://crawdad.cs.dartmouth.edu/snu/wow_via_wimax



(a) Downlink Size CDF



(b) Uplink Size CDF

Fig. 2. Packet Size Analysis

Figure 1(b) shows the downlink packet inter-arrival time. Similarly, packet frequencies in `PvE` is smaller than those in `PvP` and `City`. In addition, a large number of packets with same inter-arrival time appears in uplink inter-arrival. The difference is that the unconspicuous pinnacle happens on 0.5s. This indicates that the client has to send a certain number of predefined information about our avatar to the server per 0.5s due to the game server-side mechanism.

B. Packet Size

Figure 2(a) shows the downlink packet size CDF distribution of the six scenarios. WiFi packet sizes in all game scenarios are smaller than those in WiBro. The reason for this phenomenon is that the exchange information between server and client is approximately equal, which makes the packet sizes in inverse proportion to the packet frequencies. WiFi has higher frequency which leads to smaller packet size. In terms of game scenarios, we noticed that in the `City` and `PvP`, packet sizes are larger than the ones in `PvE`. Moreover, in these two scenarios, large number of packets in constant size appear in the right side of the figure. It could be explained with the TCP Maximum Size Unit (MTU) limitation. As we know, the maximum packet size in a particular TCP connection was fixed as M. All of the packets in the size larger than M will be divided into segments according to the TCP MTU limitation. Therefore, a large number of packets in the size of M appearing in the figure indicates that the server sends many data with the packet size larger than M. It is reasonable in the `City` and `PvP` scenarios. Furthermore, a small pinnacle would be found around the size of 55 bytes in all six curves. It could imply that particular kinds of packets are frequently sent from the server to the client, such as environment refreshing.

Figure 2(b) shows the uplink inter-arrival CDF distribution. Similar as downlink, WiFi packet sizes are also smaller in uplink connection. There is a pinnacle around the size of 52, 36, 14 and 10 bytes for all scenarios, and in 52 bytes in `PvE`. The smallest packet size in uplink is around 6 bytes while the value in downlink is about 0 bytes.

IV. Traffic Modeling

In this section, based on the analysis result in the previous section, we model packet inter-arrival times and packet sizes for both uplink and downlink. In the characteristics modeling, we use Weibull distribution [11], which is widely used for game traffic statistical modeling. A Weibull distribution, $f(x:\mu,k)$, is defined as follows:

$$f(x:\mu,k)=\frac{k}{\lambda}(\frac{x}{\lambda})^{(k-1)}e^{-(\frac{x}{\lambda})^{k}} \quad (1)$$

where λ and k are scale and shape parameters in Weibull distribution, respectively. Thus, the modeling approach in our work is to describe the packet inter-arrival time and packet size individually with the λ and k parameters in the transmission between server and client.

A. Packet Inter-Arrival Time

For the packet inter-arrival time, the Weibull distribution was employed for the extracted inter-arrival time data to determine *Scale* λ and *Shape* k parameters, which could be used directly in the simulation.

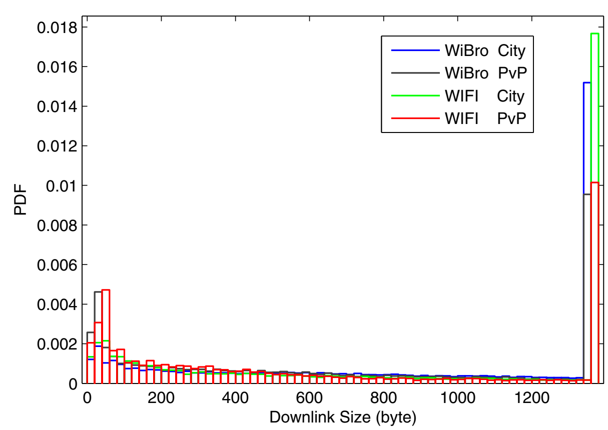


Fig. 3. Downlink Size PDF

TABLE I
WEIBULL DISTRIBUTION PARAMETERS FOR WIFI

Interval		Scale(λ)		Shape(k)		Mean		Variance	
		measurement	simulation	measurement	simulation	measurement	simulation	measurement	simulation
City	DL	0.0504719	0.0179945	0.492325	0.747708	0.10391	0.0214792	0.0563896	0.000850158
	UL	0.0418895	0.0221798	0.366698	0.789959	0.180329	0.0253612	0.432803	0.00105032
PvE	DL	0.279526	0.0830465	1.29987	0.569637	0.258168	0.134173	0.0401141	0.0634553
	UL	0.282871	0.0946906	0.543278	0.631175	0.4909	0.133797	0.961183	0.0488584
PvP	DL	0.104282	0.0972645	0.762581	0.627403	0.122502	0.138415	0.0264729	0.0530544
	UL	0.111669	0.0631296	0.532335	0.620693	0.200245	0.0910098	0.16885	0.0240858
Size		Scale(λ)		Shape(k)		Mean		Variance	
		measurement	simulation	measurement	simulation	measurement	simulation	measurement	simulation
City	DL	430.263	385.846	1.00684	1.10125	429.035	372.169	181580	114501
	UL	22.7086	22.2833	1.57848	1.55833	20.3862	20.0302	174.45	172.426
PvE	DL	109.838	110.065	1.00108	1.00794	109.788	109.701	12027.5	11845.8
	UL	29.8426	29.3258	2.25494	2.20262	26.433	25.9717	153.906	154.97
PvP	DL	344.545	315.177	0.939563	1.0097	354.51	313.909	142533	96657.8
	UL	35.4422	34.812	1.98296	1.94664	31.415	30.8694	273.847	273.373

TABLE II
WEIBULL DISTRIBUTION PARAMETERS FOR WIBRO

Interval		Scale(λ)		Shape(k)		Mean		Variance	
		measurement	simulation	measurement	simulation	measurement	simulation	measurement	simulation
City	DL	0.156378	0.16982	1.17987	0.559259	0.147757	0.281872	0.0157948	0.293688
	UL	0.133198	0.0463636	0.372789	0.490724	0.544309	0.0960461	3.71923	0.048624
PvE	DL	0.312002	0.225163	1.55946	0.661182	0.280434	0.30196	0.0337534	0.222697
	UL	0.24611	0.107781	0.624012	0.577544	0.352515	0.170753	0.34869	0.0992094
PvP	DL	0.152007	0.15094	1.16904	0.645197	0.143991	0.207944	0.0152681	0.111937
	UL	0.123891	0.0672599	0.512803	0.567453	0.236741	0.109273	0.261241	0.0425072
Size		Scale(λ)		Shape(k)		Mean		Variance	
		measurement	simulation	measurement	simulation	measurement	simulation	measurement	simulation
City	DL	562.576	488.773	1.18389	1.32519	531.074	449.729	202721	117393
	UL	21.141	20.633	1.67311	1.6481	18.8844	18.452	134.589	132.074
PvE	DL	225.527	222.425	0.967211	0.985234	228.867	223.855	56010	51627.8
	UL	33.5146	32.8854	1.81696	1.78614	29.7909	29.2558	288.362	286.845
PvP	DL	418.662	370.313	0.959961	1.06886	426.347	360.852	197349	114118
	UL	30.5503	29.909	1.82249	1.79799	27.1523	26.5991	238.228	234.292

B. Packet Size

The maximum packet sizes M in different connections are different according to the network gateway (see Figure 3). The percentage of these packets could be an important scale to describe the traffic situation. Therefore, they were summarized and the percentage of them was recorded as β. We find out that the β for uplink scenarios are all 0. However, for the downlink flows, the β of `City`, `PvE` and `PvP` in WiFi are 0.349986, 0.00554128 and 0.200236 respectively, and the value of `City`, `PvE` and `PvP` in WiBro are 0.298059, 0.0195241 and 0.186228.

After removing these packets, we fit the remaining packets with Weibull distribution appropriate λ and k. Thus, the packet size follow the distribution below:

$$Size = \begin{cases} M, & \gamma \in [0, \beta) \\ follows\ f(x : \mu, k), x \in (0, M) & \gamma \in [\beta, 1] \end{cases} \tag{2}$$

where γ follows a uniform distribution within $[0, 1]$.

V. TRAFFIC GENERATOR FOR WOW

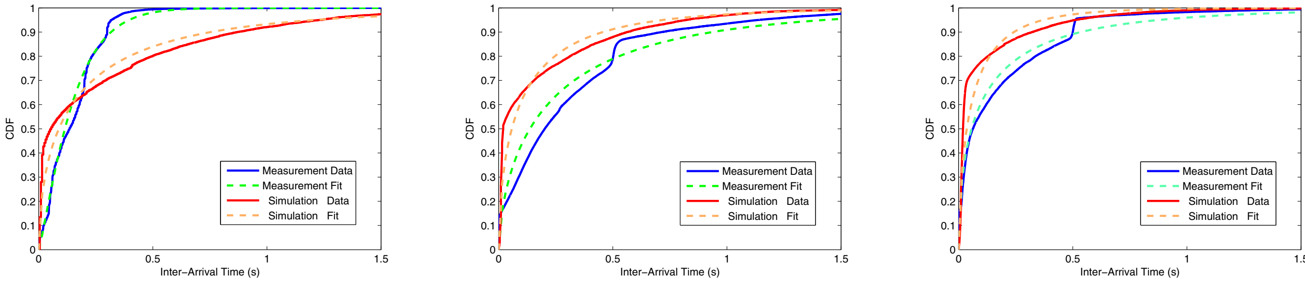
We have implemented a random traffic generator for WoW based on ns-2. The LWX[5] patch was used for our WiBro scenario simulations since the original ns-2 does not have the WiMax module. Our random traffic generator works well with this patch.

For the inter-arrival time, we add a new traffic type named Application/Traffic/MMORPG. With this application layer traffic, we could simulate the packets with random inter-arrival time and it fits for the Weibull distributions with λ and k parameters.

In order to control the transmission packet size, we add a new type of FullTcp node, which we name it Agent/TCP/FullTcp/MMORPG. With the parameters λ , k, M, and β, the new node can simulate packets with random size which fits the packet size formula (2).

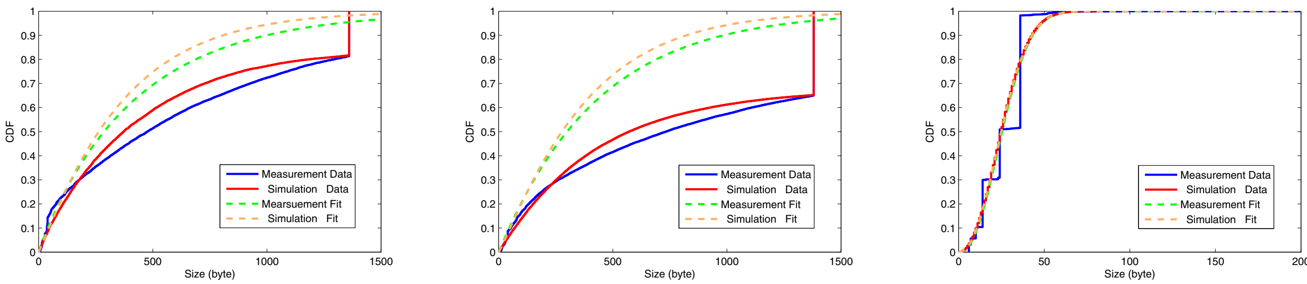
To evaluate the correctness of our random traffic generator, we simulate all the scenarios we measured before for evaluation. Table I and Table II present all of the parameters for packet inter-arrival time and size in measurement and simulation respectively. We focus on the differences between

[5]http://code.google.com/p/lwx/



(a) WiBro City Downlink (b) WiBro PvE Uplink (c) WiFi PvP Uplink

Fig. 4. Simulation Result Comparison : Inter-Arrival Time



(a) WiBro PvP Downlink (b) WiFi City Downlink (c) WiFi PvE Uplink

Fig. 5. Simulation Result Comparison : Size

the simulation data and the measurement one in details. The results in the tables shows that our traffic generator matches well on the packet size. However, for the inter-arrival time, prominent tolerances are still existing since our generator focuses on the application layer but not the Median Access Control (MAC) layer. Packet control mechanisms in MAC or even lower layer may vary in the inter-arrival time.

A. Packet Inter-Arrival Time

Figure 4 shows the inter-arrival time comparison between the measurement data and the simulation. The curves of the simulated inter-arrival times approximate well to the measurement results, though, the two curves are not totally coincident. The reason is that our modification of inter-arrival time is on the application layer. The TCP connection has mechanism to calculate the time for packet sending, *e.g.* backoff inter-arrival time. Therefore, the simulated inter-arrival time is uncontrollable from the application layer in ns-2.

B. Packet Size

Figure 5 shows the simulation result of packet size. It is clear that our traffic generator matches well with the simulated packet size. In practice, for downlink scenarios, the simulation results and their shape of packet size are approximately identical to the ones we extracted from the game of WoW.

VI. Conclusion

In this paper, we perform WoW traffic measurement, analysis and modeling on WiFi and WiBro network connections in three distinct game scenarios. The analysis identifies the traffic characteristics in MMOPRGs and the modeling helps the improvement of game and network protocol design. Furthermore, a random WoW traffic generator based on ns-2 was develeoped in our work as a research platform of MMORPG.

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