The Revolution of StarCraft Network Traffic

Choong-Soo Lee
Department of Mathematics and Computer Science
Gustavus Adolphus College, Saint Peter, MN 56082, USA
Email: clee7@gustavus.edu

I. Introduction

Online games have become more popular over the past decade and many games have entered the realm of electronic sports (eSports). One of the most successful eSports games is a real-time strategy game called StarCraft. StarCraft I was released in 1998 and StarCraft II launched in 2010. StarCraft players are frustrated when they experience degradation in Quality of Experience due to various network conditions such as delay, jitter and loss. While this issue is important to all players, it is especially critical to professional players, spectators and casters. Lags and drops in both routine and professional matches result in interruptions and restarts. This paper will present the StarCraft II traffic characteristics, traffic model, and simulation and emulation tools.

II. StarCraft I Traffic

Real-time strategy (RTS) games tend to use a peer-to-peer architecture where each participant in the game communicates with every other participant. StarCraft I is not an exception to this trend. Claypool *et al.* analyze client throughput, packet size distribution and packet rate for StarCraft I traffic [1]. The authors observe that the client's outgoing throughput is linearly proportional to the number of participants in the game. The increase in throughput is directly related to the increase in outgoing packet rate. Because of the peer-to-peer architecture, the client is required to send packets to more recipients. However, the authors note that the packet size distribution remains identical for a given number of players. Dainotti *et al.* provide a more in-depth analysis of StarCraft I network traffic [2]. They make the same observation that the packet rate increases with the number of players in the game as noted by the authors of [1]. Although they also note that the incoming and outgoing packet sizes have almost identical distributions, they conclude that the packet size increases with regard to the number of players, while the inter-packet times decrease.

III. StarCraft II Traffic Characteristics and Modeling

We captured StarCraft II traffic using Wireshark and analyzed the trace files. Inspection of the Wireshark trace files revealed that StarCraft II uses both TCP and UDP communication channels. Both TCP and UDP packets are received from and sent to a Battle.net server at port 1119. This reveals that StarCraft II uses a client-server architecture, not a peer-to-peer architecture. We noticed that there is minimal TCP traffic during the gameplay phase, and that UDP traffic becomes active and dominant once an active StarCraft II game starts. Because we are interested in StarCraft II traffic during the gameplay phase, we focus on UDP packets only. We speculate that TCP is used to communicate with the Battle.net service for authentication, chat, map downloads, and other control messages. UDP packets of StarCraft II traffic are further categorized by the packet direction (client-to-server and server-to-client) and game type (1v1, 2v2, 3v3 and 4v4).

Upon examining the traces, we noticed that additional filtering is required for traces of 2v2, 3v3 and 4v4 games. In 1v1 games, a game session terminates once a player leaves the game. However, 2v2, 3v3 and 4v4 game sessions may continue as long as there is at least one player left in each team. Due to the potential changes in the number of players in 2v2, 3v3 and 4v4 games, we inspected and modified the traces manually to include only packets that correspond to the correct number of players. We also excluded the first 10 seconds and last 10 seconds of the trace to avoid any transition effects.

Constructing a traffic model involves dividing the experimental distribution into segments to fit each segment to well-known theoretical distributions such as normal, beta, gamma and triangular distributions. The distribution with the most visual closeness and the smallest R^2 value is chosen to represent the segment. All the fitted distributions for each segment resulted in the R^2 values of greater than 0.99. After assigning theoretical distributions to represent each segment, we use the statistical methods described in [3] and [4] to quantify the goodness of the fit, λ^2.

A. Inter-packet Time

Inter-packet times are computed by measuring the time difference between consecutive packets in the same direction. Based on observation and for simplification, we consider two inter-packet time distributions: client-to-server and server-to-client. There does not appear to be a dominant inter-packet time in both distributions. The average client-to-server inter-packet time is 68.97 ms with the standard deviation of 45.07 ms and the mean of 59.95 ms, while the average server-to-client inter-packet time is 77.62 ms with the standard deviation of 42.86 ms and the median of 77.89 ms. Table I summarizes the mathematical model for client-to-server and server-to-client inter-packet times. We divide each inter-packet time model into five segments, where nine segments out of ten are fitted with beta distributions with various α and β parameters.

TABLE I
SUMMARY OF INTER-PACKET TIME MODELS

	Model	Parameters	λ^2
Client-to-Server Inter-packet Times			
$< 7.0\%, < 3$ ms	uniform		
$< 26.5\%, < 37$ ms	beta	$\alpha = 1.06, \beta = 0.95$	
$< 52.4\%, < 66$ ms	beta	$\alpha = 2.53, \beta = 100.49$	0.06
$< 75.4\%, < 113$ ms	beta	$\alpha = 289.21, \beta = 93.46$	
≤ 150 ms	beta	$\alpha = 14.57, \beta = 3.00$	
Server-to-Client Inter-packet Times			
$< 19.3\%, < 31$ ms	beta	$\alpha = 1.07, \beta = 1.31$	
$< 33.0\%, < 54$ ms	beta	$\alpha = 1.14, \beta = 1.05$	
$< 49.0\%, < 75$ ms	beta	$\alpha = 5.83, \beta = 44.93$	0.18
$< 66.4\%, < 75$ ms	beta	$\alpha = 0.94, \beta = 0.76$	
≤ 200 ms	beta	$\alpha = 3.13, \beta = 2.21$	

B. Packet Size

The packet size here includes the IPv4 header (20 bytes) and the UDP header (8 bytes). The average of client-to-server packet sizes is 55 bytes with the standard deviation of 11 bytes and the median of 52 bytes. About 90% of packets consist of only three packet sizes; 20%, 55% and 15% of packets are 48 bytes, 52 bytes and 63 bytes respectively. About 35% of server-to-client packets are 48 bytes long. Unlike client-to-server packet sizes, the average packet sizes increases from 89 bytes, 116 bytes, 146 bytes to 180 bytes for 1v1, 2v2, 3v3 and 4v4 games respectively. Because the inter-packet time distributions are constant, the Battle.net service must distribute more updates in larger packets due to the presence of more participants. Table II summarizes the mathematical model for client-to-server and server-to-client packet sizes. All client-to-server packets are modeled together, while server-to-client packets are classified by the game type.

IV. SIMULATION AND EMULATION TOOLS

We developed simulation and emulation tools for generating StarCraft II traffic. Both the simulation and emulation tools record StarCraft II packet transmission and reception events. Each event consists of three pieces of information: event type, timestamp and payload size. It is important to note that the payload size does not include the IPv4 and UDP header sizes. The simulation tool generates a log file from the client's perspective on a single machine, and it records packets received from the server and packets sent to the server. The emulation tool, however, requires executing scripts in server mode on one machine and in client mode on another machine. All the tools and their detailed usage can be found at http://tinyurl.com/sc2model with the traces.

V. SUMMARY

StarCraft II uses a client-server architecture while StarCraft I uses a peer-to-peer architecture. StarCraft I clients utilize more outgoing bandwidth for each additional player in the game, while StarCraft II clients maintain constant client-to-server bandwidth regardless of the number of players. StarCraft I and StarCraft II exhibit distinct packet size and inter-packet size distributions. For StarCraft II, we model inter-packet time distributions for both client-to-server and server-to-client traffic regardless of the number of players. The packet size distribution for client-to-server traffic also remains constant regardless of the number of players while the packet size distribution for server-to-client traffic shifts with regard to the number of players. We segmented each of these distributions, and fit each segment with a uniform, beta, gamma or triangular distribution, constructing the model for StarCraft II network traffic.

TABLE II
SUMMARY OF PACKET SIZE MODELS

	Model	Parameters	λ^2
Client-to-Server Packet Sizes			
$< 18.3\%$, 48 bytes			
$< 73.5\%$, 52 bytes			
$< 75.3\%$, 54-62 bytes	normal	$\mu = 58.87, \sigma = 0.51$	1.73
$< 90.0\%$, 63 bytes			
64-576 bytes	beta	$\alpha = 0.92, \beta = 2.46$	
Server-to-Client Packet Sizes			
2 players			
$< 35.1\%$, 48 bytes			
$< 35.2\%$, 55-97 bytes	triangular	$a = 58.59, b = 85.17$	
		$c = 81.03$	
$< 62.5\%$, 99-104 bytes	triangular	$a = 98.93, b = 101.14$	
		$c = 98.99$	0.35
$< 69.0\%$, 105-110 bytes	beta	$\alpha = 1.04, \beta = 3.10$	
$< 80.8\%$, 111-116 bytes	gamma	$\mu = 1.16, \sigma = 1.40$	
117-576 bytes	gamma	$\mu = 0.92, \sigma = 18.37$	
4 players			
$< 33.6\%$, 48 bytes			
$< 34.2\%$, 54-108 bytes	gamma	$\mu = 0.02, \sigma = 6.31$	
$< 50.2\%$,134-139 bytes	triangular	$a = 133.99, b = 136.20$	
		$c = 134.00$	0.07
$< 55.9\%$, 140-145 bytes	gamma	$\mu = 1.07, \sigma = 0.75$	
$< 69.6\%$, 146-151 bytes	gamma	$\mu = 1.72, \sigma = 0.83$	
152-576 bytes	beta	$\alpha = 0.93, \beta = 2.88$	
6 players			
$< 32.6\%$, 48 bytes			
$< 32.9\%$, 54-108 bytes	gamma	$\mu = 0.04, \sigma = 17.88$	
$< 34.2\%$, 152-157 bytes	triangular	$a = 151.89, b = 154.37$	
		$c = 151.95$	0.15
$< 34.9\%$, 158-163 bytes	gamma	$\mu = 1.06, \sigma = 0.96$	
$< 36.4\%$, 164-169 bytes	gamma	$\mu = 1.09, \sigma = 1.68$	
170-576 bytes	beta	$\alpha = 0.95, \beta = 2.50$	
8 players			
$< 28.7\%$, 48 bytes			
$< 29.7\%$, 54-108 bytes	gamma	$\mu = 0.12, \sigma = 23.06$	
$< 36.4\%$, 205-210 bytes	triangular	$a = 204.85, b = 207.87$	
		$c = 204.91$	0.01
$< 40.3\%$, 211-216 bytes	beta	$\alpha = 0.72, \beta = 2.42$	
$< 49.1\%$, 217-222 bytes	beta	$\alpha = 1.11, \beta = 2.70$	
223-576 bytes	beta	$\alpha = 0.98, \beta = 3.02$	

REFERENCES

[1] M. Claypool, D. LaPoint, and J. Winslow, "Network Analysis of Counter-strike and Starcraft," in *Proceedings of the 22nd IEEE International Performance, Computing, and Communications Conference (IPCCC)*, Phoenix, AZ, USA, April 2003.

[2] A. Dainotti, A. Pescape, and G. Ventre, "A Packet-level Traffic Model of Starcraft," in *Proceedings of the second international workshop on Hot Topics on Peer-to-Peer Systems (HOT-P2P)*, La Jolla, CA, USA, July 2005.

[3] S. P. Pederson and M. E. Johnson, "Estimating Model Discrepancy," *Technometrics*, vol. 32, no. 3, pp. 305–314, August 1990.

[4] J. Lakkakorpi, A. Heiner, and J. Ruutu, "Measurement and Characterization of Internet Gaming Traffic," Helsinki University of Technology, Networking Laboratory, Espoo, Finland, February 2002.