ON THE FEASIBILITY OF VIDEO GAMING ON DEMAND IN WIRELESS LAN/WIMAX

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ABSTRACT

Using OPNET tools, we design a network configuration to model the idea of video games-on-demand. We created a network where video game content is delivered to a user with wired-connection with a latency of 80ms. Using this network configuration, we explore alternatives to provide other last mile options to users, namely Wireless LAN 802.11g and WiMAX 802.16e. We designed different scenarios for simulation to identify the impact that these wireless protocols have on the latency and scalability of video games on demand.

***Index Terms*—** 802.11g, WiMAX, 802.16e, Video-Games, on-Demand

1. INTRODUCTION

Video Games-on-Demand (VGoD), also known as *cloud gaming*, is a revolutionary idea to the PC gaming industry that was first proposed by OnLive [1], a startup company based in Silicon Valley. VGoD is the idea where users enjoy video games on personal computer screens, while the video game and video gameplay are stored and executed in a server that reside in a data center, also known as the *cloud*. Users connect to the server and send commands to the server that executes based on the user input and generates the gameplay and sends the information back to the users as compressed video streams. For the user to experience VGoD as if the video game actually resides on his local machine, the game video bitstream must be delivered to the user within 80 ms after the user executed a command. This physical requirement is the threshold in which the user feels he is in control of the game.

Figure 1 shows how video gameplay is delivered to the user in less than 80 ms. According to [2], OnLive servers are located in various data-centers computes the video gameplay from the user commands that it receives, and compresses the video before transmitting it to the video game users. The compression at the server side requires about 1 ms, using OnLive proprietary video compression technology. At the receiving end, game users typically requires 8 ms to decompress the gameplay video. HD quality gameplay delivers at 30 frames per second, so that the separation time between two adjacent frames arrive at 34 ms apart. The propagation delay of the network depends on location of the user and the server, and is assumed to be at 21 ms, and finally, the "last mile" delivery encounters a delay of 25 ms. As video gaming become more widespread to mobile devices, we feel that both WiMAX and WiFi will be prominent alternatives as "last mile" delivery of video game content to user. OnLive currently does not support wireless connections for their VGoD system, due to network instability that cannot guarantee steady gaming experience [2]. Indeed, wireless connection tend to produces unexpected network delay, as illustrated in figure 2 using a web application called Ping Test [3].

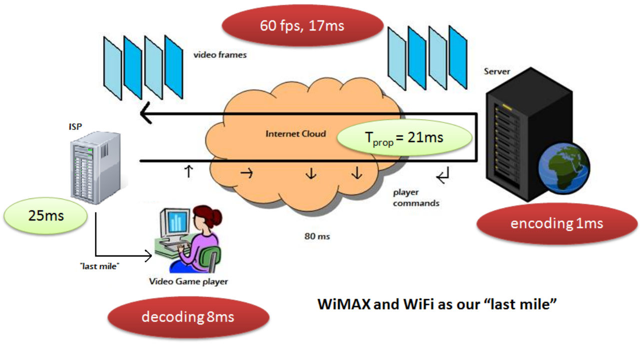
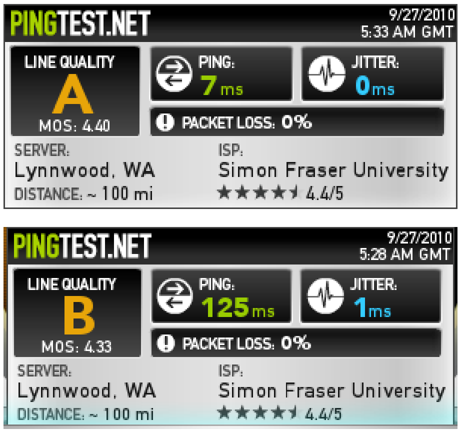


Fig. 1. Video Games-on-Demand Model

The top figure shows the propagation delay of a computer connected via an ethernet cable using the SFU network, whereas the bottom figure shows the same delay of a laptop connected to the network using WiFi 802.11g. This example shows that there is additional propagation delay incurred using wireless networks, thus places another timing constraint to designing of VGoD. Therefore, in this project we investigate the feasibility of using WiMAX [4] and Wireless LAN [5, 6] as the"last mile" to deliver video frames to the user. We will examine the impact these technologies have to the VGoD system. Specifically, we focus on how these wireless protocols affect the latency and scalability of the system.

This paper is organized as follows. Section 2 gives a brief overview of the WiMAX and WiFi standards that we will be using. In section 3, we discuss how we model the VGoD system in OPNET and explain assumptions that we made. In section 4, we discuss the scenarios that are designed for our simulation. Finally we conclude our work in section 5.


PINGTEST.NET
9/27/2010
5:33 AM GMT
LINE QUALITY A
MOS: 4.40
PING: 7 ms
JITTER: 0 ms
PACKET LOSS: 0%
SERVER: Lynnwood, WA
DISTANCE: ~ 100 mi
ISP: Simon Fraser University
★★★★½ 4.4/5

PINGTEST.NET
9/27/2010
5:28 AM GMT
LINE QUALITY B
MOS: 4.33
PING: 125 ms
JITTER: 1 ms
PACKET LOSS: 0%
SERVER: Lynnwood, WA
DISTANCE: ~ 100 mi
ISP: Simon Fraser University
★★★★½ 4.4/5

Fig. 2. A simple ping test (top) on a wired connection (bottom) on a wireless connection

2. STANDARDS OVERVIEW

In this project, we use the IEEE WiMAX 802.16e standard and IEEE Wireless LAN 802.11g standard as the last mile to connect the user to the Internet. We are motivated to use these two wireless protocols because of its growing importance of the technologies and the popularity of mobile devices usage in North America.

2.1. Wireless LAN 802.11g

The IEEE 802.11 protocol, also known as Wireless LAN or *WiFi*, is the wireless extension of a LAN network. Its goal is to allow fast connection within a small area network, typically within 100 meters, and is targeted for non-moving receivers. The small distance between workstations and the access point results small propagation delay for Internet traffic. The *g* extension of the 802.11 protocol has a peak data rate of 54 Mbps, but averages at about 22 Mbps [7]. The data rate is adaptable because the standard is backward compatible with extension *a* and *b*.

Despite being wireless, WiFi is designed to have low mobility, meaning that optimal performance is achieved when the workstation is fixed, rather than in motion. Current mobile devices such as iPhone 3G supports Wifi extensions of *a/b/g*.

2.2. Mobile WiMAX 802.16e

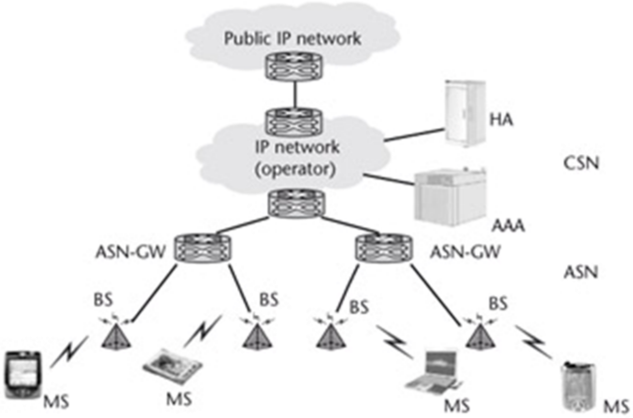


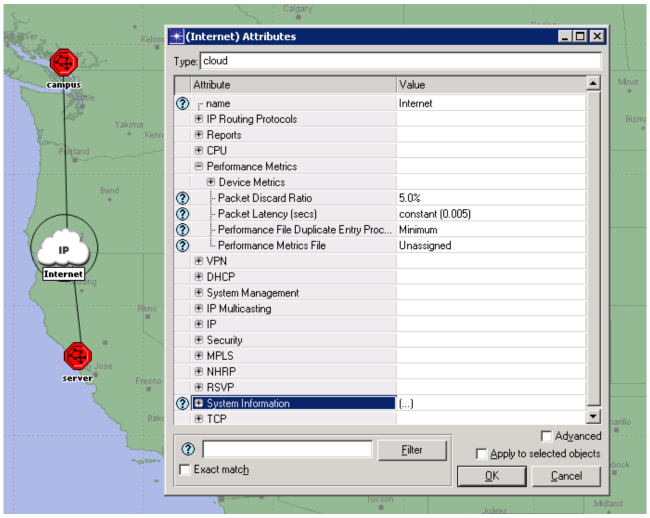
Fig. 3. WiMAX configuration [7]

The IEEE 802.16 standard is WiMAX, which is wireless protocol for wide area network (WAN). Its typical range is from $8-15$ km, but up to 70 miles [8]. It is fundamentally different from Wifi in that WiMAX is a commercial service and a connection-oriented service as a result it provides better reliability and quality-of-service (QoS). A WiMAX configuration is shown in figure 2.2. Mobile stations (MS) such as laptops and Internet-enabled cellphones are connected to nearby base stations (BS) that relay traffic between the users and the Internet. A BS in WiMAX operates similarly as a BS in the cellphone network. Each BS covers has a cell coverage, and cell frequencies are reused. For the purposes of this project, we are only concerned with the physical and MAC layers of the WiMAX configuration. That is, we only model the base station's characteristics.

3. VGOD MODELING IN OPNET

In this section, we discuss how we model the video game server at the server side and the game user at the client side. We set our server location to be at San Francisco. A server subnet is introduced as an abstraction for all the nodes that reside in the server side. Our client location is initially set to be 1000 miles away from the server. In our initial setup, our client is located in Vancouver, as shown in figure 4. The server and client subnets are connected to the Internet via 45 Mbps duplex links, and is modelled by an abstract IP cloud node. Since the distance between the server and client is approximately 1600 km (1000 miles), the propagation delay is calculated to be about 2.5 ms one way. To simulate this behaviour, we set the packet delay in the IP cloud node to be at 5 ms, representing a round-trip delay. Moreover, we arbitrary set the packet discard ratio to be 5%, which mimics packet drops in real world networks.

Our first step is to design a base configuration configuration to model the VGoD system. The base configuration is our benchmark that we use to compare to our wireless configurations. That is, before we design our WiFi configurations, we need a VGoD system that streams video content to the user located at 1000 miles away to experience an end-to-end delay of well under 80 ms. After establishing our baseline model,



Type: cloud

Attribute	Value
name	Internet
⊞ IP Routing Protocols	
⊞ Reports	
⊞ CPU	
⊟ Performance Metrics	
⊞ Device Metrics	
Packet Discard Ratio	5.0%
Packet Latency (secs)	constant (0.005)
Performance File Duplicate Entry Proc...	Minimum
Performance Metrics File	Unassigned
⊞ VPN	
⊞ DHCP	
⊞ System Management	
⊞ IP Multicasting	
⊞ IP	
⊞ Security	
⊞ MPLS	
⊞ NHRP	
⊞ RSVP	
⊞ System Information	(...)
⊞ TCP	

Fig. 4. Network model topology

we create our wireless configurations and compare its performance. Our base configuration consists of a 3 WiFi users, each located in a separate cell with a dedicated access point (AP) server that covers the region of the cell.

3.1. Video Traces

To simulate game video, we use the video traces provided by Arizona State University [9], and an import video to OPNET using the instructions given in [10]. After importing the video traces, we create the application configuration and profile configuration, that allows a server to provide streaming video services to the clients [11].

Based on [2], OnLive's proprietary video compression technology is capable of delivering HD quality video content (1080 × 1920) at a data rate 5 Mbps, and a standard TV quality (480 × 720) at 1 Mbps. Accordingly, we chose the video traces that are correspondingly close to 5 Mbps and 1 Mbps, respectively. We chose the *Terminator 2* video trace that was encoded at 30 frames per second, or 34 ms per frame separation, with quantization parameter of $Q = 5$ and $Q = 30$.

3.2. Server Side Modeling

Video game servers are dedicated servers that execute gameplay based on the user commands, and generate video frames to deliver to the users. Therefore, the server generates video stream to the user. Moreover, since the VGoD server relies on user's game commands, we set up a HTTP profile to allow users to send HTTP traffic to the server for processing. Our server is an *ethernet server* node from OPNET, shown in figure 5. It is connected to a switch and then to router via

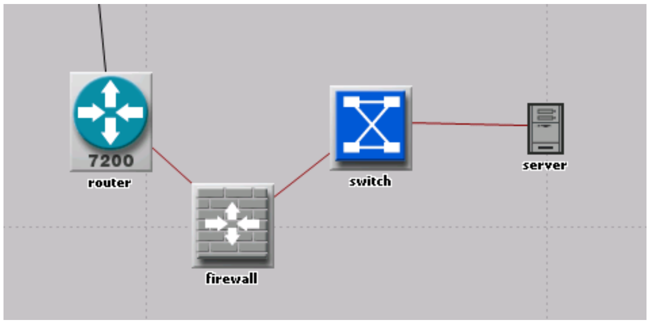


Fig. 5. VGoD server side model

a 10 Mbps *10BaseT* link. The router is connected to a local client that acts to control the server and communicates with the server with light HTTP traffic. The router connects to the Internet via a point-to-point DS3 link that is capable of transmitting at 45 Mbps.

It is important to realize that our server is dedicated to only supports two services - delivering video content and receiving light HTTP traffic. The reason is because of simplicity and practicality. In practice, executing video gameplay is a demanding process, and servers should be dedicated to processing, rather than virtualizing a server to perform other tasks.

To model a 1 ms compression time, we configure an initial timing offset of 1 ms to stream our video content. We also support background load in the 10 Mbps links in order to arrive at a overall latency of 80 ms.

3.3. Client Side Modeling

To model traditional game users, we assume users are connected to the Internet from their laptop to an access point located across the campus, typically behind a firewall and a proxy server provided by the ISP. The user is modelled by a wireless *ethernet workstation*, configured to accept video content from the server. A local server at the client side will act to deliver HTTP traffic to the VGoD server to simulate the notion of sending game commands to the server.

Figure 6 shows the network topology at the client side, which models a campus. In the model, Internet traffic first passes through a router, then to a campus firewall, then to a switch before reaching the access points. The links connecting the firewall are 100 Mbps, whereas the links connecting to the access points are only 10 Mbps. We reason that a 10 Mbps links for the access point is sufficient because of the number of users we simulate for the experiment. Since we are simulating up to two WiFi users per access point, with up to 5 Mbps of data requested per user, there is no need for extra bandwidth connecting to each access point. The access points provide guaranteed coverage of WiFi for the region

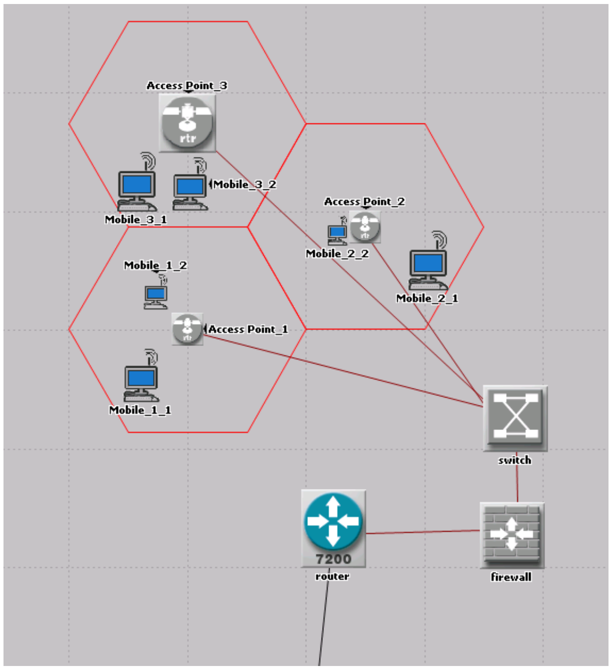


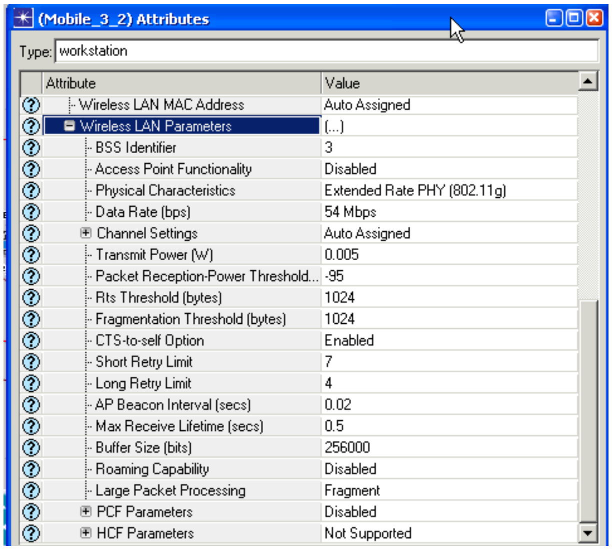
Fig. 6. VGoD client side model

outlined by the hexagon-shaped region, but it also provides *non-guaranteed* coverage coverage outside that region. In general, the farther the user is from the assigned access point outside the guaranteed range, the weaker the signal becomes. The clients are randomly placed within each cell, and are set up to accept standard quality video that requires 1.5 Mbps.

Figure 7 shows the WiFi configuration of the IEEE 802.11g standard. Majority of the attributes are kept in default, except for the properties of *request to send* (RTS), *fragmentation*, and buffer size, which we modified to suit our VGoD system. As alluded earlier, The WiFi *g* extension has a data rate of 54 Mbps, but in practice, less than half the capacity is reached due to packet collisions in the channel. The concepts of RTS and fragmentation are mechanism to help reduce contention among packets in the shared channels, as introduced to the WLAN standard [12]. More details are given in the next section in our simulation results.

4. WIRELESS CONFIGURATIONS AND SCENARIO DESIGNS

Having designed our baseline network configuration, we now turn to modelling our wireless configurations. We designed five WiFi scenarios. Our scenarios will assume the same server side configuration that was described in section 3.2.


(Mobile_3_2) Attributes

Type: workstation

Attribute	Value
Wireless LAN MAC Address	Auto Assigned
⊟ Wireless LAN Parameters	(...)
BSS Identifier	3
Access Point Functionality	Disabled
Physical Characteristics	Extended Rate PHY (802.11g)
Data Rate (bps)	54 Mbps
⊞ Channel Settings	Auto Assigned
Transmit Power (W)	0.005
Packet Reception-Power Threshold...	-95
Rts Threshold (bytes)	1024
Fragmentation Threshold (bytes)	1024
CTS-to-self Option	Enabled
Short Retry Limit	7
Long Retry Limit	4
AP Beacon Interval (secs)	0.02
Max Receive Lifetime (secs)	0.5
Buffer Size (bits)	256000
Roaming Capability	Disabled
Large Packet Processing	Fragment
⊞ PCF Parameters	Disabled
⊞ HCF Parameters	Not Supported

Fig. 7. WiFi 802.11g configuration on mobile workstation

4.1. Base Case

In this scenario, we are interested in how scalable the VGoD system is with a growing number of WiFi users. We measure the end-to-end delay as experienced each user as we increase the number of users from three to six. We will show that our model can handle up to six WiFi users while maintaining an end-to-end (ETE) delay of the system of under 80 ms. Figure 8 shows that after running our simulation for 20 minutes, the ETE delay of our six-user scenario steadily reaches to 80 ms, while the three-user scenario is well under the threshold, thus suitable for VGoD gaming. For a closer look at how the ETE delay is affected by the intermediary nodes, we take a look at the delay that is incurred at an access point. Figure 9 shows that a 50% increase in delay as we double the number of users in each cell. However, this delay is not significant since it adds only 0.5 ms to the overall delay. As a result, most of the delay comes from contention of the channel among users. It should be noted that in the three-user scenario, there is no contention of the access point, hence the channel, so each user can be regarded to have a dedicated channel to the network. When more users join the network to share a channel, collisions of packets occurs, and packets get dropped in an increasing rate as the number of users increases. Thus, as figure 10 shows, the number of packets that are sent do not agree with the number of packets that are received. Some of the packets never made it to the destination, and are considered “dropped” in the network. With more users, more packets get dropped.

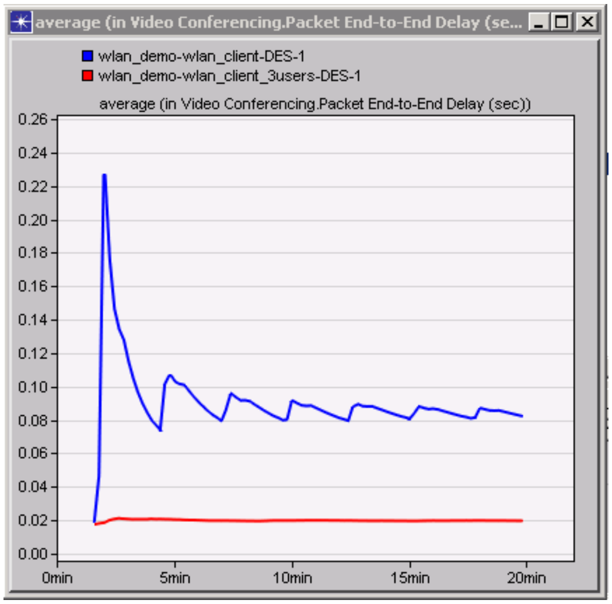


Fig. 8. Packets end-to-end delay of base case scenario

4.2. Background Load

In this scenario, we are interested to know how does the presence of background load in the links affect the gaming experience of the user, specifically how does background load affect the ETE delay and the delay variation. Figure 11 shows the presence of different degree of background load present in the network. Recall the link between the switch to the access point is 10 Mbps, so a 5 Mbps background load is half the capacity of the link. Figure 12 shows the network packet variability, or jitter, at different load. We see that when the background load is less than half the capacity, the video game users experience little jitter in the gaming experience, but when the background load reaches 50%, there is a slight increase in jitter, rendering a poor gaming experience. This occurs when other users are consuming network bandwidth such as sending large files across the Internet. Figure 13 shows the packet end-to-end delay as background load increases. The results show similar behaviour as compared to the network jitter as background load increases.

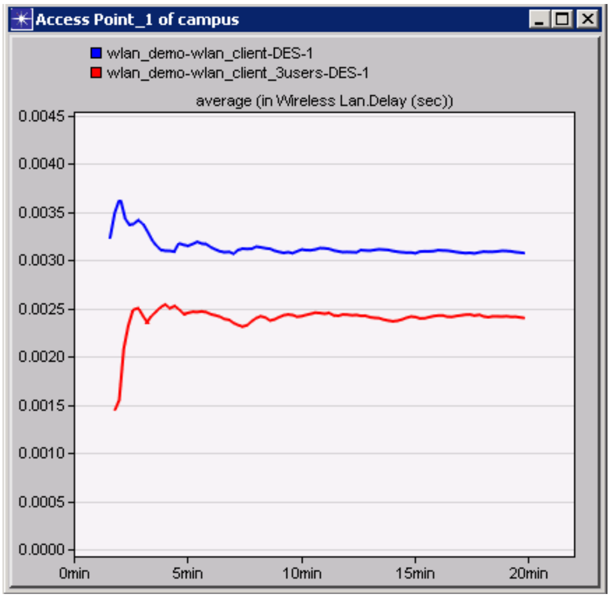


Fig. 9. Delay incurred at access point

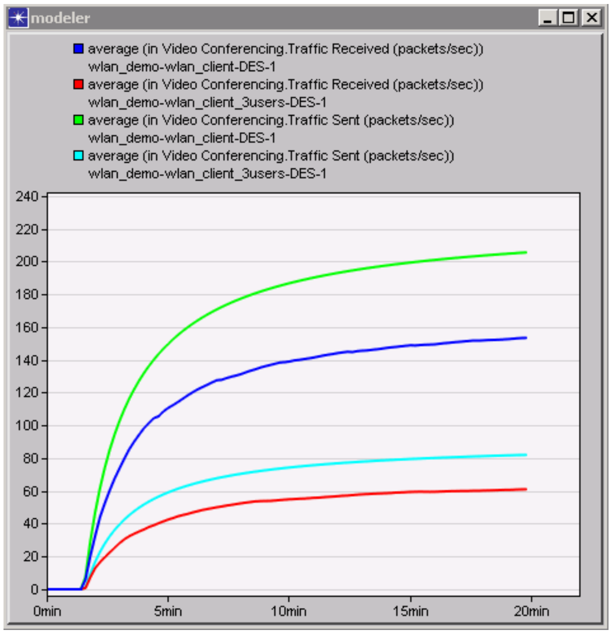


Fig. 10. Packet sent and receive as the number of users grow

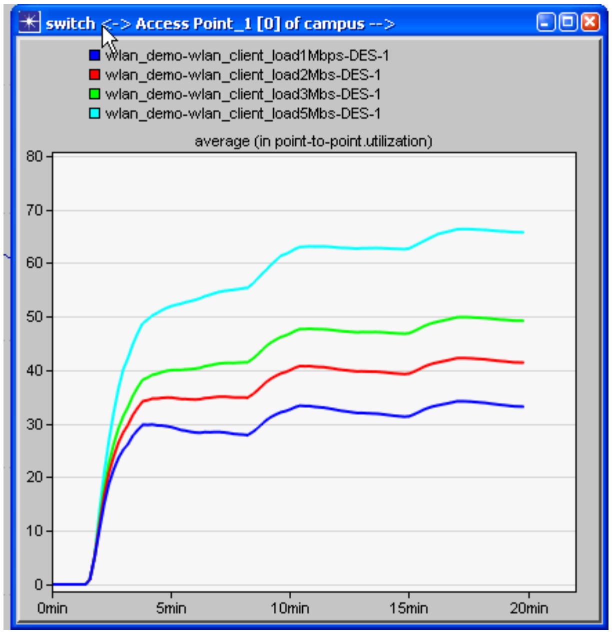


Fig. 11. Background load connecting access point to switch

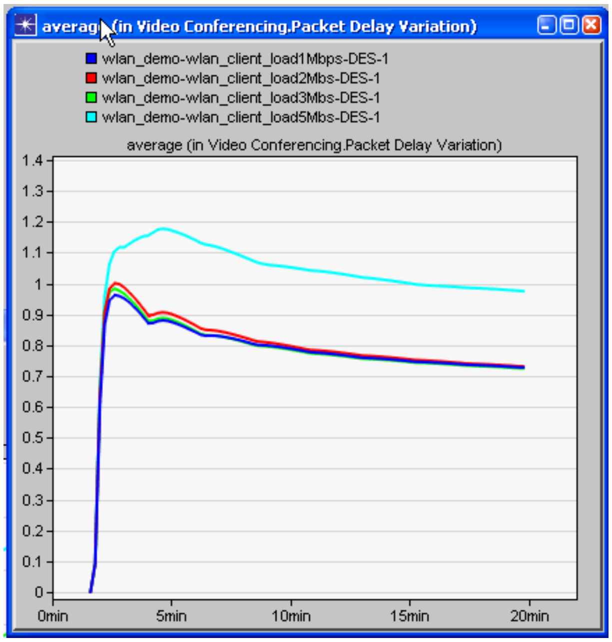


Fig. 12. Packet delay variability as background load increases

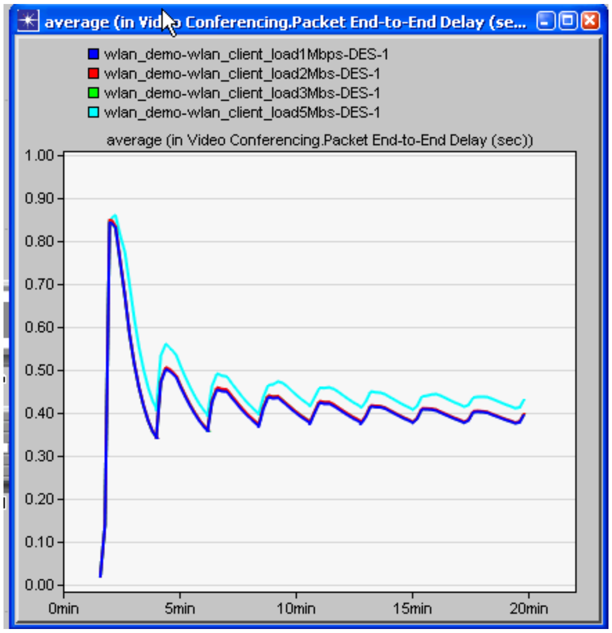


Fig. 13. Packet end-to-end delay as background load increases

4.3. WiFi Configuration without RTS and Fragmentation

In our third scenario, we look at two characteristics of the WiFi system, namely the request-to-send (RTS) mechanism and fragmentation of packets. Any node wishing to send a frame may *optionally* send an RTS frame requesting to use the channel. Any node receiving this RTS frame should refrain from sending data until a specified time. This approach avoids frame collision, and is similar to CSMA method found in Ethernet [12].

Fragmentation, on the other hand, is breaking a large packet into smaller pieces, to ensure that at least part of the large packet can be sent through the network and reach the destination. If a large packet, such as a video packet is sent across a work and get dropped, the entire packet needs to be resent. However, if that packet is fragmented into pieces, with little a little overhead that identifies the fragmented pieces, statistically it is more efficient than sending a large packet. However, the size of fragmented pieces depends on the source of the data that is sent across the network [12]. Figure 14 shows what happens to a mobile node when fragmentation is switched off. The blue and green lines both illustrate the situation when there is no fragmentation. In both cases, there is either a high drop rate (blue), or frequent drops (green). The red line has a fragmentation of 256 kb, has relatively fewer data drops.

As fewer packets get dropped, packets do not need to resend, which can significantly lower the end-to-end delay of the system. This is illustrated in figure 15, where the blue line shows the situation when both RTS and fragmentation are dis-

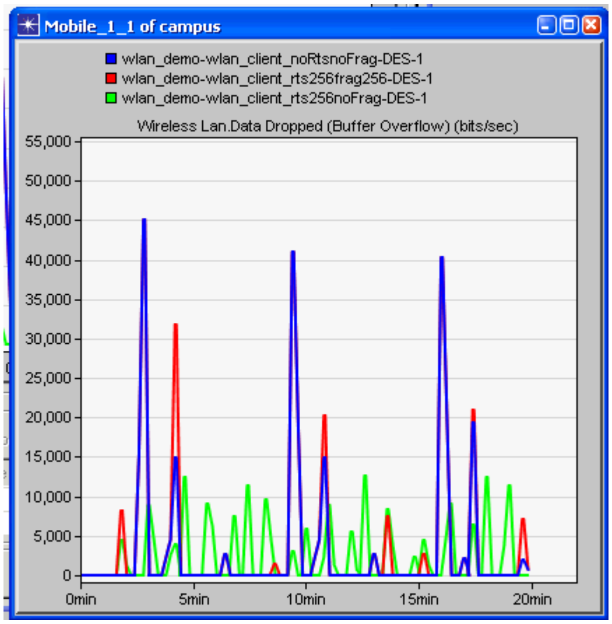


Fig. 14. data drops (bits/sec) due to fragmentation

abled. When RTS is enabled, as shown in the green line, the delay is greatly reduced. However, with the presence of fragmentation, shown in the red line, the delay increases again. This is not surprising as there is a cost to reducing the chance of packet drops. Fortunately, with both RTS and fragmentation enabled, the end-to-end delay is lower than with both mechanisms disabled.

4.4. WiFi with moving Mobile Users

In this scenario, we consider a mobile user that is moving. For example, WiFi users could be walking around campus, at a rate of 2 m/s (7 km/hr), while playing video game on their mobile phone. In this scenario, we want to investigate how their gaming experience can be affected. Figure 16 shows the trajectory of six users moving around the campus. Users belonging to access point 1 move within the access point region, while users in access point 2 move out of the region and to another access point region. Finally, users in access point 3 move out of the WiFi area altogether.

Figure 17 shows the trajectory definition of users belonging to access point 3. As shown in the table, the user is constantly moving at 2 m/s in each direction of the trajectory. Figure 18 shows the traffic received by a user belonging to each access point. In access point 1, the user is moving within the cell, so the data received is near constant around $5,000,000$ bits/sec. User in access point 2 began within the cell then move out of the cell, and thus weakening the reception and receive data at a reduced rate of about 1.2 Mbps. At this rate, video game experience deteriorates because the reduced bit rate will not be sufficient to generate high quality

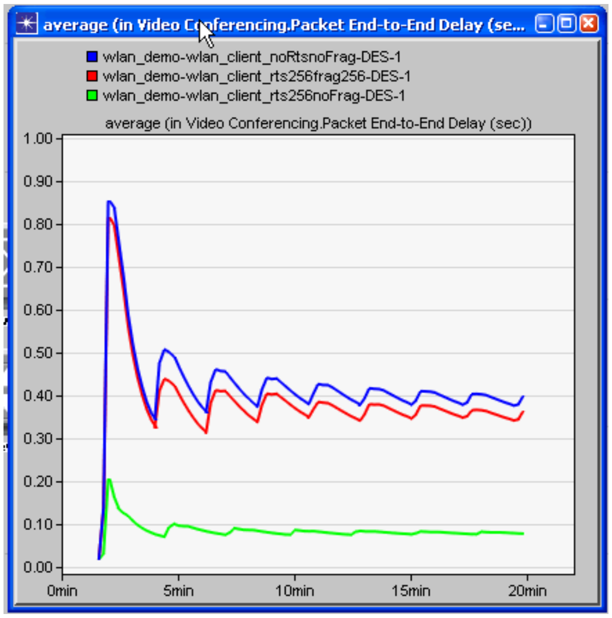


Fig. 15. Packet ETE delay due to RTS and fragmentation

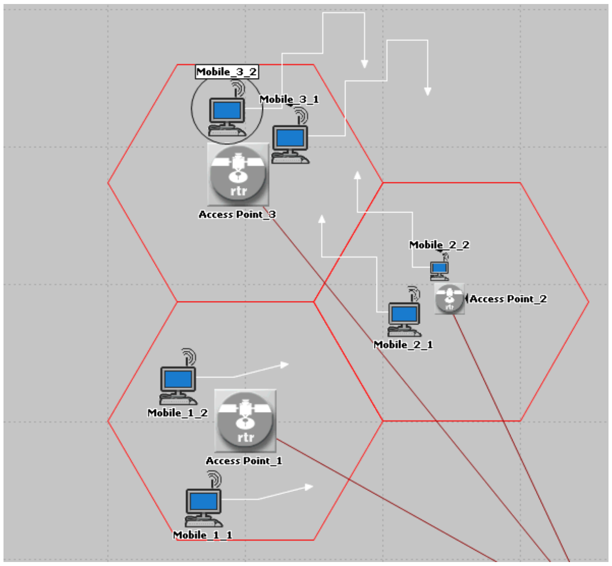
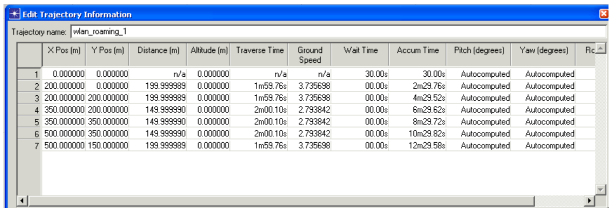


Fig. 16. Mobile workstation trajectories, moving at 2 m/s



Trajectory name: wlan_roaming_1

	X Pos (m)	Y Pos (m)	Distance (m)	Altitude (m)	Traverse Time	Ground Speed	Wait Time	Accum Time	Pitch (degrees)	Yaw (degrees)	Rc
1	0.000000	0.000000	n/a	0.000000	n/a	n/a	30.00s	30.00s	Autocomputed	Autocomputed	
2	200.000000	0.000000	199.999989	0.000000	1m59.76s	3.735698	00.00s	2m29.76s	Autocomputed	Autocomputed	
3	200.000000	200.000000	199.999989	0.000000	1m59.76s	3.735698	00.00s	4m29.52s	Autocomputed	Autocomputed	
4	350.000000	200.000000	149.999990	0.000000	2m00.10s	2.793842	00.00s	6m29.62s	Autocomputed	Autocomputed	
5	350.000000	350.000000	149.999990	0.000000	2m00.10s	2.793842	00.00s	8m29.72s	Autocomputed	Autocomputed	
6	500.000000	350.000000	149.999990	0.000000	2m00.10s	2.793842	00.00s	10m29.82s	Autocomputed	Autocomputed	
7	500.000000	150.000000	199.999989	0.000000	1m59.76s	3.735698	00.00s	12m29.58s	Autocomputed	Autocomputed	

Fig. 17. Trajectory definition for mobile user in AP #3

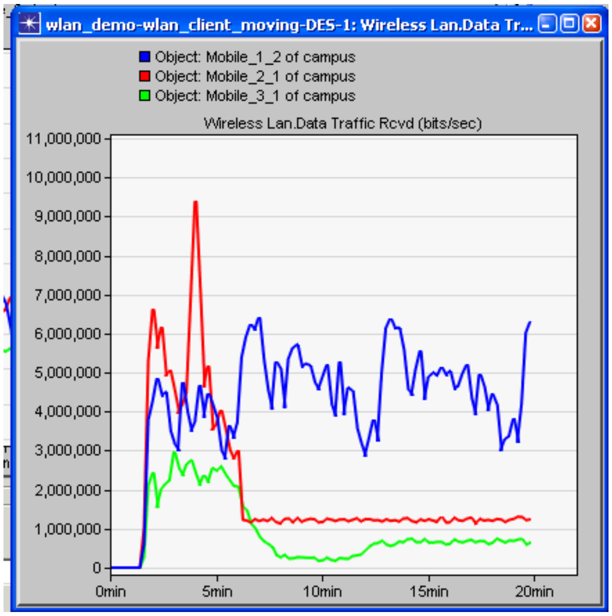


Fig. 18. Data received of mobile users

video by the decoder. Note that we did not enable roaming, so that users do not re-connect to another access point and pick up traffic right away. Finally, user in access point 3 moved out of the region earlier, and is moving along the outside of the region, also receiving data at a reduced rate, resulting in poor video quality in video games.

Moreover, mobile users also suffer from delays of their gaming experience, as shown in figure 19. The average end-to-end delay of the mobile users triple that of stationary users. This shows that mobile users are prone to delays to video games as well as reduced video quality gameplay.

4.5. WiFi with Mobile Users Joining

Finally, in our last scenario, we consider different users joining the network at different times. Figure 20 depicts the scenario of different users joining the network by connecting to the access point at different times. As shown from the figure, the trajectories are the same trajectories that are used in the scenario with moving users. The users are moving at a speed of 2 m/s to get close to the access point and thus join the network at different times. Since users join at different time, the data received by each user differs. Figure 21 shows the data that is received by a user belonging to each of the access points. As shown, the user belonging to access point #2 begins receiving data because she joins the network first, followed by the user belonging to access point #1. The amount of traffic that is received by each user largely depends on simulation. Note that, on average, each user will receive at a bit-rate specified by the source video gameplay, which is set to 5 Mbps. Finally, we look at the delay incurred by a user that joins the network at a later time compared to the user that

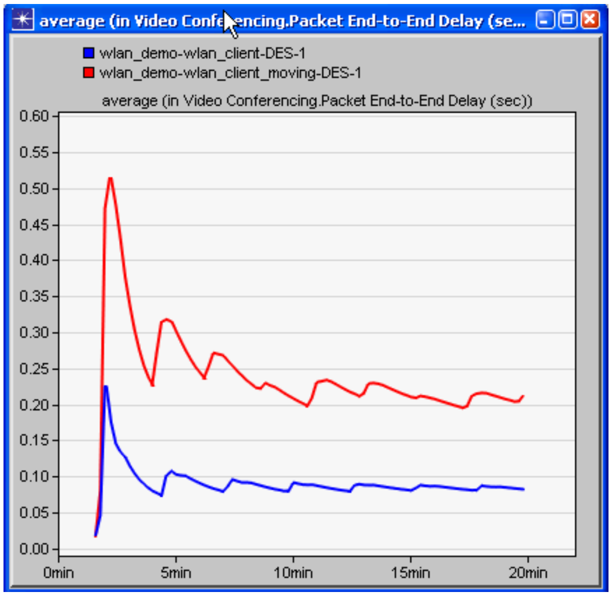


Fig. 19. ETE delay of mobile users

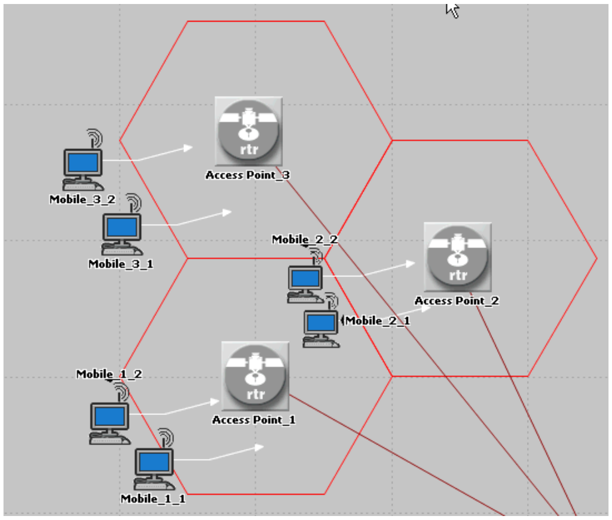


Fig. 20. Users joining the network at various times

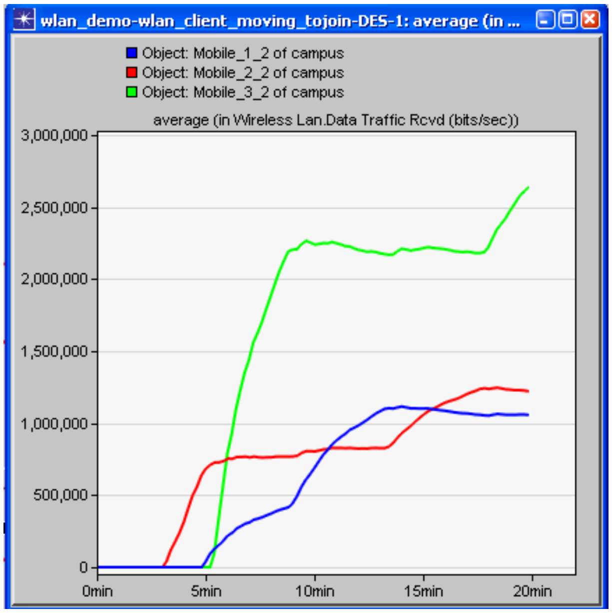


Fig. 21. User traffic begin at different times

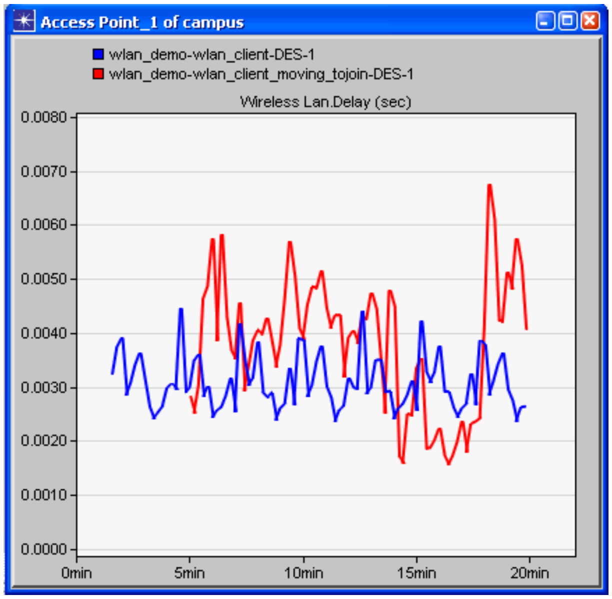


Fig. 22. Delay incurred by a mobile node joining a network

was present when the simulation starts. Figure 22 shows that a small delay is incurred when a user is joining the network. The delay is typically attributed to the time that the mobile node needs to set up a connection with the access point.

5. CONCLUSION

In this project, we simulated various scenarios of the VGoD system using the WiFi 802.11g standard. We first created a VGoD scenario with on the server side with video game server servicing HD video stream at 5 Mbps. At the client side, we model a campus where students connect their laptops to various access points across campus.

We considered five scenarios for our simulation. We first looked at a base case with three users each connecting to an access point showing negligible end-to-end delay, thus allowing smooth video gaming experience.

Next, we scaled up the number of users and find that our network model can still deliver adequate gaming experience to the user, as the end-to-end delay reaches a steady state of 80 ms. Next, we consider the case with background load in the links connecting the access point to the switch. We showed that when the background reaches near 50% of the capacity, the gaming experience starts to degrade with increased delay and jitter.

In the third scenario, we considered the RTS and fragmentation mechanisms to reduce frame collisions among contending users. We showed that the use of these mechanisms do help reduce data drop, and together they improve on the overall delay of the system by having fewer packets resend because of packet drops.

When users are moving, we found that it deteriorates the gaming experience greatly. It affects both the video quality because of a reduced bit rate being received, and also a larger delay being incurred in the system. Thus, video game users should be stationary in order to maximize the gaming experience.

Finally, we consider users who are joining the network at different times. We found that there is a slight increase in delay when users join the network at different times.

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