A Synthetic Traffic Model for Quake3

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ABSTRACT

This paper presents our development of a synthetic traffic model for the interactive online computer game Quake3. The goal is a traffic model that can be used by researchers and Internet Service Provider engineers to estimate the potential future impact of Quake3 traffic over IP networks. We developed our ns2 simulation model for Quake3's IP traffic by running live network experiments and characterising the observed packet length, packet inter-arrival times, and data rates (in packets- and bits- per second). Our observations are documented in this paper, and we expect our traffic model will assist network planners who wish to better support real-time game traffic.

Categories and Subject Descriptors

I.6.5 [**Simulation and Modeling**]: Model development– *traffic measurement, statistical analyses, model implementation.*

General Terms

Algorithms, Measurement, Performance, Experimentation

Keywords

Quake 3, Internet, Traffic, Modeling, Simulation,

1. INTRODUCTION

In recent years interactive network games have become more popular with Internet users and constitute an increasingly important component of the traffic seen on the Internet. Interactive game traffic has different characteristics to the WWW and e-mail traffic prevailing on the Internet today and therefore imposes different requirements on the underlying network.

Providing premium service to the increasing on-line gaming community could be a promising source of revenue for ISPs. To provide this service an ISP must have knowledge of the traffic load offered by game traffic to provision their networks accordingly. Some researchers have already looked at the traffic characteristics of different popular on-line games to provide a suitable traffic model to test existing or planed network for their capability to support game traffic [1] -[4].

In this paper we present our investigation of Quake3, an Internet first person shooter game. Due to the short reaction times necessary to play this kind of game, it is especially sensitive to network characteristics [5]. An evaluation of the traffic load offered to the network by such a game can be used to evaluate the suitability of existing networks to support first person shooter games and to design new networks with special consideration of game traffic.

In this paper we first present the main traffic characteristics of Quake3 in terms of packet lengths, packet inter-arrival time, packet per second (PPS) and data rates. We then develop a traffic model based on these observed characteristics. The traffic model is not aimed at describing the game in every detail but to capture the main characteristics of Quake3 game traffic. As in all modeling we were aiming for a balance of accurately describing real world data and reasonable execution speed of a simulation model including hundreds of network hosts.

2. QUAKE3 TRAFFIC

2.1 Experiments and set-up

We captured several months of Quake3 game traffic from games played over our university LAN. The network setup is shown in Figure 1. The client machines were at most one hop from the game server, resulting in round trip times of less than 10 ms.

The game server was also running pkthisto [6]. Pkthisto creates packet length and packet inter-arrival time histograms for each individual UDP/IP flow from client to server and server to client. Source and destination IP addresses and port numbers specify a flow. Pkthisto also logs packet per second and data rates for each flow. We configured pkthisto to create per-flow histograms (and PPS estimates) every 2000 consecutive packets. Pkthisto must see at least 200 packets before a histogram is logged, and will consider a flow to be idle if consecutive packets are more than 800 ms apart. In addition to per flow statistics, pkthisto also creates aggregate histograms based on all traffic to or from a specific node on the LAN (in our case the game server).

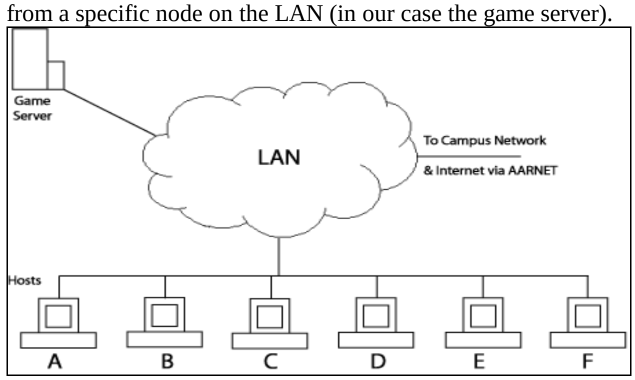

Figure 1. Experiment set-up

We observed a number of Quake3 games played over a 2 month period, with games having between 2 and 8 players. During the 2 months observation period the map cycle on the game server was changed twice The first map cycle (cycle 1) consists of 3 maps: pigskin, coralctf and runtfest, the 2nd map (cycle 2) had 4 maps: pigskin, platform6, bal3dm3 and cetacean and the 3rd map cycle (cycle 3) also contained 4 maps: pigskin, q3dm19, platform6 and q3ctf4. In total we observed 8 different maps and the observations presented in this paper are valid for all games irrespective of the map cycle.

2.2 Packet lengths

The packet lengths discussed in this section are the lengths of the IP datagrams.

2.2.1 Server to Individual Clients

The packet lengths from the server to the different clients are strongly dependent on the number of players in the game. Figure 2 and Figure 3 show a game in which the number of participants changed from 4 to 2. The packet lengths for a 4 player game are in Figure 2 while the packet lengths for a 2 player game are in Figure 3. For each number of participants the whole map cycle cycle1 was played. It can be seen in these two figures that all maps except pigskin have essentially the same packet length distribution (this was also observed for the data rates in Figure 13.

Figure 4 shows the packet lengths from the server to a client during a game that had 5 participants from beginning to end (across the multiple maps in cycle3). As was observed for the game with 4 and 2 players the particular map only has a minor impact on the packet length distribution.

Figure 5 shows how packet length distribution spreads as the number of players in the game increases.

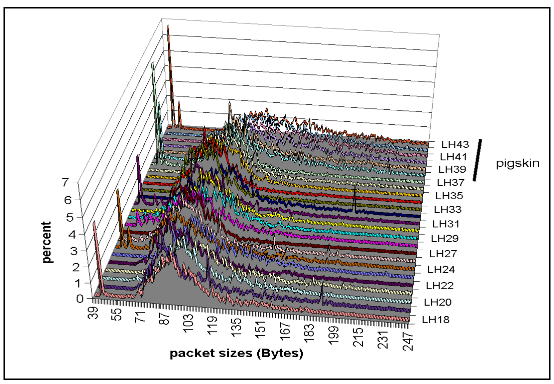

Figure 2. Server to client packet lengths: 4 players, map cycle1

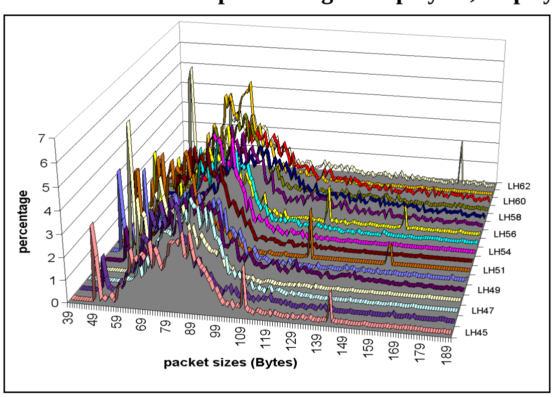

Figure 3. Server to client packet lengths: 2 players, map cycle1

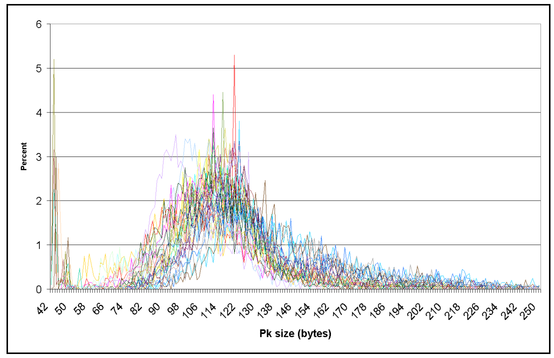

Figure 4. Server to client packet lengths: 5 players, map cycle3

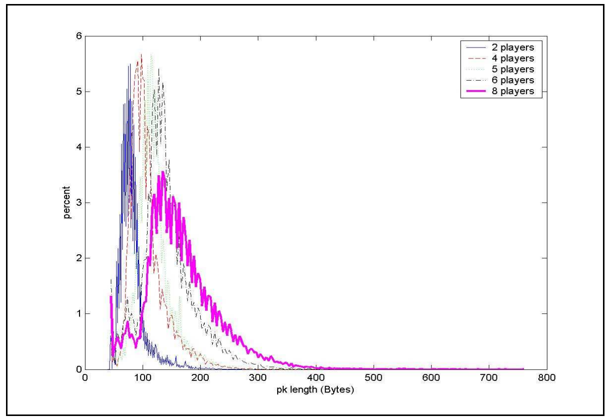

Figure 5. Server to client packet lengths vs number of players

2.2.2 Client to Server

The packet lengths from the individual clients to the server is independent of map type or number of players. Figure 6 and Figure 7 show aggregate packet length plots, representing the packets that the server has received from all clients during one game with map cycle cycle1 and one game with map cycle cycle2

Client to server packets have a more limited range than server to client packets.The smaller packets are about 50 bytes long and the largest ones are around 70 bytes.

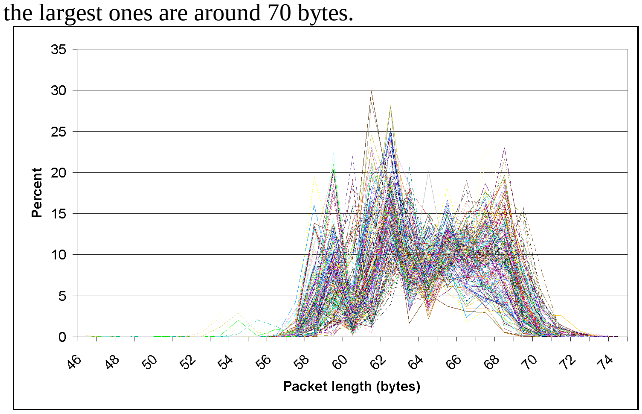

Figure 6. All clients to server packet lengths, cycle1

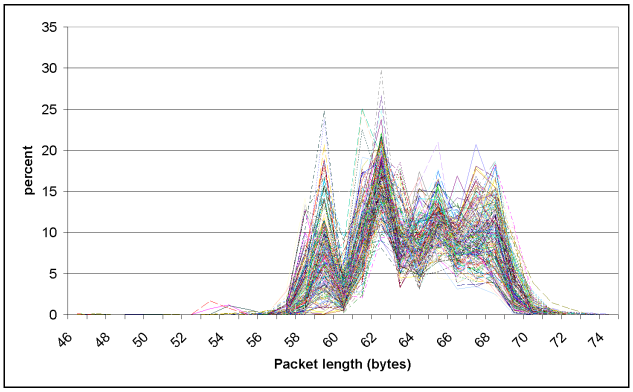

Figure 7. All client to server packet lengths, cycle2

2.3 Packet inter-arrival times

2.3.1 Server to Client

The server to client packet inter-arrival times are very regular (Figure 8). The server sends one update packet aproximately every 50 ms to each client. This behaviour is independent of the number of clients connected to the server or the map cycle of the game.

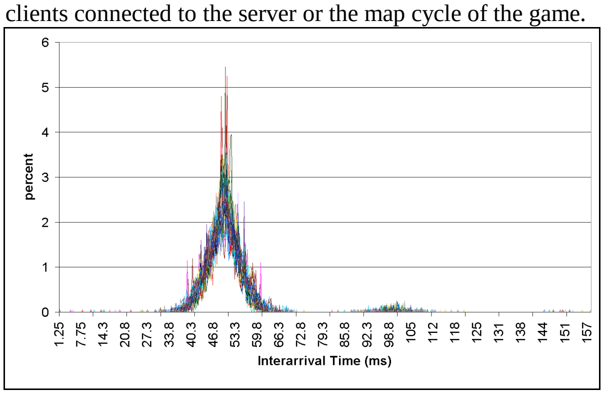

Figure 8 server to individual client packet inter-arrival times

The packets to all clients are transmitted in a back-to-back burst. If L clients are connected to the server during a particular game, the server sends a burst of L data packets every 50 ms. Therefore (100*(L-1)/L)% of the aggregate packet inter-arrival times (server to all clients) are close to 0 ms and the rest of the inter-arrival times are concentrated around 50 ms).

2.3.2 Client to Server

The characteristics of traffic from different clients depends on variables such as the client's graphics card and the map being played. Three different graphic cards were used during our game trials. Figure 9 to Figure 11 show packet transmission rates across map cycle cycle2 for all 3 graphic cards. Figure 9 is the plot for a Dell GX260 (CPU speed 2 GHz, 256 MB RAM) with a 32 Mb Intel 845G graphics controler graphics card (graphic card 1), Figure 10 shows a Compaq EV500 (CPU speed 1.6 GHz, 256 MB RAM) with a 32Mb Nvidia GeForce2 MX/MX 400 graphics card (graphic card 2) and Figure 11 is from a similar Compaq machine but with a 16Mb Nvidia Vanta/Vanta LT graphics card (graphic card 3). The Dell and the Compaq machines with more modern graphics systems (more RAM and faster graphics processing chips) send more packets per second then he Compaq machines with 16 Mb graphics card, but even between these 2 more modern graphics card differences can be noticed Graphic card 1 (Figure 9) is the most modern card and has the least spread of packet transmission times for most maps observed. For most maps, with the exception of pigskin and cetacean, this particular client transmits one packet approximately every 10.75 ms. For pigskin and cetacean the spread of packet transmission times is between 10 and 30 ms.

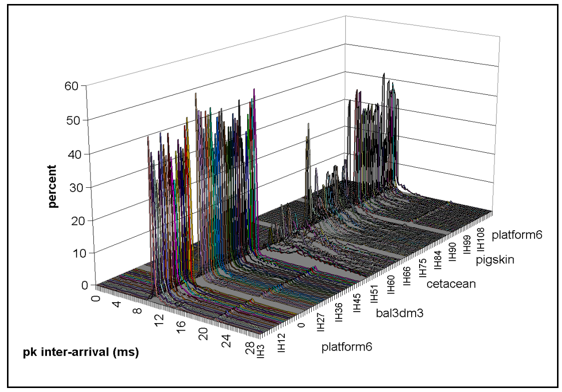

Figure 9 packet inter-arrival from Compaq 32 Mb graphic card client to server

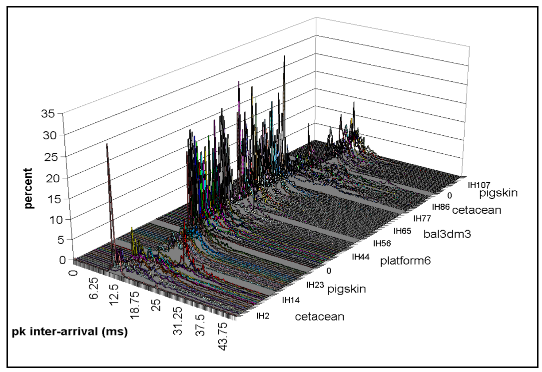

Figure 10 packet inter-arrival from Dell client to server

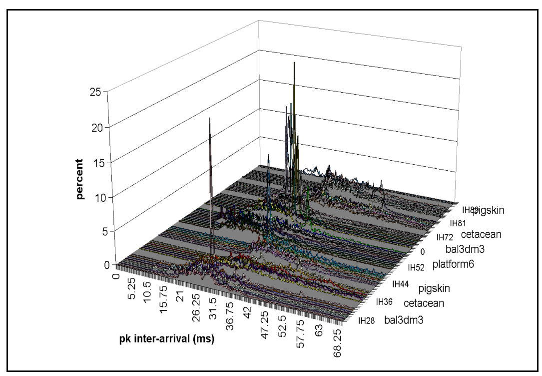

Figure 11 packet inter-arrival from Compaq client with 16 Mb graphics card to server

Graphic card 1 (Figure 9) is the most modern card and has the least spread of packet transmission times for most maps observed. For most maps, with the exception of pigskin and cetacean, this particular client transmits one packet approximately every 10.75 ms. For pigskin and cetacean the spread of packet transmission times is between 10 and 30 ms.

Graphic card 2's (Figure 10) packet transmission pattern is quite similar to graphic card 1. For all maps, except pigskin and cetacean, there is a distinct peak at 10.75 ms, however, as can be seen in Figure 12, there is a second peak at 11.75 ms and some packets are spread up to 25 ms apart. With pigskin and cetacean the packet are transmitted at a rate of one every 10 to one every 40 ms.

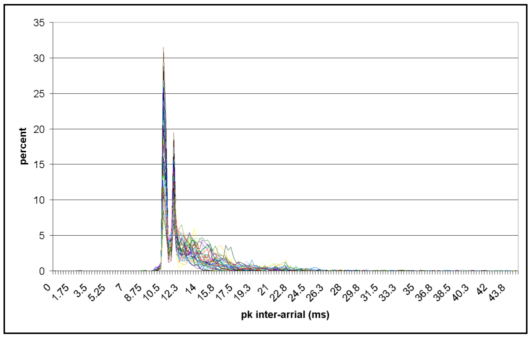

Figure 12. Packet inter-arrival times for graphic card 2

For the oldest graphic card, (Figure 11), the packet transmission is very dependent on the particular map played. In general the packet transmission times range from one every 10 ms to one every 60 ms.

2.4 Packet per second (PPS) and data rates

2.4.1 Server to Client

The PPS rate from server to the individual clients is only slightly varying between 20 and 19 packets per second (i.e. approximately 1 packet every 50 ms, Figure 8).

The actual data rate (in bits/second) from the server to the individual clients fluctuates with the server to client packet lengths. Figure 13 shows a dependency on the number of clients (and to a lesser extent the map) consistent with the packet length dependencies discussed section 2.2.

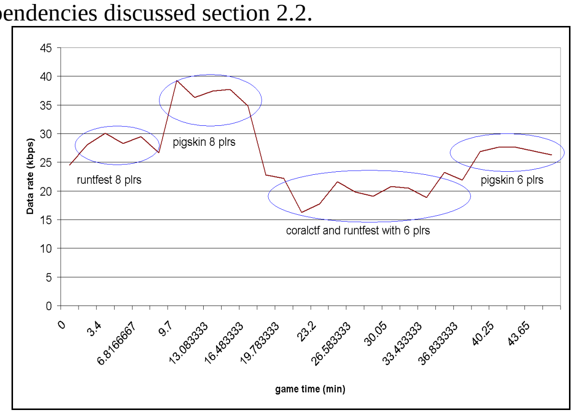

Figure 13. Data rate server to individual client

2.4.2 Client to Server

The packet per second rate form the individual clients to the server is as dependent on the graphic card and the map played as the packet inter-arrival times discussed previously. Figure 14 shows the PPS rate for the same three clients that were discussed.

As discussed previously, higher end graphic cards transmit more packets than lower end ones and so have a much higher PPS rate. Independent of the graphic card, the map played always has the same impact on the packet rate. Pigskin and cetacean maps cause fewer packets to be transmitted than any other maps used.

Since the packet size for client to server data transmission is independent of all observed parameters (such as map or number of players in the game), the data rate of the individual clients directly corresponds to the PPS rate of the client and shows the same variation according the graphic card and map. Graphic card 1's data rate is between 40 and 45 kbps for all maps and between 25 and 35 kbps for pigskin and cetacean. The data rate for machines using graphic card 2 is about 5 kbps lower than for machines using graphic card 1 and graphic card 3 machines have average data rates between 12 and 20 kbps dependent on the map played.

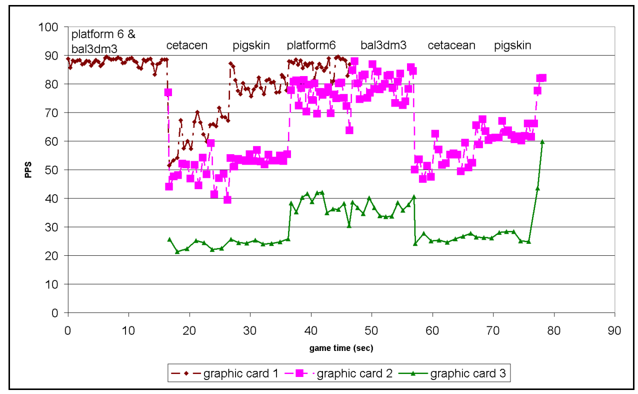

Figure 14. PPS rate for 3 clients with different graphic cards

2.5 Summary of Quake3 traffic pattern

2.5.1 Server to Client

The packet lengths were strongly dependent on the number of players participating in the game and to a lesser extent on the particular map. Each map has a base packet length distribution. Each additional player on the map creates a certain amount of activity, which results in an overall increase in the packet lengths.

The packet transmission rate from the server to the individual clients is almost constant. The server sends one update packet per client approximately every 50 ms.

2.5.2 Client to Server

The packet length distribution is independent of all observed parameters (maps, number of players, client hardware) and therefore the same for each client participating in the game.

The packet transmission rate of a client is dependent on the map played and on the client graphic card. Some maps have very regular packet transmission intervals, while for others packets are sent more randomly. For every map the observation holds that the newer the graphics card the more packets are transmitted in the same time interval.

3. SIMULATION MODEL

We analyzed the observed packet length and packet inter-arrival time distributions with the statistics tool SPSS to obtain simple statistical distributions that still have an acceptable match with the observed data. The goal was to find a balance between accurate modeling and simulation execution speed.

In [2] it has been noted that the traditional goodness of fit methods do not lead to acceptable results for packet length or inter-arrival time distributions of game traffic. We had the same experience when applying goodness-of-fit test to the Quake3 data. We chose to represent the fit using Q-Q plots. Figure 15 shows the Q-Q plot for the packet length distribution of a 2 player game against the lognormal that was chosen to model it. For packet lengths below 200 bytes the 2 distributions have an excellent match. They only start to deviate for higher packet lengths.

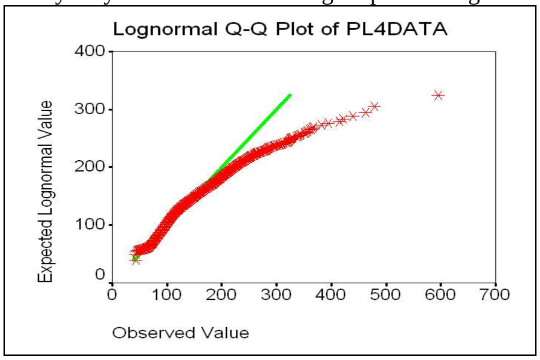

Figure 15 Q-Q plot of the packet length distribution from server to client for a 2 player game

Based on this analysis we implemented an ns2 traffic generator models for Quake3 server and Quake3 client.

3.1.1 Server to Client

The server to client packet inter-arrival time (Figure 8) could be modeled with a gamma distribution. However, since the gamma distribution is quite complex to implement we chose to approximate it with a simple spike at 50 ms.

The packet length distribution from the server to the clients is dependent on two parameters: the number of clients in the game and the map. However the observed data has shown that the number of clients in the game is the dominant parameter governing the packet length distribution. Therefore the packet length in our simulation model is only dependent on this parameter and the map played was ignored.

Our SPSS analyses of the packet length distributions for different number of clients (Table 1) indicated that with each additional client the mean packet length increases by 12 or 13 bytes. In addition, the skew-ness of the individual distribution indicated that the packet length distribution becomes more normal as the number of clients increases. This is an indication that each packet length distribution is an addition of a base distribution plus a second distribution that models the increase of the packet length per client added. The jump between the 5^{th} player and the 6^{th} player game is due to a change in map cycle, and therefore a change of base distribution.

Table 1: Mean and Skewness of observed packet length distribution for different number of players

Player	2	4	5
Mean	81.9	108	120.8
Skewness	2.6	2	2.2
Player	6	8	
Mean	142.3	166.1	
Skewness	1.3	1.08	

For our initial model of the packet length distribution we chose the distribution of the 2 player game, which is a lognormal with mean 79.340543 and standard deviation 0.24507092, as base distribution. Based on the observation on how the packet length distribution shifts to the right as the number of clients increase. We chose an exponential distribution with a mean of 13 as the additive distribution per player. Table 2 presents the mean and the skewness of the proposed packet length distribution model, while Figure 16 shows a plot of a simulated packet length distribution versus the observed one for a 5 player game.

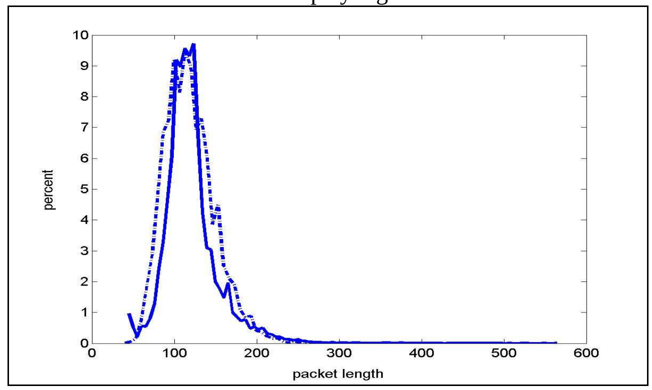

Figure 16 observed versus simulated packet length distribution for a 5 player game

Table 2 Mean and skewness of the modeled packet length distributions for different number of players

Players	3	4	5
mean	94.4	106.9	119.3
skewness	1.9	1.6	1.62

3.1.2 Client to Server

For client to server packet inter-arrival times we only chose to model the modern 32Mb graphic cards, since we assumed that players of network games will prefer the better graphic displays and are more likely to own more expensive graphic cards. Figure 17 shows the complete distribution for the packet inter-arrival time in one game for both graphic card 1 and graphic card 2.

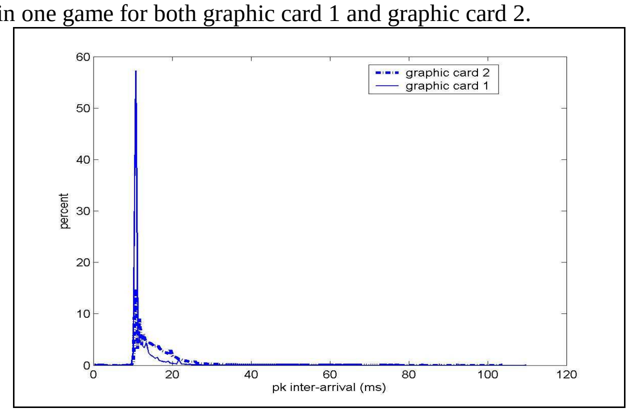

Figure 17 comparison of packet inter-arrival times of graphic card 1 and graphic card 2

Both inter-arrival time distributions consist of a spike at 10.75 ms. The spike is much stronger for graphic card 1 and accounts for 60% of packet inter-arrival times, while for graphic card 2 only 16% of the packets are transmitted 10.75 ms apart. The remainders of both distributions are modeled as an exponential with mean of 4.29 for graphic card 1 and a mean of 5.85 for graphic card 2. Figure 18 shows a comparison between the developed ns2 simulation model and the observed data.

The packet lengths from client to server are independent of all parameters (Figure 6) however their exact distribution would be very complex. For our initial simulation model we chose to model the packet length distribution as a normal with mean 64.151757 and standard deviation 3.2035755. Figure 19 shows the match between the original data and this normal distribution

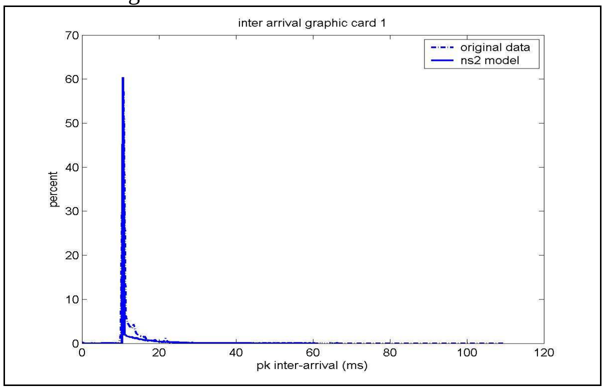

Figure 18 comparison of ns2 model and actual data for inter-arrival times of graphic card 1

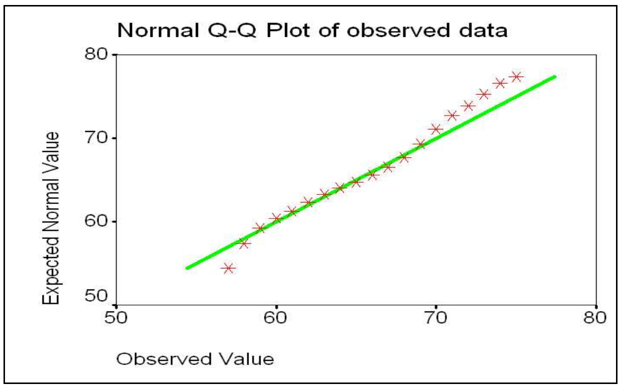

Figure 19 Q-Q plot of observed packet length client to server packet length distribution vs normal

3.1.3 Simulation Model

Since ns2 implements the normal as well as the lognormal distribution it was very easy to implement the server and the client model in this simulation tool. Below we present the main sections of server and client code.

The Quake3 server sends a packet with length dependent on the number of players to each client every 50 ms:

```
/* the packet size is dependent on the
number of players */
/* it is the base packet size distribution
(for 2 players */
/* plus a negative exponential with mean 13
for every additional player */
size_ = int (Random::lognormal(79.340543,
0.24507092));
for (int i=3; i<=nrOfPlayers; i++)
       size_ += int
       (Random::exponential(13));
/* send one packet to each player */
for (int i=1; i<=nrOfPlayers; i++)
              send(size_);
/* schedule the next transmission */
/* interval_ is 0.05 sec */
timer_.resched(interval_);
```

The following code is for the Quake3 client using graphic card 1. 60% of the packet are transmitted at 01.75 ms intervals, the rest are transmitted according to a exponential distribution with mean 4.29. The exponential distribution starts at 0, therefore 10.75 needs to be added to each exponential value to obtain the correct tail. The packet length is governed by a normal distribution and is independent of the number of players and the maps.

```
size_ = int (Random::normal(64.151757 ,
3.2035755));
send(size_);
/* schedule the next transmission */
double chooseDist = Random::uniform();
if ((gc == 1) && (chooseDist <= 0.6))
   interval_ = (0.01075);
else if ((gc == 2) && (chooseDist <= 0.16))
   interval_ = (0.01075);
else if ((gc == 1) && (chooseDist > 0.6))
   interval_ =
(Random::exponential(4.29)/1000+0.01075);
else if ((gc == 2) && (chooseDist > 0.16))
    interval_ =
(Random::exponential(5.85)/1000+0.01075);
timer_.resched(interval_);
```

4. CONCLUSION

Interactive network games are popular and are a promising source of revenue for ISPs. It is important that ISPs understand the traffic characteristics of games to provision the network accordingly.

In this paper we analyzed Quake3. We characterised Quake3 traffic in terms of packet inter-arrival times, packet lengths and data rates. Based on the observed characteristics we developed ns2 simulation models for Quake3 servers and Quake3 clients that can be used to evaluate existing networks for their suitability to support game traffic, as well as help in the design of new networks with adequate QoS for online games.

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