ENSC 835: HIGH-PERFORMANCE NETWORKS

Online Interactive Game Traffic: A Survey & Performance Analysis on 802.11 Network

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Final Project

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Abstract

With rapid growth of notebooks and mobile devices, the wireless local area network (WLAN) is expected to carry more vast varieties of traffic. While traffic such as file transferring, voice and video are carefully studied, online interactive game traffic has not yet received much attention with respect to its growing share in today's Internet traffic. Some papers had analyzed and proposed traffic models to various types of online interactive games. This project presents a survey on 3 types of online game traffic, and utilizes one of the proposed models to investigate the WLAN performance with the selected type of game traffic load. Specifically, the performance of an IEEE 802.11 network with a first person shooting game, Counter Strike, traffic load is studied.

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1. Introduction

IEEE 802.11 is one of the primary protocols in wireless local area networks (WLAN). With increasing popularity of notebooks and mobile devices, it is expected that the WLAN will handle vast varieties of network traffic types. Traffic like data transferring, voice and video had been carefully studied. Algorithms such as reliable data transfer, compression and buffering have been developed specifically to improve transferring of these types of traffic. On the other hand, few algorithms are dedicated to serve the purpose of optimizing online interactive gaming traffic.

In a study on wide area IP traffic pattern [1], it reported that 3~4% of all packets in a backbone network could be associated with only six popular games. This study was published in year 2000. The game traffic occupancy can only go up higher this date. The increase popularity of online game is world wide, and a huge market potential is associated with it. Online interactive games can charge fee when clients establishing connection to game servers. Such a sales strategy easily eliminates the software pirating problem, and generates ongoing revenue for as long as the game service is provided.

WLAN and online interactive games are both the trends in network communication. It is interesting to see how well can a WLAN handle such a latency-intolerant application. On top of that, no specific algorithm is developed to serve the quality of service of this type application.

This project starts with a survey of previous studies on various types of online interactive games, including the game architecture, traffic traits and possible proposed traffic model. Only one of the game traffic models, Counter Strike, is chosen for simulation to investigate the feasibility of playing online interactive game over a WLAN. The network performance is evaluated via OPNET simulation version 11.0.

A survey on different types of online interactive games is presented in Section 2. The topology, simulation setup and traffic model manipulation is discussed in Section 3. The simulation result is presented and discussed in Section 4. Finally, we end with conclusions and future improvements in Section 5.

2. Characteristics of Online Interactive Games

By nature, video games usually involve a lot of actions that require fast response (ie. low latency), and lost packet retransmission is impractical in the circumstance. As a result, traffic generated by online interactive games usually consists of burst of small UPD (User Datagram Protocol) packets. The traffic is also highly periodic due to the necessary status updating among the players and the game server. The periodicity depends on the game dynamic requirement. In some cases, traffic generated exhibits short term temporal dependence.

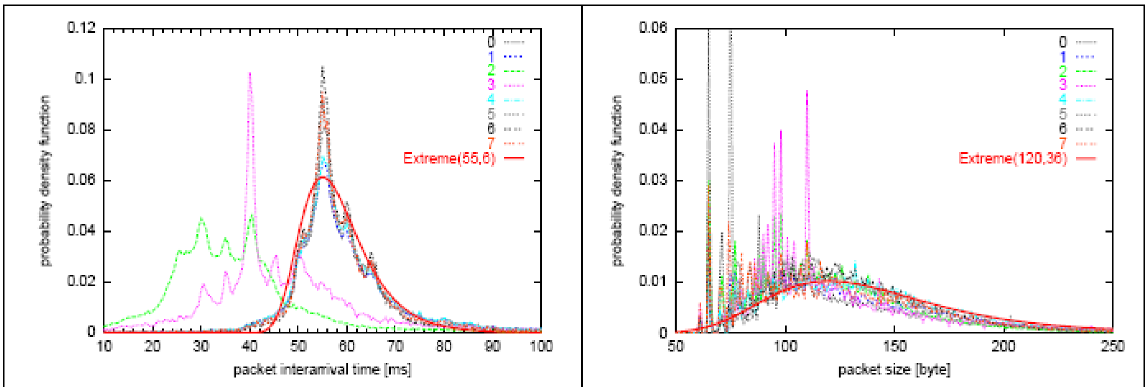
Online interactive games are divided into classes based on the game nature. In this paper, three major types of online games are described, and previous studies on their traffic characteristics are also outlined.

2.1. First Person Shooting

First person shooting game is a type of action game where players join in teams and fight against each other. Each player is equipped with a gun or a weapon to attack others' life point. The goal is to defeat the other teams. One of the very popular games of this type is called Counter Strike.

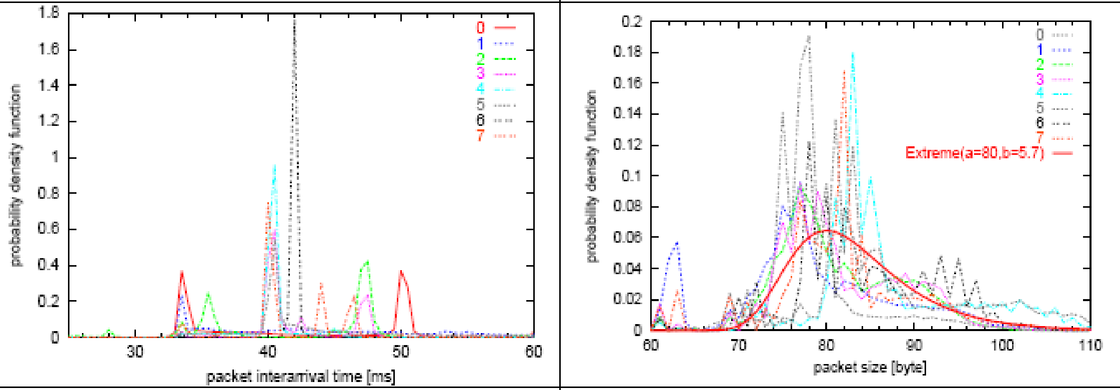
Counter Strike is a client-server type of application where players connect to a centralized server. In the game, two teams join the same game map and continue to play back-to-back rounds of shooting. In [2], Färber studied data generated at a 36-hour LAN party with 50 participants. Several matches with 8 to 30 active players are observed.

Server traffic (from server to clients) has a bursty nature when the server sends packets to each client every cycle to update status of other participants. As a result, the aggregate traffic flow of a server depends on the number of active players. On the other hand, clients attempt to synchronize their game states with the server, and at the same time sending their new status to the server. The observed client traffic (from clients to server) has an almost constant packet data rate. Figure 1 illustrates the traffic probability density function (PDF) of only 8 out of 27 players in the first match.



(a) PDF of Server Traffic Packet Inter-arrival Time per Client

(b) PDF of Server Traffic Packet Size per Client



(c) PDF of Client Traffic Packet Inter-Arrival Time per Client

(d) PDF of Client Traffic Packet Size per Client

Figure 1. Server and Client Traffic for Counter Strike

Note that Figure 1(a) has two clients with relatively lower PDF's, but the other 24 clients show almost identical pattern. Färber suggested traffic models in terms of packet inter-arrival time and packet size to characterize the Counter Strike traffic.

Table 1 lists the best fit server-to-client and client-to-server traffic models, and the model is plotted in Figure 1 as well.

Table 1. Counter Strike Traffic Model

	Server per client	Client
Inter-arrival time (ms)	Extreme (a=55, b=6)	Deterministic (40)
Packet size (byte)	Extreme (a=120, b=36)	Extreme (a=80, b=5.7)

The Extreme Value distribution can be expressed as its PDF in the following equation, where *a* is the location of the distribution and *b* is the scale.

$$f(x) = \frac{1}{b} e^{-\frac{x-a}{b}} e^{-e^{-\frac{x-a}{b}}}, \quad b > 0 \tag{1}$$

A few other distributions such as shifted Lognormal or shifted Weibull are also ideal to model the traffic. Färber chose Extreme Value distribution particularly to compare with previous related work.

In Counter Strike, game maps typically rotate every 30 minutes to allow loading of new maps and new acceptances of players. As a result, other than frequent periodic burst of small UDP packet during a game session, the game server experiences a dip in load when the map is changed. The traffic load of a typical Counter Strike server is depicted in Figure 2 [3].

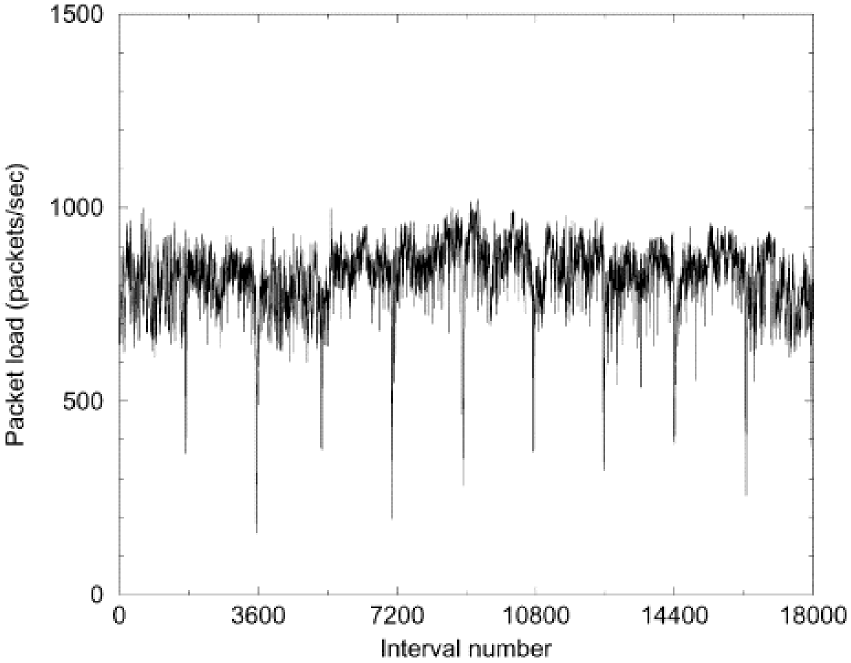


Figure 2. Total Server Packet Load Plotted for 1sec Interval

This data was collected by Feng *et al.* from a popular Counter Strike server, and the server is configured with a maximum capacity of 22 players. The plot is generated based a 7-day trace file with 1 second data sampling rate. A noticeable dip is observed every 30 minutes, which is solely due to the server performing local tasks for a map change over.

2.2. Real-time Strategy

Another type of online interactive game is real-time strategy game. Players join the same game map, and start building their own troops. The players have the option of forming an ally. The goal of the game is to develop an effective strategy to wipe out opponents' troops. A representative game of this type is called Starcraft.

Starcraft is a synchronous Peer-to-Peer application, and one game map can support up to 8 players. Players themselves form a network, and every computer calculates the position and action of the players. At the beginning of a game session, one player acts as a listen server (the game host) to wait for others to join the session. During this phase, TCP (transmission control protocol) packets are sent back and forth to setup the connection. After the game started, UDP is employed as the transport protocol to minimize latency.

In [4], Dainotti *et al.* collected traffic traces from 4, 6 and 8-player games. They analyzed the traffic in terms of IAT (Inter Arrival Time), IDT (Inter Departure Time), PSI (Packet Size – Input) and PSO (Packet Size – Output) from the point of view of a participated station. Dainotti *et al.* split PSI, PSO and IDT of a 6-player scenario traffic into parts and modeled each part separately. Table 2 [4] lists the analytical results obtained from a 6-player scenario.

Table 2. Starcraft Traffic Analysis for 6-player Scenario

	Model
IAT (sec)	Exponential (μ=0.043633)
IDT (sec)	Deterministic (0), for probability of 66.2% Uniform (a=0.05, b=0.17), for probability of 27.8% Deterministic (0.21), for probability of 6%
PSI (byte)	Deterministic (16), for probability of 3.2% Deterministic (17), for probability of 10.8% Deterministic (23), for probability of 72.4% Deterministic (27), for probability of 6.2% Deterministic (33), for probability of 7.4%
PSO (byte)	Deterministic (16), for probability of 6.2% Deterministic (17), for probability of 10.9% Deterministic (23), for probability of 74.2% Deterministic (27), for probability of 8.7%

IAT and IDT are both very short. The IDT is 0 second more than 66% of the time. This implies that each participant constantly sends copies of packets to other players to update his or her status. These packets travel through different paths and arrive at each player at different time, resulting in slightly inconsistent in inter-arrival time. Thus, IAT is less concentrated at particular time point, and is modeled by an Exponential distribution with a very small mean.

As of the packet size, more than 70% of chances that both inbound and outbound traffic has a packet payload of 23 bytes, and approximately 90% of the time that the PSI and PSO payload are smaller than 23 bytes. If we consider a typical IP (Internet Protocol) header of 20 bytes and a typical UDP header of 8 bytes, the combined header is bigger than the payload itself. It is obvious that approximately half of the traffic load actually comes from the communication protocol.

2.3. MMORPG

MMORPG (Massive Multiplayer Online Role Playing Games) is another type of online interactive game. In MMORPG, each player creates a role and plays as that role inside the game world. Each character advances to the next level by engaging in combats with artificially created monsters in the game world. The goal of the game is to accomplish game-designed missions to acquire prizes or generally advance the role to higher levels to defeat an even stronger monster.

MMORPG is a client-server application, but unlike first person shooting and real-time strategy games, a game map usually is much bigger. MMORPG can support thousands or even hundreds of thousands of concurrent players. Since the game world is too large to support by a single computer, game activities are divided into groups. Clusters of servers together support several game worlds. To avoid cheating, game servers perform the game logic and store the status of each role in the database. The standard MMORPG infra-structure is illustrated in Figure 3 [5].

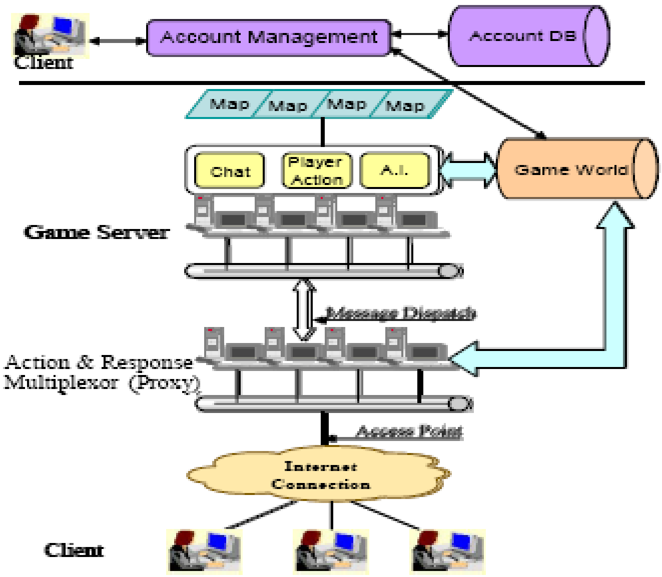


Figure 3. Standard Infra-structure of an MMORPG

In [6], Chen *et al.* studied the traffic trace collected from a MMROPG server, ShenZhou Online in this case. To some surprises, most MMORPG's in Asia exchange packets using TCP. An online role playing game generally is much less action intensive than first person shooting or real-time strategy games. With more latency tolerance, the precision of the game may be of pursuit. However, they found out that the 98% of client packets have payload size smaller than or equal to 31 bytes. With TCP headers and its reliable transfer algorithm, protocol headers takes up 73% of the transmission load, and TCP acknowledgement alone takes up 30% of the load [6]. As of the server, server packet size is bigger and has a wider distribution with average payload of 114 bytes. Figure 4 [6] shows the complementary distribution function of the payload size of the server and client traffic.

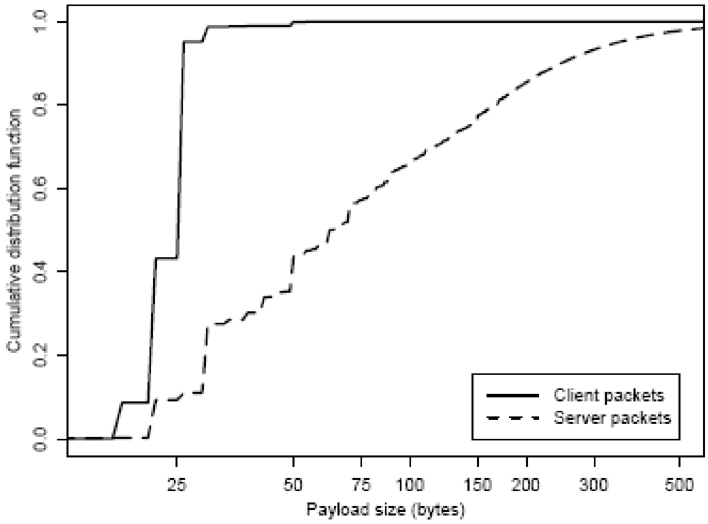


Figure 4. Payload Size Distribution of Server and Client Traffic for ShenZhou Online

Traffic in MMORPG also exhibits high periodicity. In ShenZhou Online, server updates the positioning of nearby objects or characters within certain metrics in multiples of 5 Hz (ie. every 0.2sec, 0.1sec and 0.06sec). In other words, objects closer to a player's role are refreshed more often the far objects. The client in return sends out movements or commands in multiples of 6 Hz (ie. every 0.16sec, 0.08sec and 0.05sec). The frequency of client movements depends on the skill level or weapon held by each role. Figure 5 [6] illustrates the power spectral density of client and server traffic for ShenZhou Online. Server traffic is cleaner (more concentrated) because the trace file was collected at the server side. Client traffic travels across the Internet and experiences different delays when arrives at the server, resulting in more diverse arrival rate.

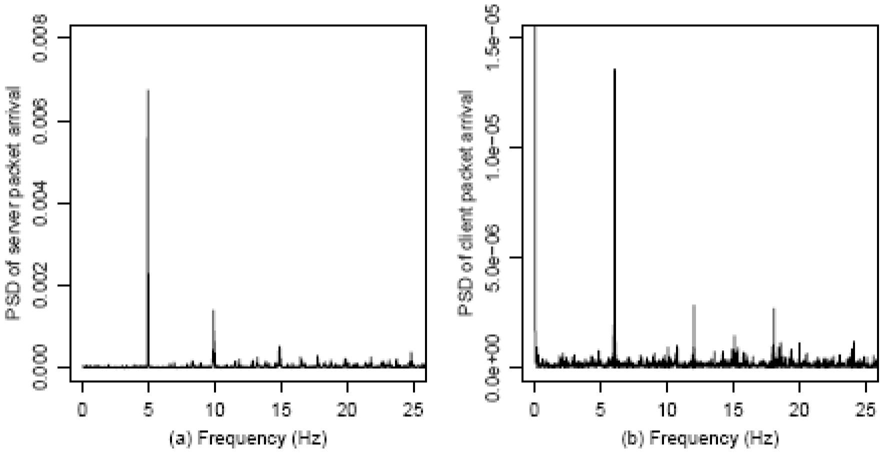


Figure 5. Power Spectral Density of Sever and Client Traffic for ShenZhou Online

Other major findings includes that the both server and client traffic exhibits a short term positive auto-correlations. This can be explained by spatial locality of the move-by objects as the role moves around the game map. However, such an auto-correlation still exists in aggregated traffic. This is thought to be caused by the global game world event.

2.3.1. Attempts to Collect MMORPG Trace

I had attempted to collect trace myself for another MMORPG. Based on the inbound and outbound traffic collected from my computer, I could obtain the client traffic and the server per client traffic. I tried to use Windows version of tcpdump, WinDump[1], but due to probable software conflict, WinDump failed to run on my computer.

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[1] http://www.winpcap.org/windump/default.htm

3. OPNET Simulation Setup

Among all game types, I chose Counter Strike traffic model proposed by Färber [2] to analyze its performance on a 802.11 WLAN. Färber provided a relatively simple to use model. In addition, Counter Strike is one of the most popular online games, and it is a very action intensive. Consequently, it would be more interesting to see how well 802.11 handle this kind of applications. Before going into the simulation, it is important to have an overview of the network topology and the settings. Please note that the simulation tool used in this project is OPNET version 11.0.

3.1. Network Topology & Settings

Counter Strike is a client-server based application, and therefore the network topology includes wireless stations acting as clients and a wire-lined Ethernet station acting as the game server. The wireless stations are enabled with 802.11 protocol, and they are connected to a bridge acting as an access point (AP). The bridge is then connected to the game server via a 100Mbps link. Figure 6 illustrates the general network topology of this project.

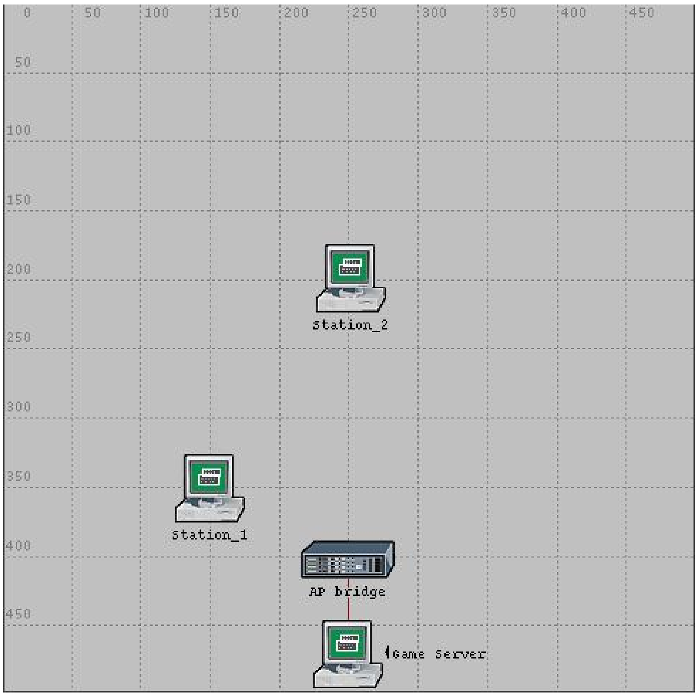


Figure 6. General Network Topology

Since this project focuses on evaluating the performance of 802.11, the network elements chosen involve only up to the medium access control (MAC) layer. Stations instead of workstations (involved TCP layer) [7] are chosen for both wireless stations and game server. A simple 2-layer wireless bridge is in place as the AP instead of a complicated router. Figure 7 shows the node model of the wireless station. Higher layers are simplified to a traffic source and sink.

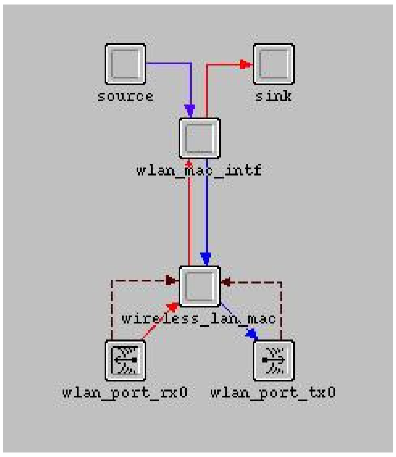
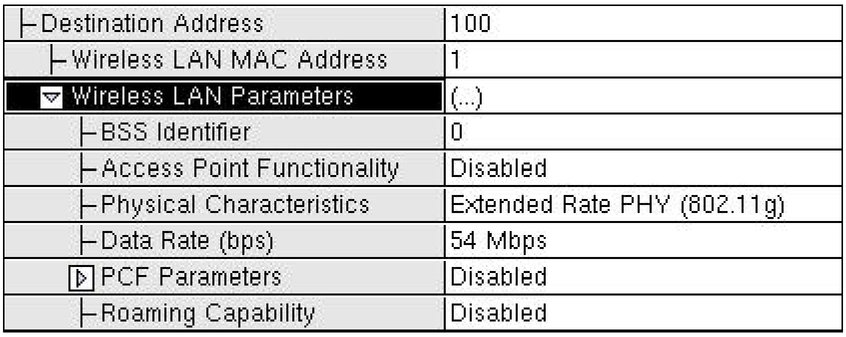


Figure 7. Node Model for Wireless Stations

All network elements reside on a 500x500 meters campus map. Stations and the game server send information back and forth to update and synchronize the game state. Each station is configured identically except the MAC address. Figure 8 shows the key settings of the wireless stations.



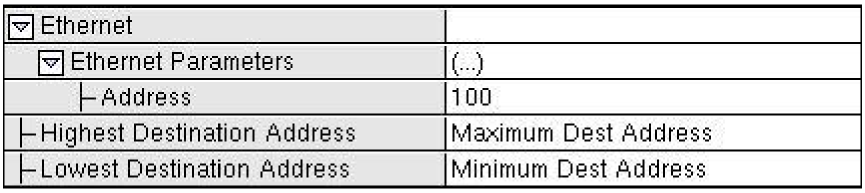
Destination Address	100
Wireless LAN MAC Address	1
Wireless LAN Parameters	(...)
BSS Identifier	0
Access Point Functionality	Disabled
Physical Characteristics	Extended Rate PHY (802.11g)
Data Rate (bps)	54 Mbps
PCF Parameters	Disabled
Roaming Capability	Disabled

Figure 8. Wireless Settings of the Stations

The destination address is the address of the game server, which is 100 in this case. Each station is then assigned with a unique MAC address, but all stations belong to the same basic service set (BSS). In 802.11 Standard, a station can also configure as an AP as well, but this functionality is not necessary in this project. Thus the access point functionality is disabled for all stations. The point coordination function (PCF) of 802.11 Standard is disabled to simplify the protocol architecture. Lastly, I assume players do not travel around with their laptop while they play the game. Thus, the roaming capability of the stations is disabled as well.

Furthermore, among several standards in the 802.11 family, I chose 802.11g with the highest data rate of 54Mbps in order to have the most optimized wireless environment. Though the recently released 802.11e Standard contains better quality of service algorithm, 802.11e is not yet available in standard OPNET wireless LAN package.

As of the server, it is assigned with an address number of 100, and its destination address includes all wireless stations ranging from the minimum address to the maximum address in the network. As a result, the server traffic is sent to all stations in the wireless network. Figure 9 shows the server network settings.



▽ Ethernet	
▽ Ethernet Parameters	(...)
├ Address	100
├ Highest Destination Address	Maximum Dest Address
├ Lowest Destination Address	Minimum Dest Address

Figure 9. Game Server Network Settings

3.2. Traffic Model & Assumptions

The Counter Strike model used in this project is the one proposed by Färber [2]. The model was listed in Section 2.1, and is listed again in Table 3.

Table 3. Counter Strike Traffic Model

	Server per client	Client
Interarrival time (ms)	Extreme (a=55, b=6)	Deterministic (40)
Packet size (byte)	Extreme (a=120, b=36)	Extreme (a=80, b=5.7)

This traffic model is subject to assumptions as indicated in [2]. First of all, each player behaves independently and generates client traffic independent of each other. Secondly, the total server traffic changes with respect to the number of clients, but the server per client traffic remains independent to the number of clients. Finally, the client traffic is independent to the corresponding server traffic. Note that this model provides the traffic distribution when the game is active. However, the server traffic experiences a dip in load every 30 minutes during a map change over. This characteristic can be modeled by specifying the duration of the packet generation. OPNET uses ON and OFF State time to capture this attribute. Packet only generated during the ON State time, and no packet is generated during the OFF State time.

3.3. Server Traffic Modification

The server traffic model given in previous section is a per-client basis. In this project scenarios with different number of stations within a BSS are simulated. Thus, the server traffic should be adjusted with respect to the number of stations.

Based on the second assumption in the previous section, each client should receive the same amount of packets from the server. The packet size of each updating packet sent from the server traffic should remain pretty stable. Nevertheless, the aggregate server traffic should increase with respect to the number of stations. Consequently, in order to change the aggregated server traffic, I modified the inter-arrival time of the server traffic. The amount of total server traffic should double when the number of client is doubled because the same information is sent to twice as many stations. By halving the mean inter-arrival time of the server traffic, the total amount of the traffic sending from the server to clients is doubled.

According to the OPNET documentation [8], Extreme Value distribution is depicted the same as in equation (1) in Section 2.1. To halve the inter-arrival time, I divide the mean by two. The mean of Extreme Value distribution can be expressed as in equation (2) [8].

$$E(x) = a - b \cdot \Gamma'(1)\,, \quad \Gamma'(1) = -0.57721 \tag{2}$$

Assuming the scale factor, *b*, remains the same, I can calculated the value of *a* if I want to half the mean. Table 4 lists all server traffic modifications done in this project.

Table 4. Server Traffic Modifications

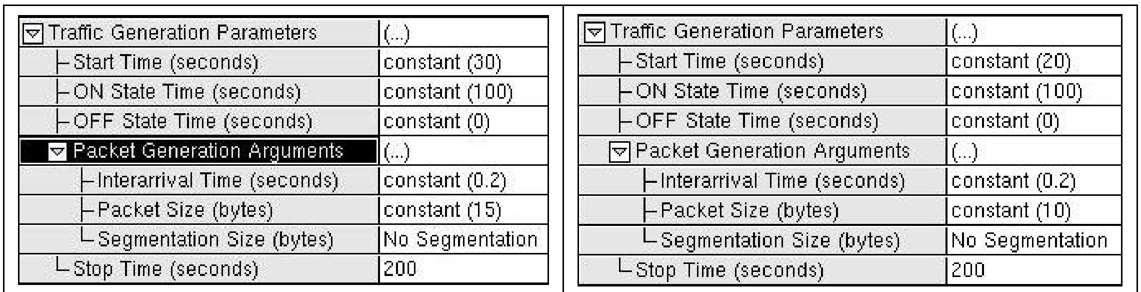
Number of Stations	Interarrival time (ms)	Packet Size (byte)
1	Extreme (a=55, b=6)	Extreme (a=120, b=36)
3	Extreme (a=16.024, b=6)	Extreme (a=120, b=36)
5	Extreme (a=8.229, b=6)	Extreme (a=120, b=36)
8	Extreme (a=3.844, b=6)	Extreme (a=120, b=36)

4. Simulation & Discussion

Before applying Counter Strike traffic to the network, I first start with a verification run with constant rate of traffic sending back and forth between the wireless stations and the game server.

4.1. Verification Scenario

The verification network topology is the same as in Figure 6 in Section 3.1. The network consists of one game server which generate a constant 600bps of load destined to two wireless stations (Station 1 and 2) starting at time equals to 20 seconds. The two stations each generate constant 400bps of traffic to send to the game server starting at time equals to 30 seconds. The packet generation lasts for ON State Time of 100 seconds, and it stops for 0 second. Then the generation cycle continues. However, all traffic is configured to stop at time equals to 200 seconds. Figure 10 shows the traffic settings of the game server and the stations.



Traffic Generation Parameters	(...)
├ Start Time (seconds)	constant (30)
├ ON State Time (seconds)	constant (100)
├ OFF State Time (seconds)	constant (0)
Packet Generation Arguments	(...)
├ Interarrival Time (seconds)	constant (0.2)
├ Packet Size (bytes)	constant (15)
└ Segmentation Size (bytes)	No Segmentation
└ Stop Time (seconds)	200

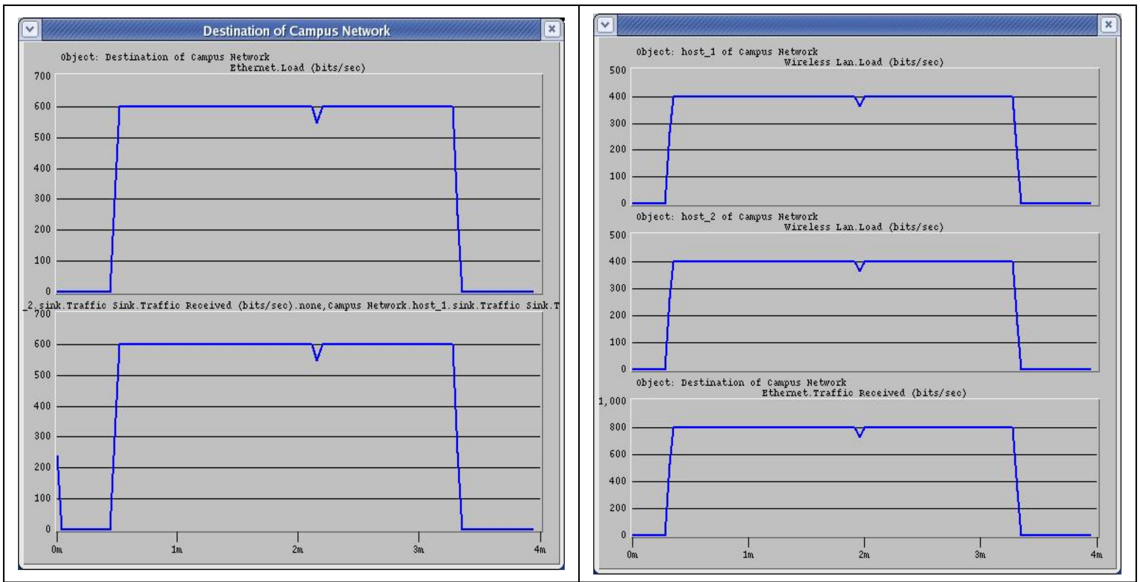
(a) Game Server Traffic Generation

Traffic Generation Parameters	(...)
├ Start Time (seconds)	constant (20)
├ ON State Time (seconds)	constant (100)
├ OFF State Time (seconds)	constant (0)
Packet Generation Arguments	(...)
├ Interarrival Time (seconds)	constant (0.2)
├ Packet Size (bytes)	constant (10)
└ Segmentation Size (bytes)	No Segmentation
└ Stop Time (seconds)	200

(b) Station Traffic Generation

Figure 10. Traffic Generation Settings – Verification Scenario

If the network is configured properly, the traffic received at the receiving side should equals to the traffic sent at the sending side. Figure 11 shows the traffic received versus traffic load for both directions.



(a) Game Server Load vs. Total Traffic Received by Stations	(b) Total Stations Load vs. Game Server Traffic Received

Figure 11. Sending Traffic Load vs. Traffic Received – Verification Scenario

In Figure 11a, the top graph shows a constant traffic load of 600bps starting from t=30 seconds at the game server. The constant traffic continues for 100 seconds and dips a little bit during the ON State and OFF State change over. The traffic generation then ends at t=200 seconds as specified. The bottom graph is the sum of traffic received by the two stations, and it indicates that all packets are successfully by the wireless stations. The little spike at the beginning of traffic received came from the Bridge Protocol Data Units sent by the AP-bridge at the initialization of the network.

Figure 11b shows the traffic in the other direction (from stations to the game server). The top two graphs represent the constant 400bps traffic generation at Station 1 and 2. The dip is again due to the ON and OFF State change over. A total of constant 800bps traffic has been received by the server as shown in the bottom graph. The result indicates that the network links are properly configured, and the end systems can communicate successfully.

4.2. Counter Strike Traffic with 3 Stations

The network topology of the 3-station scenario is illustrated in Figure 12.

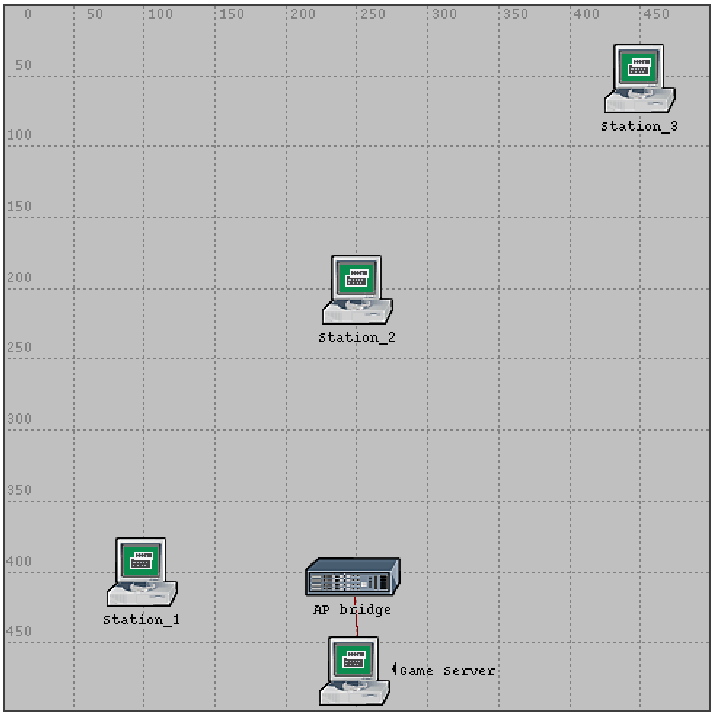


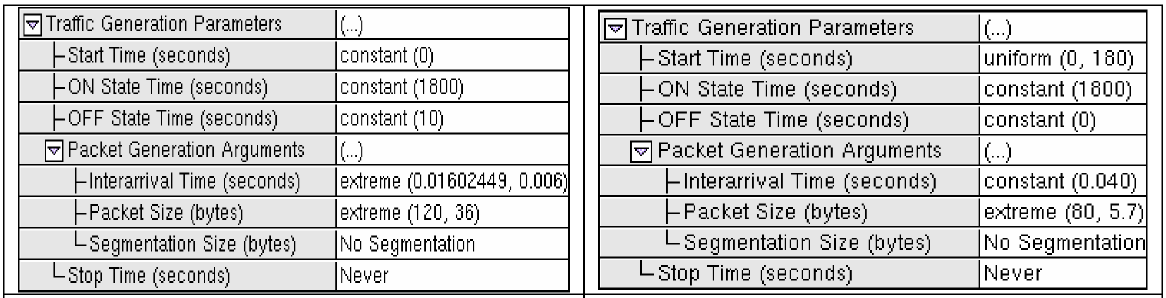
Figure 12. Network Topology for 3 Counter Strike Stations

The stations are scatter in the 500x500 meters map, where the distance to the AP is summarized in Table 5.

Table 5. Distances Between Stations and the AP – 3-Station Scenario

	Station1	Station2	Station3
Distance to AP	150m left	200m above	403m top-right

The stations and the server are loaded with the traffic model described in Section 3.2 with only one modification on the server inter-arrival time as described in Section 3.3. The server traffic is adjusted to 3-station load with an Extreme (a=16.024, b=6) distribution. Figure 13 indicates the server and client traffic settings for this scenario. I assume the server starts to send traffic at time 0, and the stations start to join the game with a uniform probability bewteen 0 to 3 minutes. The ON State Times are set to 30 minutes to correspond to one Counter Strike game session. The OFF State Time of the server is set to 10 seconds to indicate a dip in load during the map change over, but the clients remain connected during this brief change over. Both traffic patterns never stop until the end of the simulation. The total simulation time is set to 45 minutes to have fair amount statistic collection.



▽ Traffic Generation Parameters	(...)
├ Start Time (seconds)	constant (0)
├ ON State Time (seconds)	constant (1800)
├ OFF State Time (seconds)	constant (10)
▽ Packet Generation Arguments	(...)
├ Interarrival Time (seconds)	extreme (0.01602449, 0.006)
├ Packet Size (bytes)	extreme (120, 36)
└ Segmentation Size (bytes)	No Segmentation
└ Stop Time (seconds)	Never

(a) Game Server Traffic Generation

▽ Traffic Generation Parameters	(...)
├ Start Time (seconds)	uniform (0, 180)
├ ON State Time (seconds)	constant (1800)
├ OFF State Time (seconds)	constant (0)
▽ Packet Generation Arguments	(...)
├ Interarrival Time (seconds)	constant (0.040)
├ Packet Size (bytes)	extreme (80, 5.7)
└ Segmentation Size (bytes)	No Segmentation
└ Stop Time (seconds)	Never

(b) Station Traffic Generation

Figure 13. Traffic Generation Settings – 3-Station Scenario

4.2.1. Results and Discussions – 3-Station Scenario

Several statistics are collected for all wireless stations, AP-bridge and the server. One of the most important statistics is the end-to-end (ete) delay. The ete-delay is measured from the generation of the packet at the server to the reception of the packet at the station right before the packet being passed to the TCP layer (traffic sink in station node model, Figure 7). The time-averaged ete-delay is illustrated in Figure 14. Please note that the simulation was done before changing the naming convention from host_1 to Station_1 and etc.

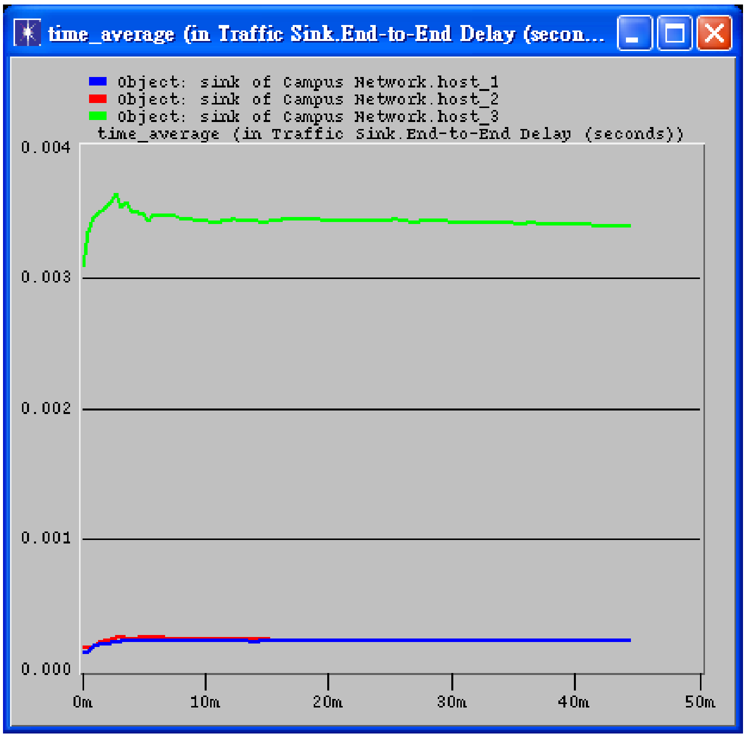


Figure 14. Time-Averaged Station End-to-End Delay – 3-Station Scenario

The ete-delays for first two stations are almost identical and steady at approximately 0.22ms. The ete-delay increases to 3.40ms at Station 3, an almost 17 times increased.

Another important statistic is the packet reception rate. The traffic received measured the rate of traffic that passes through the MAC layer and gets forwarded to higher layers. The time-averaged traffic received at each station is illustrated in Figure 15.

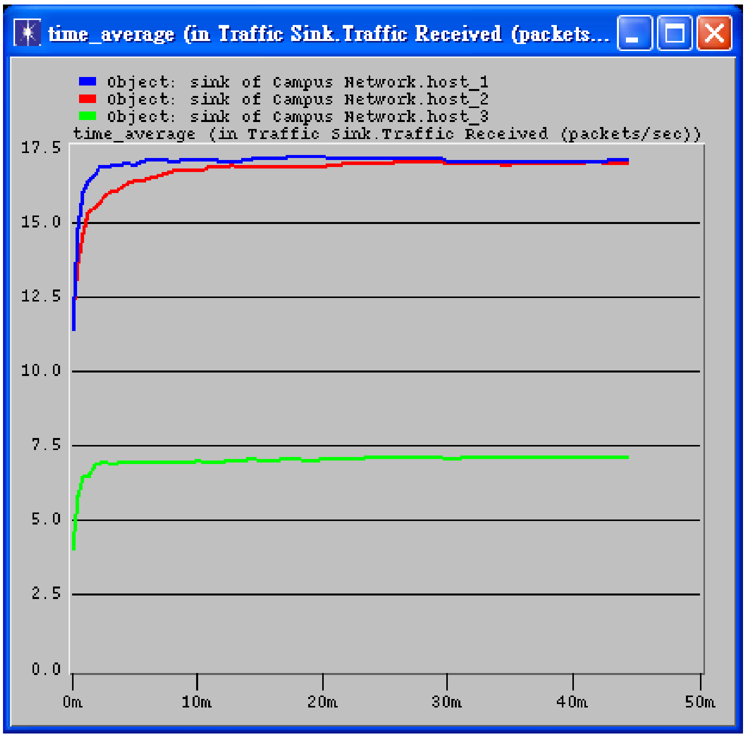


Figure 15. Time-Averaged Station Traffic Received – 3-Station Scenario

The traffic receptions at Station 1 and 2 are not identical but they reach almost the same steady value of approximately 17 packets per second. Station 3 receives packets at a rate of 7.1 packets per second, which is approximately 40% of the first two stations.

One other statistics that measure the transmission ability is the packet drop rate. This statistic is recorded when buffer that stores outgoing traffic overflows, or failure to all retransmission attempts. The buffer sized is set to 32kbytes for this project. Figure 16 shows the packet drop rate for the 3 stations. Station 1 and 2 experience perfect zero transmission drops while Station 3 suffers a time-averaged drop of 10.26 packets per second.

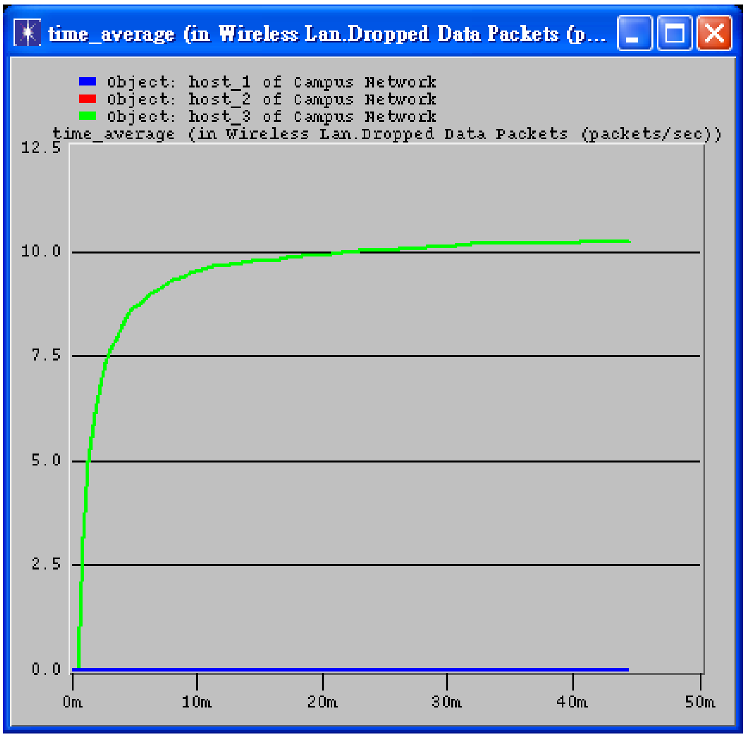


Figure 16. Time-Averaged Packet Drop Rate – 3-Station Scenario

The above results indicate that Station 3 has the worst performance in both reception and transmission. The only difference in Station 3 is its outstanding distance to the AP-bridge. Station 3 is located approximately 403 meters away from the AP while Station 1 and 2 are located 150 meters and 200 meters away respectively. As indicated in OPNET wireless LAN module guide [7], the communication distance for wireless stations is 300 meters as part of the 802.11 Standard. Therefore, stations like Station 1 and 2 receive and transmit with the regular WLAN capability. As a result, inferring from the ete-delay of the first two stations, the 802.11g WLAN is capable of handling the game traffic for 3-station scenario. The major factor of the performance is the distance between the station and the AP.

More statistics are collected and summarized in Table 6. Statistics coloured in black are performance measurements relating to reception, and statistics coloured in blue are measurements relating to transmission.

Table 6. Network Performances – 3-Station Scenario

Statistics	Station 1	Station 2	Station 3
End-to-end Delay (ms)	0.22	0.22	3.40
Traffic Received (pkt/s)	17.1	17.0	7.1
Throughput (kbps)	19.1	19.0	7.3
Control Traffic Received (pkt/s)	86.46	86.46	96.08
Data Traffic Received (pkt/s)	151.50	273.87	33.46
Data Packet Drop (pkt/s)	0	0	10.26
MAC Access Delay (μs)	15.0	2.1	11.1
Control Traffic Sent (pkt/s)	17.06	16.97	7.12
Data Traffic Sent (pkt/s)	24.68	23.69	121.56
Retransmission Attempt (pkt)	0.168	0.168	2957
Backoff Slots (slot)	5.17E3	5.17E3	5.72E5

Control traffic received and data traffic received are traffic received after the physical layer from the WLAN network. At MAC layer, traffic is manipulated and reassembled before passing to higher layers. More headers or management data may involve in the lower layer. This is why the control/data traffic received is higher than the traffic received. Observing from the results, Station 3 receives slightly higher control traffic but it suffers a lot more in data traffic comparing to Station 1 and 2. This result implies that Station 3 spends more resources on getting managed with the AP instead of receiving data.

The MAC access delay records the time it takes for the packet to be sent to the physical layer for the first time from a station. Though the MAC access delay seems to vary across stations, the delay is in microsecond range, which is minor compared to other delay.

The control/data traffic sent is the transmission correspondence of the control/data traffic received. It is also measured at the MAC layer. Station 3 has much higher data traffic sent than the two. This phenomenon can result from Station 3 being unable to detect the busy medium and still sending the data to the network. When the data is sent, it collides with other stations. Retransmission attempt initializes but collisions keep happening due to the bad communication ability to AP-bridge. Thus, the same packet may be sent several times resulting in high data traffic sent. This also explains why retransmission attempts and backoff slots are significantly higher in Station 3. Backoff slot is one of the collision avoidance parameters in 802.11 protocol. The number of backoff slots increases every time a collision happened.

4.3. Counter Strike Traffic with 5 Stations

The network is increased from 3 to 5 stations in this scenario to see the impact on the performance. Figure 17 illustrates the topology and the locations of each station, and Table 7 lists the distance between each station and the AP.

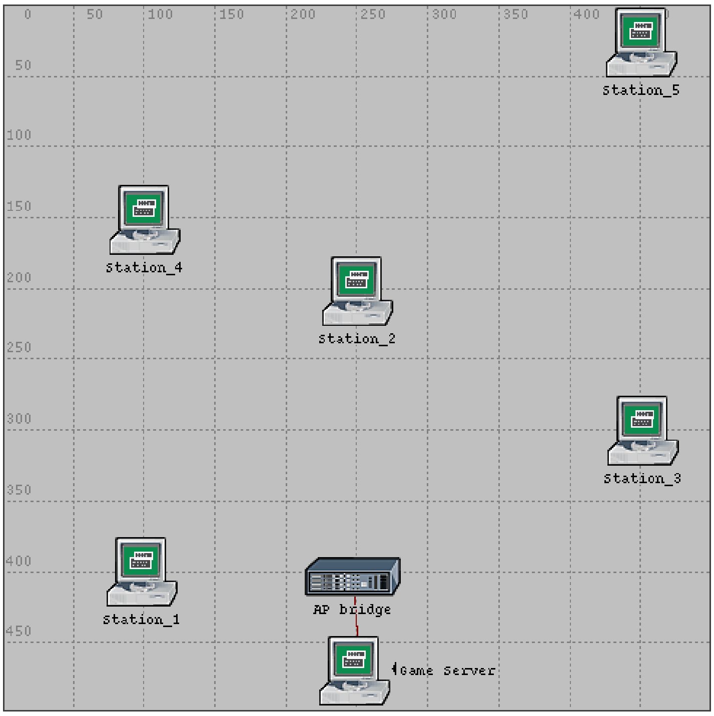


Figure 17. Network Topology for 5 Counter Strike Stations

Table 7. Distances Between Stations and the AP – 5-Station Scenario

	Station1	Station2	Station 3	Station 4	Station 5
Distance to AP	150m left	200m above	224m top-right	291m top-left	425m top-right

The station traffic setting is identical to the 3-station scenario as shown in Figure 13b. The server traffic is also the same as shown in Figure 13a except the adjustment in server inter-arrival time. The new model for server packet inter-arrival time is Extreme (a=8.229, b=6).

4.3.1. Results and Discussions – 5-Station Scenario

The same statistics as in 3-station scenario are collected. The time-averaged ete-delay for 5-station scenario is depicted in Figure 21.

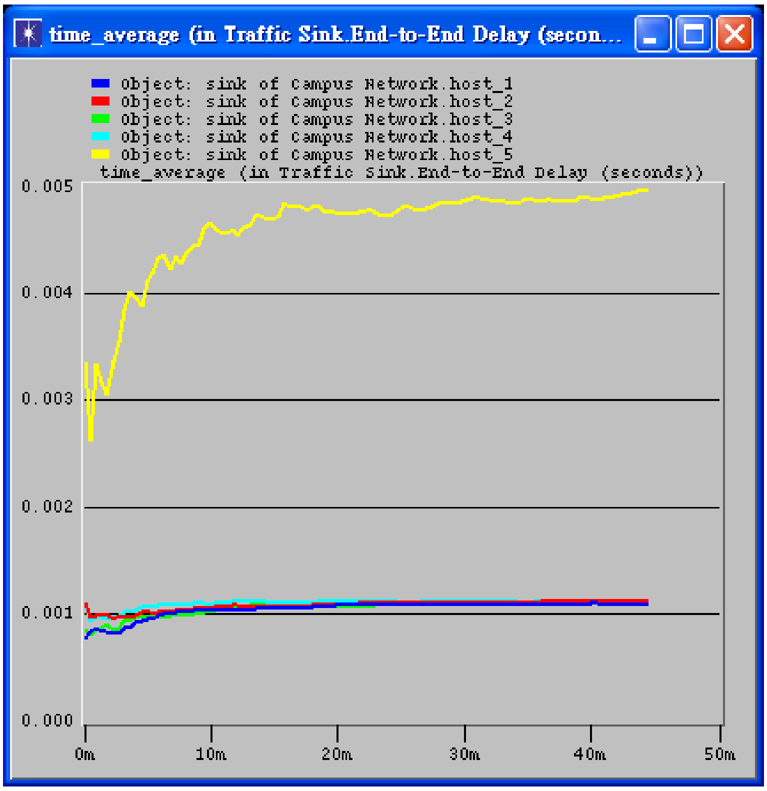


Figure 18. Time-Averaged Station End-to-End Delay – 5-Station Scenario

The ete-delays for first four stations are very similar, and they reach a steady value at approximately 1.10ms. The first 4 stations are located within the 300 meters range from the AP, so they have comparable performance. As of Station 5, its far distance away from the AP has enhanced the ete-delay to almost 5ms, a 17 times increased from the first 4 stations.

The packet received packet reception at Station 5 also suffers to only 5% of the other 4 stations as depicted in Figure 19. Stations 1 to 4 receive packets at 16.6 packets per second while Station 5 receives less than 1 packet per second.

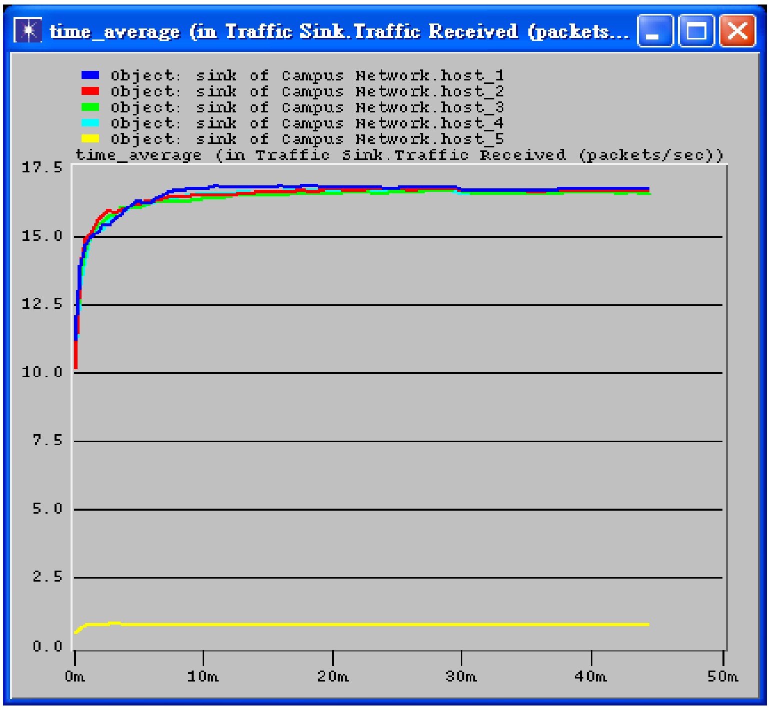


Figure 19. Time-Averaged Station Traffic Received – 5-Station Scenario

As of the packet drop, the first four stations have perfect transmission with zero packet drop. Station 5 drops the packets at a rate of 21.3 packets per second, and it does not show it has reached a steady state yet. The packet drop statistic is illustrated in Figure 20.

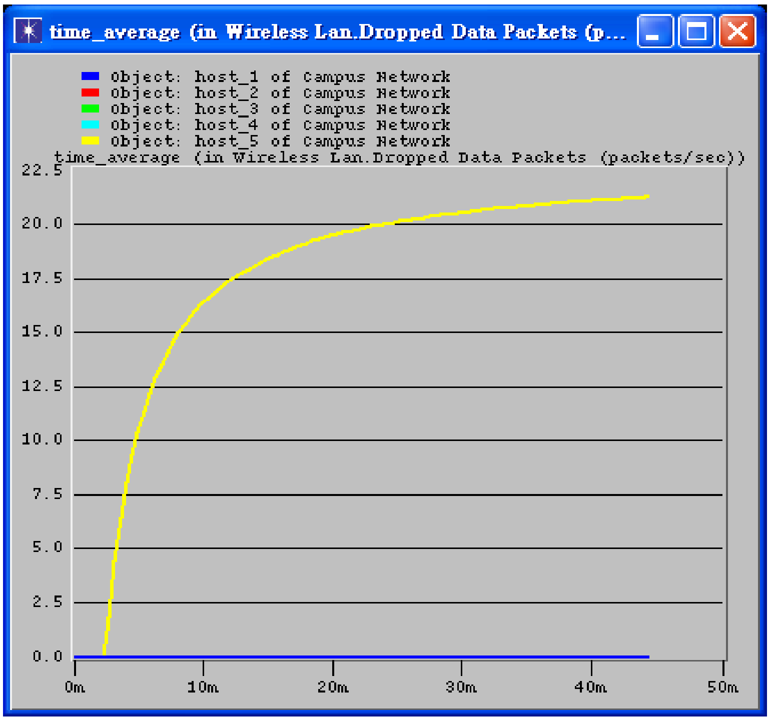


Figure 20. Time-Averaged Packet Drop Rate – 5-Station Scenario

Based on the above results, distance from the station to the AP is still the major factor of WLAN performance. Discarding the out of range stations, the ete-delay increase from 0.22ms in 3-station scenario to 1.10ms in 5-station scenario, a 5 times increased with only two additional stations. This indicates that the network can start to “feel” the load of the traffic.

Other statistics are listed in Table 8, and colour-coded with respect to reception and transmission. Black statistics are reception measurements, and blue statistics are transmission measurements.

Table 8. Network Performances – 5-Station Scenario

Statistics	Station 1	Station 2	Station 3	Station 4	Station 5
End-to-end Delay (ms)	1.09	1.11	1.10	1.12	4.96
Traffic Received (pkt/s)	16.7	16.6	16.6	16.6	0.767
Throughput (kbps)	18.7	18.7	18.6	18.6	0.719
Control Traffic Received (pkt/s)	150	150	150	150	165
Data Traffic Received (pkt/s)	241	410	383	318	62.5
Data Packet Drop (pkt/s)	0	0	0	0	21.3
MAC Access Delay (µs)	3.11	3.11	4.22	8.30	16.0
Control Traffic Sent (pkt/s)	16.7	16.6	16.6	16.6	0.767
Data Traffic Sent (pkt/s)	23.9	23.9	23.9	23.9	157
Retransmission Attempt (pkt)	0.192	0.192	0.194	6.14	4455
Backoff Slots (slot)	5.21E3	5.21E3	5.21E3	5.21E3	1.02E6

The MAC access delay is still in the microsecond range, but the trends of having longer access delay at further stations begins to show. Station 5 sends a huge amount to data traffic to the network due to high collisions with other stations, the same reasoning as explained in 3-station scenario. The high retransmission rate also reflects on the backoff slot number.

4.4. Counter Strike Traffic with 8 Stations

This scenario contains 8 stations playing Counter Strike. Figure 21 illustrates the network topology and the location of each station is listed in Table 9.

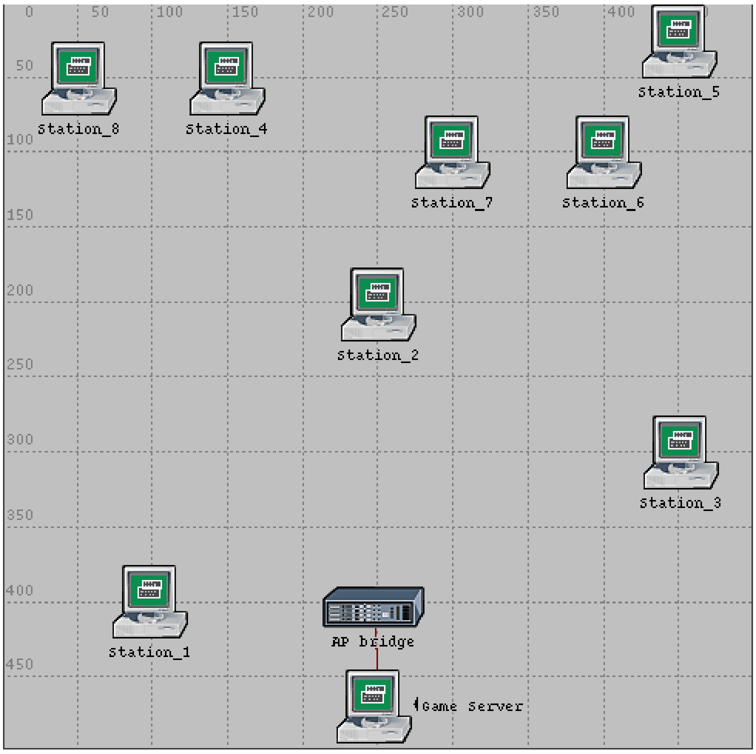


Figure 21. Network Topology for 8 Counter Strike Stations

Table 9. Distances Between Stations and the AP – 8-Station Scenario

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
Distance to AP	150m	200m	224m	364m	425m	335m	304m	403m

The traffic setting is the same as the 3 and 5-station scenarios. Only the server packet inter-arrival time is adjusted to support 8 stations, and it is modeled with Extreme (a=3.845, b=6) distribution.

4.4.1. Results and Discussions – 8-Station Scenario

Same statistics as the first two scenarios are collected. Figure 22 shows the time-averaged ete-delay across all stations. Figure 23 illustrates the time-averaged traffic received, and Figure 24 shows the transmission packet drop rate.

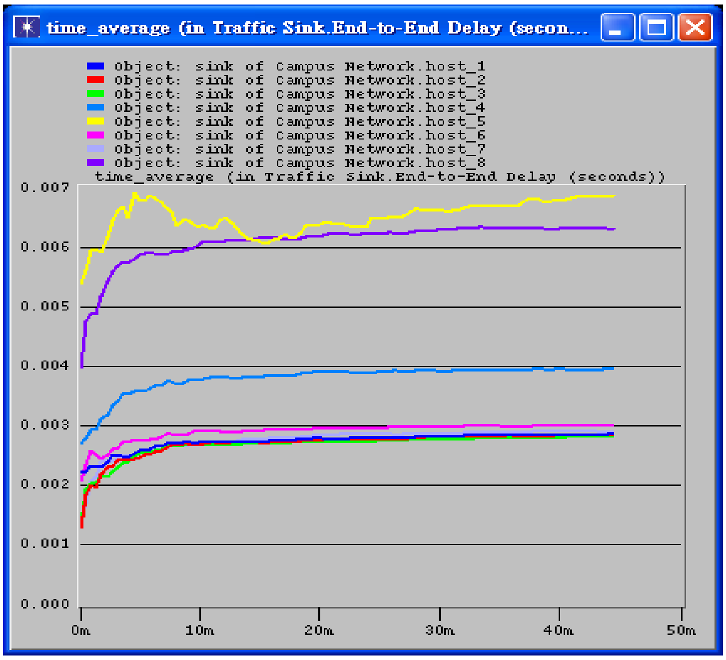


Figure 22. Time-Averaged Station End-to-End Delay – 8-Station Scenario

We can start to observe a gradual increased in ete-delay across the stations starting at 335 meters. Stations within 335 meters range have a delay of 3.0ms. The delay grows to 3.94ms for Station 4, which is 364 meters away from AP. The delay increases to 6.30ms and 6.84ms for stations that are located 403 meters and 405 meters away respectively. The result indicates that the ete-delay raise rather quickly beyond 335 meters.

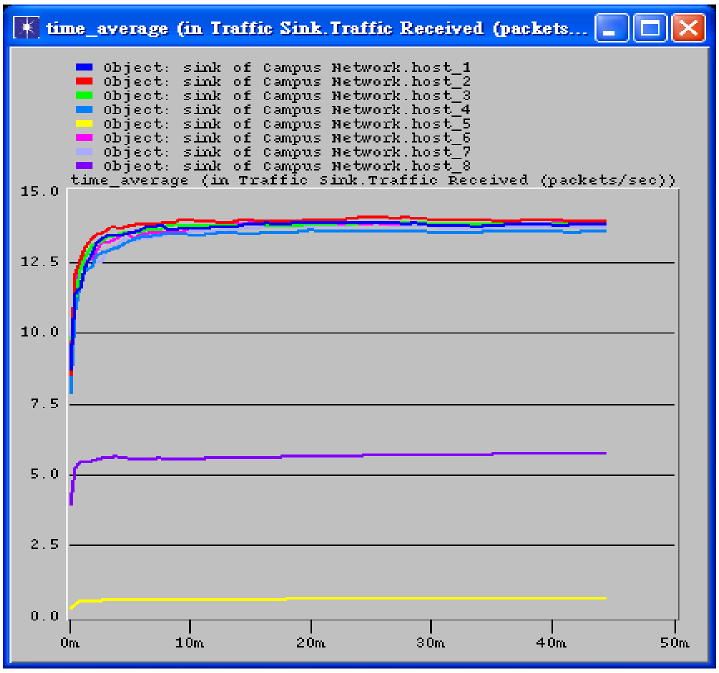


Figure 23. Time-Averaged Station Traffic Received – 8-Station Scenario

Even with growing ete-delay in Station 4, 364 meters away, Station 4 is still capable of receiving traffic at an almost the same rate of 13.6 packets per second as the closer stations. On the other hand, the two most far away stations, Station 8 and 5, each receive packets at a rate of 5.74 and 0.616 packets per second. This implies that traffic reception start to degrade at around 360 meters range.

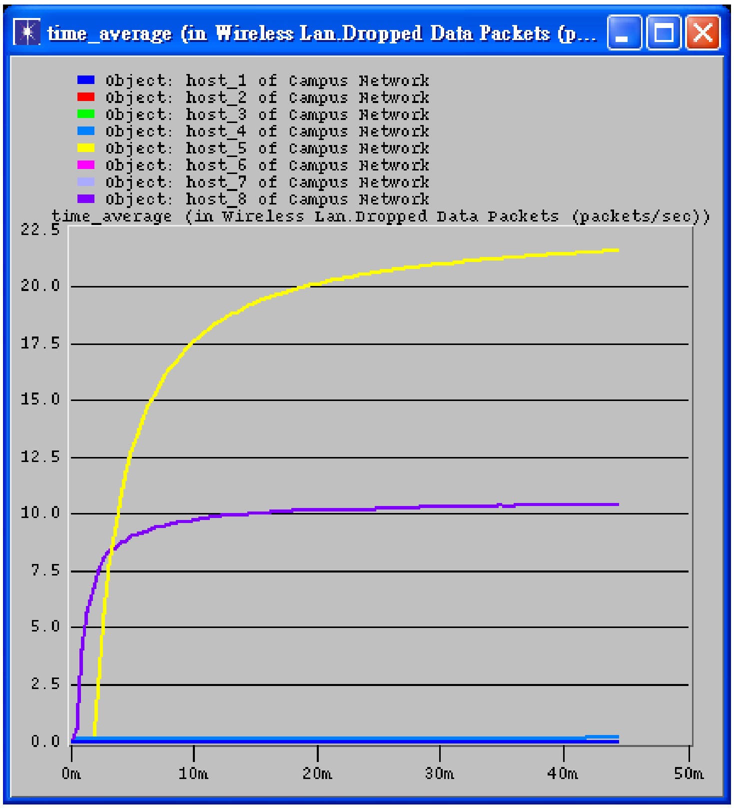


Figure 24. Time-Averaged Packet Drop Rate – 8-Station Scenario

Following the similar pattern as of traffic received, packet drop starts to kick in at around 360 meters range. Station 4, 364 meters away, has a packet drop rate of 0.151 packets per second. Station 8 and 5 each drops packets at a rate of 10.4 and 21.6 packets per second respectively.

All statistics that are collected from the 3,5 and 8-station scenarios are summarized altogether in Table 10. Please note that the stations are listed in ascending order of their distances to the AP. Statistics are again colour-coded with respect to reception and transmission. Some distances that are not available in the scenario are grey-out.

Table 10. Network Performances – 3, 5, 8-Station Scenario

Statistics		150m	200m	224m	291m	304m	335m	364m	403m	425m
End-to-end Delay (ms)	3	0.22	0.22						3.40	
	5	1.09	1.11	1.10	1.12					4.96
	8	2.85	2.84	2.81		2.89	3.00	3.94	6.30	6.84
Traffic Received (pkt/s)	3	17.1	17.0						7.1	
	5	16.7	16.6	16.6	16.6					0.767
	8	13.8	13.9	13.9		13.7	13.9	13.6	5.74	0.616
Throughput (kbps)	3	19.1	19.0						7.3	
	5	18.7	18.7	18.6	18.6					0.719
	8	15.6	15.6	15.5		15.4	15.6	15.2	5.89	0.581
Ctrl Traffic Received (pkt/s)	3	86.46	86.46						96.08	
	5	150	150	150	150					165
	8	237	237	237		237	237	238	245	249
Data Traffic Received (pkt/s)	3	151.50	273.87						33.46	
	5	241	410	383	318					62.5
	8	458	704	533		685	598	504	176	164
Data Packet Drop (pkt/s)	3	0	0						10.26	
	5	0	0	0	0					21.3
	8	0	0	0		0	0	0.151	10.4	21.6
MAC Access Delay (μs)	3	15.0	2.1						11.1	
	5	3.11	3.11	4.22	8.30					16.0
	8	55.1	5.86	14.0		6.16	8.91	17.5	44.5	26.7
Ctrl Traffic Sent (pkt/s)	3	17.06	16.97						7.12	
	5	16.7	16.6	16.6	16.6					0.767
	8	13.8	13.9	13.9		13.7	13.9	13.6	5.74	0.616
Data Traffic Sent (pkt/s)	3	24.68	23.69						121.56	
	5	23.9	23.9	23.9	23.9					157
	8	24.8	24.5	24.5		24.1	28.5	47.4	122	159
Retransmission Attempt (pkt)	3	0.168	0.168						2957	
	5	0.192	0.192	0.194	6.14					4455
	8	4.05	0.5	1.39		21.3	121	622	2951	4468
Backoff Slots (slot)	3	5.17E3	5.17E3						5.72E5	
	5	5.21E3	5.21E3	5.21E3	5.21E3					1.02E6
	8	7.17E3	5.44E3	5.85E3		5.77E3	8.13E3	6.70E4	7.29E5	1.86E6

In general, the 8-station scenario follows the same pattern as we observed in the first two scenarios. The far most station performs the worst, but the ete-delay for the closer stations has increased from 1.10ms in 5-station scenario to approximately 2.85ms. The results also start to reveal the workable range of the AP. Stations within the 330 meters range to the AP appear to share the same ete-delay. Those are the ones that still have still have traffic sent back and forth with the server. However, stations are better to stay within 300 meters to the AP to have fewer transmission attempts and a more stable connection. For stations beyond 400 meters range, delay is no longer the major problem. The main concern for them is that their traffic is not getting through the network.

4.5. Across Scenario Discussion

Across scenarios, taking Station 1 as an example the ete-delay has increased from 0.22ms to 1.10ms and from 1.10ms to 2.85ms. With identical location to the AP, an almost 13 times of growth in ete-delay with less than triple increased in station number. Figure 25 shows the ete-delay across 3, 5 and 8-station scenario. A bigger increase when station number grows from 5 to 8 than from 3 to 5.

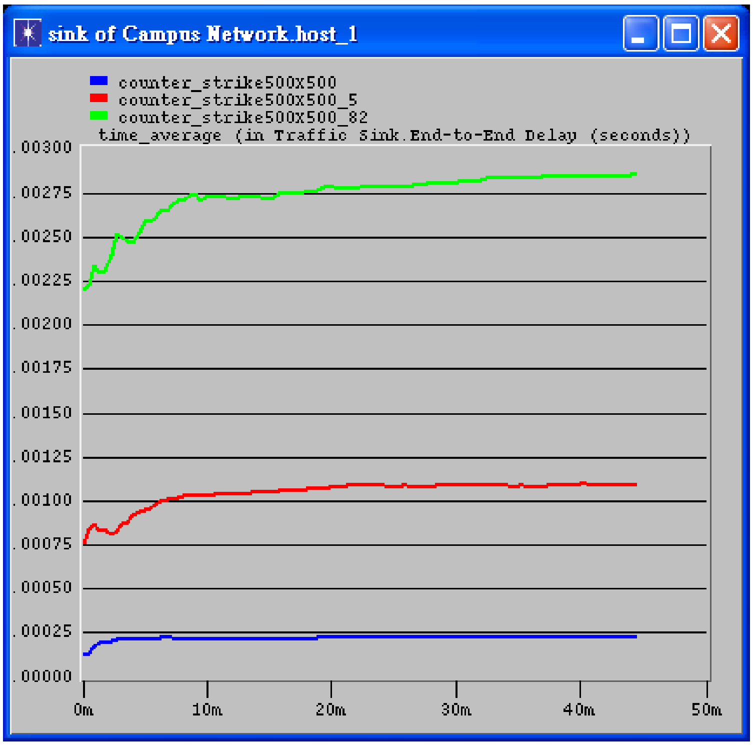


Figure 25. End-to-end Delay for Station 1 across 3, 5 and 8-Station Scenarios

Traffic received for Station 1 across scenarios also suffers a little as number of stations increased, but the little decrease can caused by less precise server inter-arrival model after shifting the mean. Taking less precise server load into account, the traffic received stay pretty intact across all scenarios. This infers that the network is still passing packets around the network across all scenarios. Figure 26 shows the traffic received at Station 1 across three scenarios.

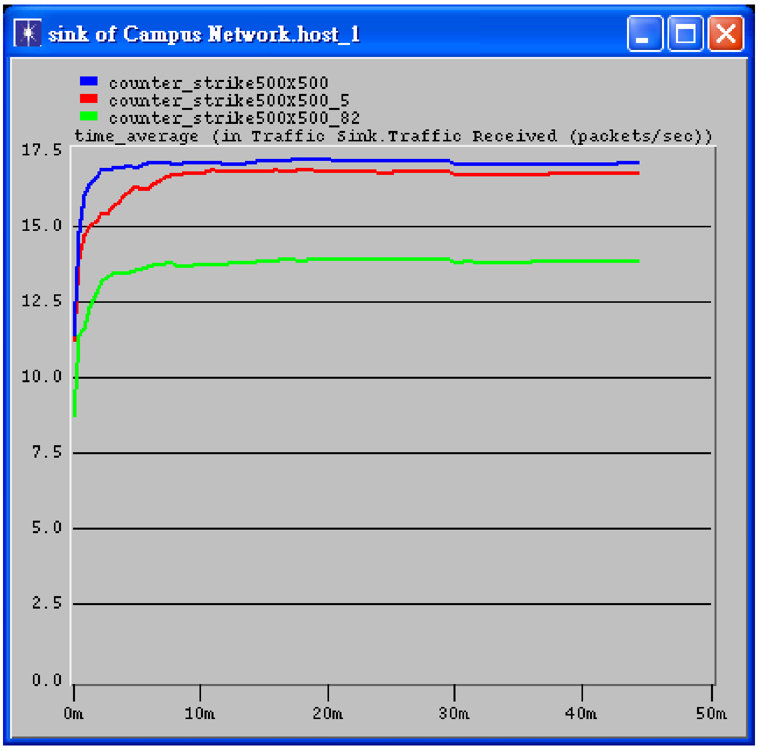
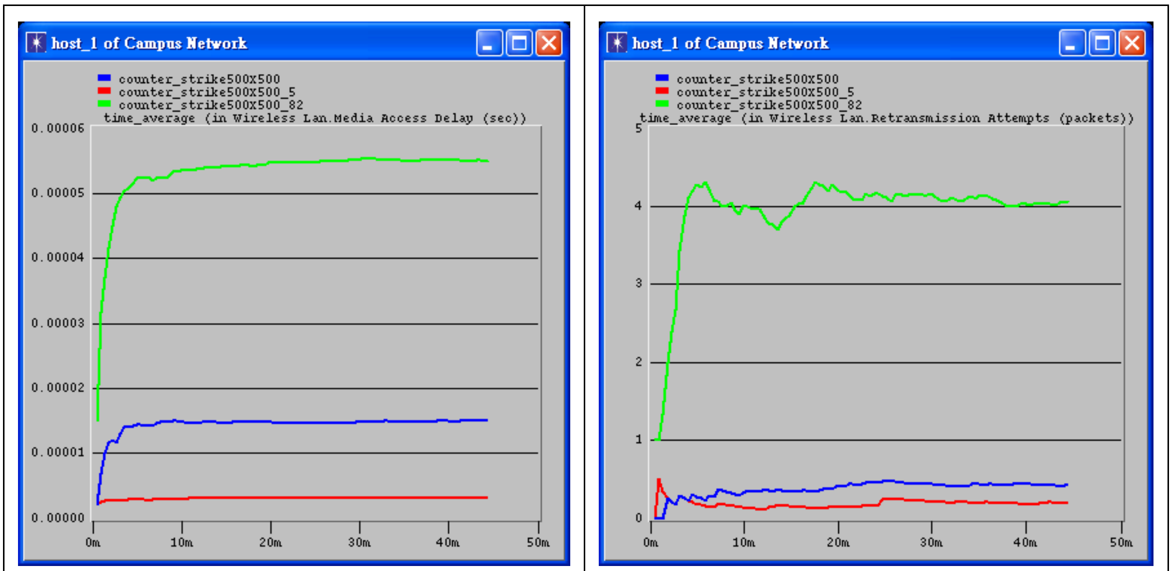


Figure 26. Traffic Received for Station 1 across 3, 5 and 8-Station Scenarios

In addition, the retransmission attempts and backoff slots start to rise across all stations as more stations are added to the network. This result indicates that more and more collisions happen when stations try to transmit their data. Such collision reflects on the increase of MAC access delay. Figure 27 illustrates the MAC access delay and retransmission attempts at Station 1 across all scenarios.



(a) Station 1 MAC Access Delay

(b) Station 1 Retransmission Attempts

Figure 27. MAC Access Delay and Retransmission Attmepts of Station 1 Accross 3, 5 and 8-Station Scenarios

Based on the rate of increase in ete-delay, retransmission attempts and MAC access delay, we can conclude the network is still capable of handling the load, but we start to reach the network capacity.

4.6. Additional Discussions

Based on Färber's citations [2], a ping time below 50ms is considered to be an excellent gaming condition. The playability becomes noticeable when ping is beyond 100ms, and 150ms is intolerable. It seems that 802.11g network can provide excellent playing condition. However, I need to emphasize that the station model employed in this project includes only up to MAC layer. Consequently, the delay reported encapsulates only up to MAC layer. Significant amount of delay is added after the transport and application layer. Also, the ete-delay is unidirectional, and ping time measures the round-trip time. Round-trip time would be almost twice of the ete-delay.

Furthermore, OPNET tends to simulate a very stable wireless medium. In real life, 802.11 is subject to a lot of interference from other devices, for example microwave. Obstacles along the path also diffract the signal and weaken the signal strength. The unstable nature of the wireless medium can add more delay to players' gaming experience.

5. Conclusion & Future Improvements

In this report, we started with a survey on different types of online interactive games. First person shooting, real-time strategy and MMORPG are the types of game that we discussed in this report. However, only the first person shooting game, specifically Counter Strike, traffic model is utilized to evaluate its performance on an 802.11g network in OPNET.

We concluded that the network is capable of handling 8 concurrent Counter-Strike-playing stations though the performance of the network degrades quickly with increase number of stations. Aside from the number of active stations in the network, the distance between a station and the access point is the major factor of performance. Only stations within the 300 meters range can experience the normal network performance. Stations that are beyond 330 meters start have long end-to-end delay. End-to-end delay is no longer the only concern for stations that are located out 360 meters range. They perform poorly in both reception and transmission. Their packet are not getting passed or received around the network.

A few future improvements is suggested to better investigate the game traffic in wireless local area network. First of all, a packet error generator can be implemented to simulate the lossy nature of the wireless medium. Secondly, a station model that incorporates transport layer can be utilized to encapsulate more delays. Lastly, a better traffic model, traffic route or even trace data can be collected to conduct a trace-driven simulation.

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