ENSC 894 COMMUNICATION NETWORKS
Project Report

PERFORMANCE OF CLOUD GAMING USING RIVERBED MODELER

Team Number 5

https://cloudgamenetworking.wordpress.com/performance-of-cloud-gaming-using-riverbed-m

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Abstract

Amongst every generation since the 1960s, video games have been tremendously prominent, evolving every decade with life-like graphics, powerful systems and a larger variety of games to choose from. With the arrival of cloud technology, game accessibility and ubiquity have a bright future as games can be hosted in a centralized server and accessed through the Internet by a thin client on a wide variety of devices with modest capabilities.[1] Cloud Gaming or 'Gaming on Demand' enables playing visually rich games locally irrespective of the machine's processing power because the game is hosted on multiple servers and rendered back to the user, frame-by-frame, from powerful machines. This is very helpful for users with less powerful devices that are otherwise incapable of playing high-quality games. With this in mind, Cloud Gaming is not limited to location; servers and players can be located anywhere in the world with networks linking them together. With this configuration, the quality of service in terms of performance and game responsiveness will lag and diminish the players' Quality of Experience (QoE). QoE describes the service given to the user by the client. Due to these potential advantages, many companies like OnLive, G-Cluster [2], PlayStation Now, Gaikai, and T5-Labs are offering Cloud Gaming services. Also, Sony's PS Now & Nvidia's GeForce Now already offer their subscribers a limited library of popular games at 1080p 60fps[3].This report assesses Cloud Gaming interaction using Riverbed Modeler to design a network configuration to study various scenarios to identify the feasibility of game streaming over Wi-Fi.

1 Introduction

The introduction of Cloud Gaming, or how most people know it, game streaming has changed the way users interact with their gaming consoles. Cloud Gaming is a technology that carries with it the promise of letting you use any machine to play the most demanding games, regardless of hardware requirements, at their highest settings. With Cloud Gaming, AAA-rated games such as Assassins Creed: Odyssey, for example, will allow you to play on any device, from mobile phones to tablets. Not everyone has the hardware to run the latest and most demanding video games out there, and even those who do can find keeping up with the latest computer hardware like graphics cards and processors expensive and tiresome.[4][5][6]

Game streaming works like any other streaming service. We will use Netflix as an example since this service is mostly known amongst society. Instead of movies, series or anime, game streaming offers a variety of video games categorized by genre, age or even year of production. With gaming, there are a large number of buttons on the control pad that each outputs a different type of action. For example, on a Playstation controller, the 'X' button is used to jump in action and adventure games but is also used to pass the ball in a sports-based game. Each button, when pressed or movement with the 360-degree analog stick sends an input signal to the server and the server then sends back a response signal that makes the game portray what you want it to do.

Figure 1 describes the methodology of Cloud Gaming and why the majority of users are in favor of this. Due to their sophistication, Game playing is more dynamic and complex. A combination of movements and buttons are required for there to be a reaction on the screen. In Cloud Gaming, these combinations of buttons can be thought of as signals, where each signal represents a button or movement. This signal is transmitted to a server that integrates the high-graphics requirements and other hardware to 'play' the game. The signal is then re-transmitted as low latency video to the user where the reaction from the players' input is seen. This process continues over and over again. Cloud Gaming is not only 'gaming' but there are other services companies offer. Shadow, another competitive Cloud Gaming company allows you to fully control remote machines.[7]

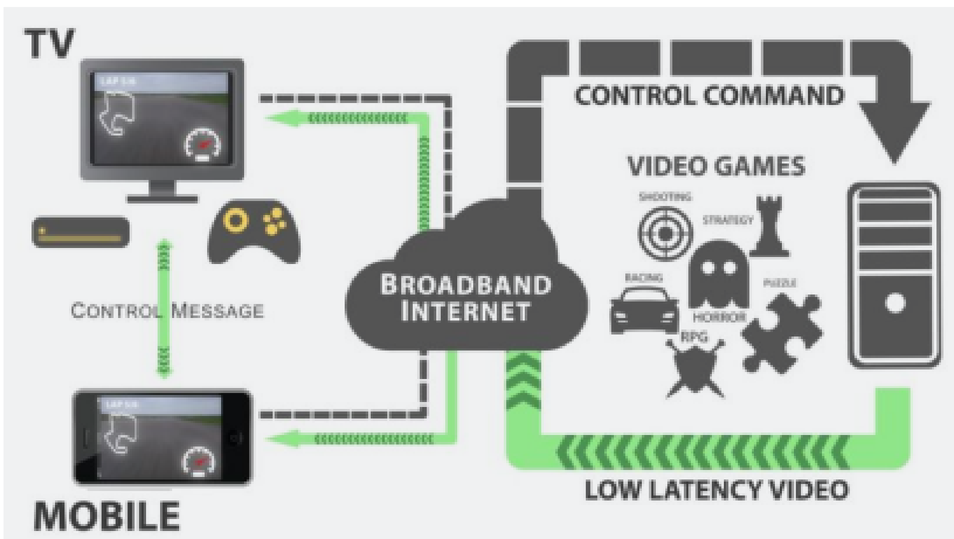


Figure 1: Cloud Gaming Topology

You pay a monthly subscription which grants you access to a virtual machine running somewhere on a server inside a data center, and you then use that virtual machine to play games. Sony Interactive Entertainment (SIE), the creators of the most advanced and highest sold gaming console, Playstation, have developed their Cloud Gaming called Playstation Now. Users who have followed the brand of gaming consoles from Playstation 1 (PS1) to the current Playstation 4 (PS4) can play any game online.[8] The best part is that the server is the component that performs all the processes, the user only requires a device that is compatible with this technology. The reason Cloud Gaming is so popular is that games usually played on mobile devices and tablets require high specifications and these devices tend to overheat due to the processing power that is required.

While game streaming services differ in terms of game selection and monetization they

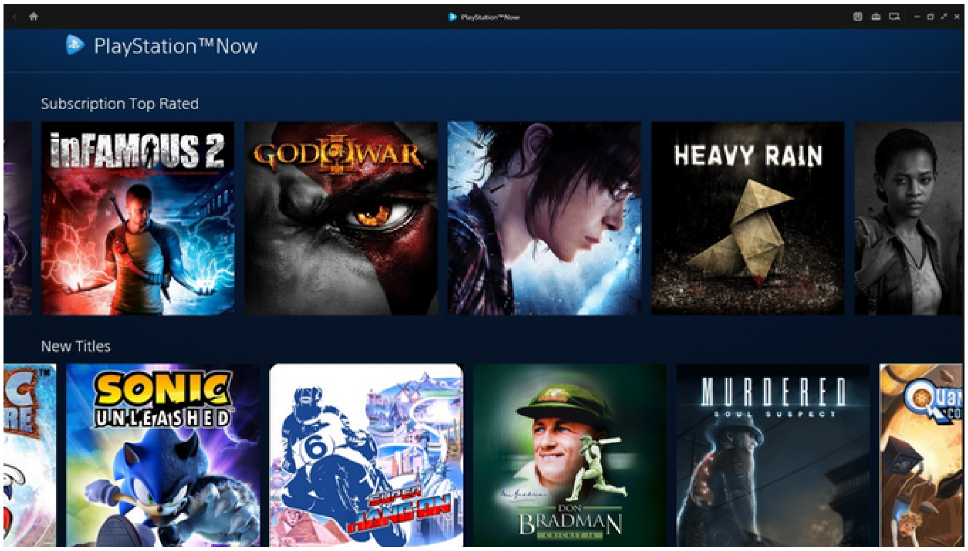


Figure 2: Playstation Now Cloud Gaming Interface. [9]

all follow the same rudimentary technical procedures: your device registers your input and sends it to the server. The server receives this process, acknowledges this and sends the result back to your console. In theory, this means that you could run games in 4K; four times the resolution of the standard 1080p at 60 frames per second fps without any lag or rendering error during gameplay. Although ideal for any gamer, this is not the case.[9]

1.1 Bandwidth and Latency

When dealing with Cloud Gaming, there are two major fields we need to understand. Bandwidth and Latency are constantly discussed as they represent the fundamentals of understanding Cloud Gaming dynamics.

1.1.1 Bandwidth

There are many ways one can describe what Bandwidth is. For the sake of this report and its body, we shall describe it as the amount of information or data it holds per unit time that a medium of transmission (coaxial cable or copper wire) can handle. This suggests that a larger bandwidth moves more data per second than a smaller, much slower bandwidth. The value for Bandwidth is typically measured in bits per second, commonly seen as 'bps'.

The Institute of Electrical and Electronics Engineers (IEEE) created standards for different wireless configurations such as the 802.11 range. Each type of configuration has its own unique values for Bandwidth, throughput, range frequencies and many other attributes. Figure 2 describes a Bandwidth test performed clearly showing the Download and Upload speeds of the internet connection. In this example, the Bandwidth shows 60.28 Mbps or 60.28 Million bits per second. This means that if there are no other applications in use, it can download 60.28 million bits every second as well as upload a file at 74.45 million bits every second.

This also bears the question - how many clients can one server process? We know that too many clients, with low bandwidth, will cause the game to lag I.e responsiveness will decrease drastically.[10]

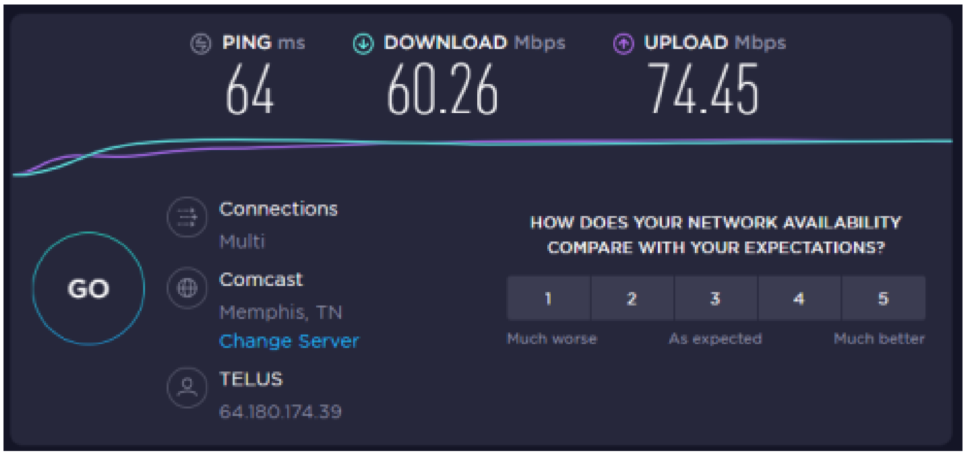


Figure 3: Speedtest for Bandwidth

1.1.2 Latency

Another parameter that directly affects Cloud Computing is Latency or ping. It is described as how long it takes for you to see a reaction from the action you initiate from a game. Quite simply, if your ping is 35, it would take 35 milliseconds (ms) for your teammate to see an action that you performed from your game client. Therefore, the client needs to be as close to the game servers as possible since we are aiming for the smallest latency/ ping possible. More specifically, in Cloud Gaming, all the processes are occurring at the server-side, suggesting that the frames are being processed there and then a series of frames are sent back to the client, which are just the updates of the inputs. Online gaming customers are much more prone to abandon a game while experiencing latency(500 additional milliseconds)[2]. The amount of acceptable latency varies from one game type to the other. In a first-person shooter (FPS) like DOOM, latency above 100 milliseconds can deteriorate the experience of the gamer [19]. Another study suggests that the most tolerable input lag is 100ms for FPS games, 500ms for MMORPG, 1000ms for RTS games beyond which the QoS (Quality of Service) and QoE (Quality of Experience) reduces considerably [20]

1.2 Voice over Internet protocol (VoIP)

VoIP plays an important part when it comes to the whole gameplay experience. With the advancement of the internet and IEEE releasing new Wi-Fi router standards, we are now in an era where game interaction with the aid of vocals is possible. the addition of voice to Cloud Gaming unlocks dimensions, making games more realistic and personal. VoIP can be measured using its QoS parameters such as end-end delay, Jitter, and Observing the sent and received packets.[11]

2 Related Works

With the advancements made in technology, cloud gaming has been the focus of attention for both industry and research. These games are becoming more resource-intensive as the delay is one of the biggest challenges to cloud gaming. This results in keeping our focus on various attributes such as consistency, responsivity, reliability, security, and persistence which makes the network more and more expensive. We will see the survey on Cloud gaming: Future of computer games [6]. Researchers have come up with the idea of Peer-to-Peer (P2P) gaming networks in which Simulation of Massively Multiplayer Online Games (MMOGs) is one of the prominent ideas [4] which we have discussed below. We'll also include a description about the past projects by Ahmed H. et al. titled "On the viability of 4K-Cloud Gaming on Wi-Fi" [24] and another project by Royyala L. N. [1] in which they modeled a Cloud-Gaming service like Gamefly using Riverbed Modeler 18.0.

2.1 A survey on Cloud Gaming: Future of Computer Games [6]

In this survey, the researchers presented the basic cloud gaming platform that supports quantitative performance measurements in which they discussed the Quality of Service (QoS) including energy consumptions and network metrics and evaluated the Quality of Experience (QoE) for gamer experience. They also discussed the optimizations for the cloud server infrastructure and communications. It was found that better gaming experience comes with better optimization which increases the cost. Most recently, the cloud gaming platforms work as a "black box" in which an already existing game can be run on the support system so that cloud gaming can be achieved.

2.2 Simulation of Massively Multiplayer Online Games using OPNET [4]

In this research, hybrid Peer-to-peer architecture has been implemented in which the complete region of interest is handled by a pair of peers called the super-peer and clone-super-peer. In this, the super-peer is responsible for sharing the game update among the players within a specified region under their control. The clone-super-peer, on the other hand, is responsible for controlling the players' migration from one region to another. This network was implemented on Opnet Modeler 18.0 for simulation and got the expected results. The dynamic load balancer served for distributing the load among the area of interest. This load balancer acts as an intermediate between the game server and the regions. It was found that the hybrid P2P architecture aims to reduce the cost of traditional game server infrastructure. It also provides an option of scalability so that a greater number of players can be deployed. It was also noticed that the transport protocol took extremely more time and memory. The other limitations were for the OPNET modeler in which the system was limited to 1000 nodes and it did not provide the technique to split the region into two regions during processing.

2.3 Cloud Gaming Simulation [1]

The simulations of the cloud gaming topology were executed on Riverbed Modeler 18. The goal of the project was to find the QoE (Quality of Experience) for players/gamers. It was concluded that cloud gaming was a viable option for gamers who are connected at a minimum network speed of 45 Mbps.

2.4 On the viability of 4K-Cloud Gaming on Wi-Fi [24]

In this project Ahmed H. et al. simulated a 4k video trace on their topology. These results were then compared to the results obtained for the same topology but with a 1080p video trace. It was concluded that the 4k is a viable option and a possibility for the future, however, there were a few limitations as well. It was found out that the minimum speed to simulate a 4k video for cloud gaming has to be 19.5 Mbps where the 5GHz Wi-fi was proved to be suitable. In the created scenarios, a limit was set to 4 gamers/players at a time for a good experience of 4k cloud gaming.

3 Background

3.1 IEEE 802.11(Wi-Fi)

The IEEE has created a family of standards for Local Area Networks (LAN) devices which are required in different scenarios such as Wireless Local Area Network and works in conjunction with Ethernet. IEEE 802.11 is a set of protocols that describe the way the Media Access Control (MAC) and Physical Layer protocols are set to provide WLAN solutions to the client. [12]

There are various versions of IEEE 802.11 (Wi-Fi), each with their own set of protocols and variations to suit specific needs and requirements. These requirements include Bandwidths, Transmission frequencies, and Data Rates. Table shown in Figure 4 illustrates the most important 802.11 protocols.[13]

From this, it was decided that we would use 802.11n due to the Data rate of 600 Mbps as well as this protocol having a frequency range of 5MHz. This frequency is ideal for Cloud Gaming.

802.11 Wireless Standards					
IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac
Year Adopted	1999	1999	2003	2009	2014
Frequency	5 GHz	2.4 GHz	2.4 GHz	2.4/5 GHz	5 GHz
Max. Data Rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1 Gbps
Typical Range Indoors*	100 ft.	100 ft.	125 ft.	225 ft.	90 ft.
Typical Range Outdoors*	400 ft.	450 ft.	450 ft.	825 ft.	1,000 ft.

Figure 4: 802.11 (Wi-Fi) Standards

3.2 VoIP

To understand VoIP we must individually look at its QoS attributes. These include Jitter, Mean Opinion Score (MOS), end-to-end delay and VoIP codecs. Only after understanding these parameters can we choose the correct specification for our objective.[14]

3.2.1 Jitter

Information is transmitted from a sender to a receiver in packets. Each packet is sent one-by-one to its destination. Packet 2 will not be sent until Packet one has been ACK (Acknowledged), therefore there will be a difference in variation time. Jitter is the difference in this time.[15]

3.2.2 Mean Opinion Score (MOS)

With Cloud Gaming, users must understand what other players are saying. Voice interaction in games opens up a new experience for players. Therefore, the quality of voice interaction needs to be high. Table in figure 5 describes a MOS table where each listening quality is assigned a score from 1-5. number 5 being the highest grade with no noise in the background whilst giving a score of 1 shows voice is inaudible. [16]

Quality Scale	Score	Listening Effort Scale
Excellent	5	No effort required
Good	4	No appreciable effort required
Fair	3	Moderate effort required
Poor	2	Considerable effort required
Bad	1	No meaning understood with effort

Figure 5: MOS Scale

3.2.3 End-To-End Delay

Similar to Jitter, this delay describes the time taken for vocals to transfer from the origin to the destination, more specifically when a user speaks, the signal is sent to the server where it is compressed and encoded. It is then sent to another user on the network where this data is decompressed and decoded. Therefore end-to-end delay is a combination of all these processes.

3.2.4 Codecs

Codec	Data rate (kbps)	MOS score
G. 711	64	4.3
G. 723	5.3	3.6
G. 726	32	4.0
G. 728	16	3.9
G. 729	8	4.0
GSM	13	3.7

Figure 6: Voice Codecs

A voice codec is an algorithm that converts analog, voice into a digital encoding. It uses MOS values to determine the quality of the voice produced. Table in figure 6 describes the different types of voice codecs and their respective MOS numbers.

Each type of voice hardware will have several codecs, The software inside the hardware will determine what codec to use based on the application being executed. From the table, we can see that 3 of the codecs have a MOS score of 4 or higher, which is the ideal case for Cloud Gaming. We, therefore, chose G. 729 as the codec since it has the lowest data rate which is optimum for long-distance transmission.[18]

4 Simulation Topology and Analysis

We built cloud gaming topology using Riverbed Modeler. We assume our client/user, who is accessing cloud gaming service, is in Vancouver and the server is situated at Memphis. We are using a PPP DS3 link (with a data rate of 44.74 Mbps) to connect both client and server to the cloud. Next, we introduced a packet latency 0.07796 s and packet discard ratio of 3% in the IP cloud node to compensate for the propagation delay which occurs due to the distance between the two subnets being around 3898.6 km.

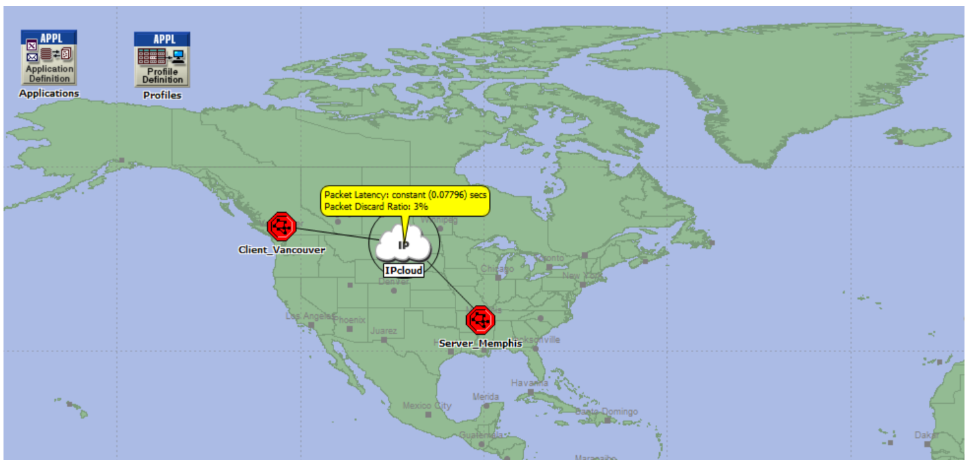


Figure 7: Cloud Gaming Topology

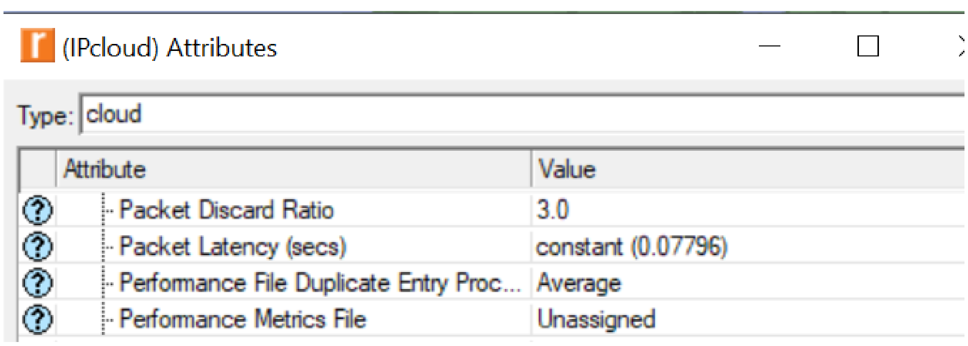
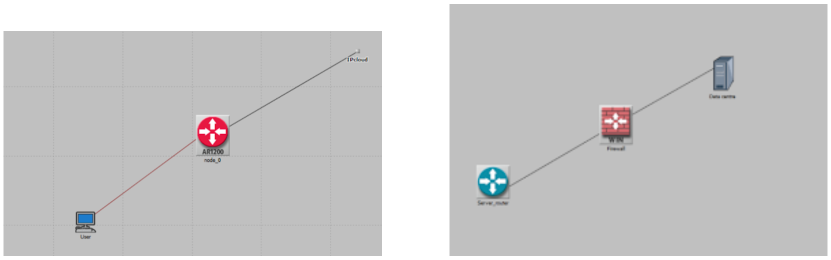


Figure 8: Editing cloud node attributes to mimic practical scenario

To demonstrate the viability of 4k and 1080p cloud gaming, we model the server-side subnet by using 3 components: data center, firewall & router. A data center is required to process & render the game scenes on part of the end-user and to handle incoming user commands; simulated by light HTTP. The data center then sends back video frames to the client-side; simulated through a video-conferencing feature of the node. Furthermore,



(a) Client-side subnet (b) Server-side subnet

Figure 9: Subnets

a firewall is used to secure the data center from malicious attacks. A router is then used to connect the data center to the user side through the PPP_DS3 link. In the case of user-side, we use a router (e.g. Huawei AR 1220W) that supports both Ethernet connection and wireless LAN technology to facilitate more users. A single user; who accesses the cloud-gaming service through an ethernet workstation and uses the internet through the router; is added to the user side subnet.

The node Application Configuration supports three applications:

- Video application that will support our video traces to run along the simulation time. We use this application to mimic cloud gaming by using video conferencing.
- VoIP application which will enable players to talk to each other while playing.
- The gamepad will process user commands through light browsing via HTTP.

The node Profile Configuration supports three profiles that contain the three applications shown in figure 10.

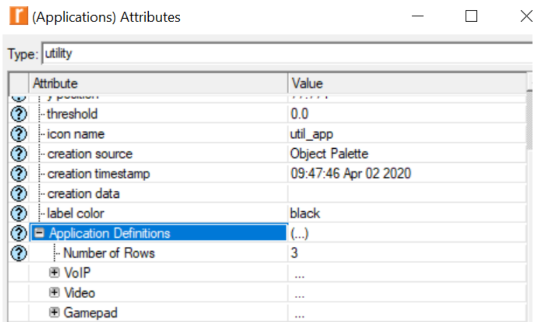
4.1 Obtaining Video Traces

For evaluating network performance for 1080p/4k cloud gaming, we needed to obtain video traces[21] to simulate into our topology. We used one 1080p video trace [22](from Arizona State University's video trace library) with a quantization of 30 at 24 fps. For importing traces to Riverbed Modeler, we followed the steps from the "Importing Video Traffic in Opnet" section in the SFU network systems lab [23].

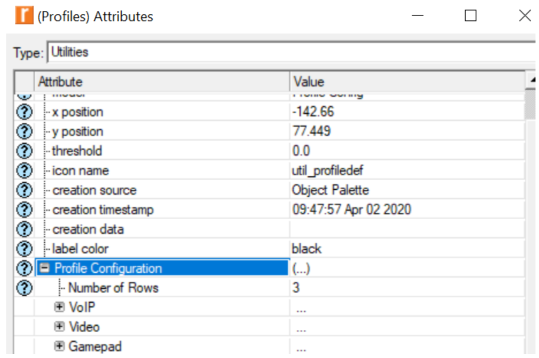
5 Results and Discussion

5.1 Scenario 1 (Single user vs Multiple users for Interactive cloud gaming)

We first simulate our topology shown in figure 9 in which we can see just a single user. In this topology, we have added three profiles: Voice conferencing, voice, and HTTP (light



(a) Application Configuration Attributes



(b) Profile Configuration Attributes

Figure 10: Attributes

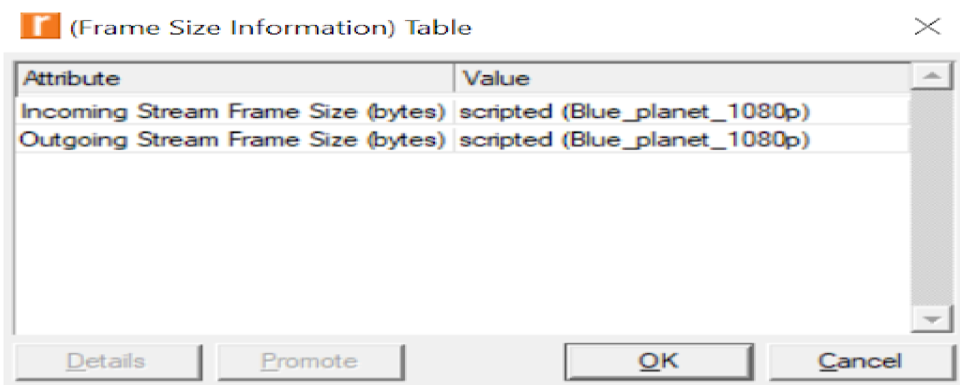


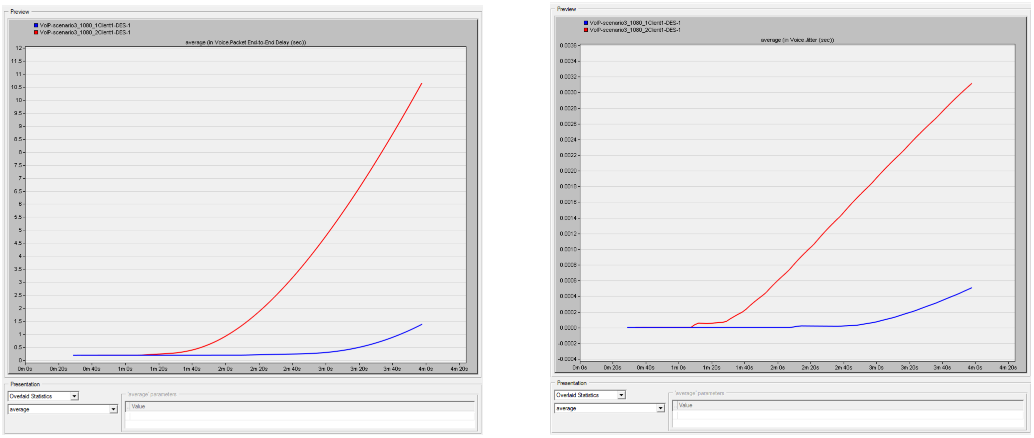
Figure 11: Importing 1080p video trace in Riverbed Modeler

browsing) for the gamepad. The application and profile attributes are set according to the tables shown above. We will first look at the end-to-end delay. For comparison, we have simulated the same network but included more users/gamers at the client-side.

We can see in figure 12 that both the delays start from 30 seconds. This is because in the profile attributes we selected the same. It can be observed from the graph that there is an exponential increase in the delay in both cases. The delay for 2 clients/gamers in a subnet increases from 0.2 to 10.7 seconds, whereas the delay for only one client barely increases from 0.2 to 1.5 seconds. This is expected behavior because as time increases we expect the delay to be more. Also, the delay for two gamers increases rapidly as there will be more packets sent from more users which will directly increase the delay over time.

Next we look at the jitter in the voice profile for the same two cases.

It can be observed that the average jitter for 2 clients/gamers in a subnet increases linearly from 0 to 0.0031 seconds, whereas the jitter for only one client increases rarely from



(a) Voice Packet end-to-end delay for 1 client (blue) and 2 clients (red)

(b) Voice Jitter for 1 client (blue) and 2 clients (red)

Figure 12: Jitter and end to end delay

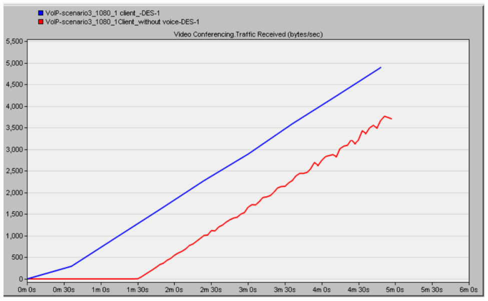
0 to 0.0005 seconds.

5.2 Scenario 2 (Effect of adding voice to 1080p cloud gaming)

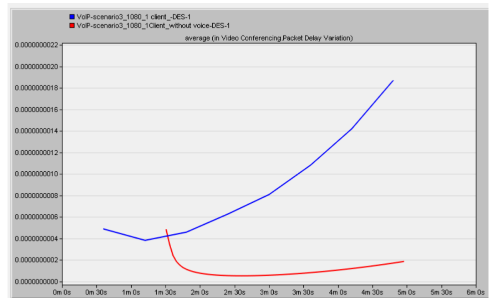
To check the effect of cloud gaming, we decided to run the 1080p video trace. Then we compare the results when the client accesses to 1080p cloud gaming without voice application to the result when the client accesses to inter-active 1080p cloud gaming with a voice application.

From Figure 13 (a), we can infer that in case of cloud gaming without the voice over IP services, the number of bytes received from the server to the client increases linearly with time on an average after 1 minute 30 seconds. The number of bytes received by a gamer accessing cloud gaming without voice application is around 3600 bps while for interactive gamers it is about 4900 bps by the end of the simulation. So as we expected, interactive cloud gaming accessing voice applications receives more traffic (1.4 times more) than cloud gamers without voice application.

In the case of cloud gaming without the voice over IP services, the packet delay variation/jitter remains almost constant as time proceeds(except for an initial couple of seconds) which is expected. For interactive cloud gaming, the delay variation rises exponentially from 4×10^{-10} to 19×10^{-10} on average. As expected, the packet delay variation is much higher when the client uses interactive cloud gaming with a voice application. Though users who access cloud gaming services with voice applications face larger delay, yet it's low enough for a seamless experience for FPS(First Person Shooter) games.



(a) Voice conferencing traffic received with voice (blue) and without voice (red)



(b) End to end delay with voice service (blue) and without voice (red)

Figure 13: traffic received and end to end delay

5.3 Scenario 3 (Interactive cloud gaming with background load)

For this scenario, a background load has been added to the PPP DS3 link that connects the IP-cloud to the subnets. This load can be seen in figure 14. A background load has been initialized on a step function for different time scales.

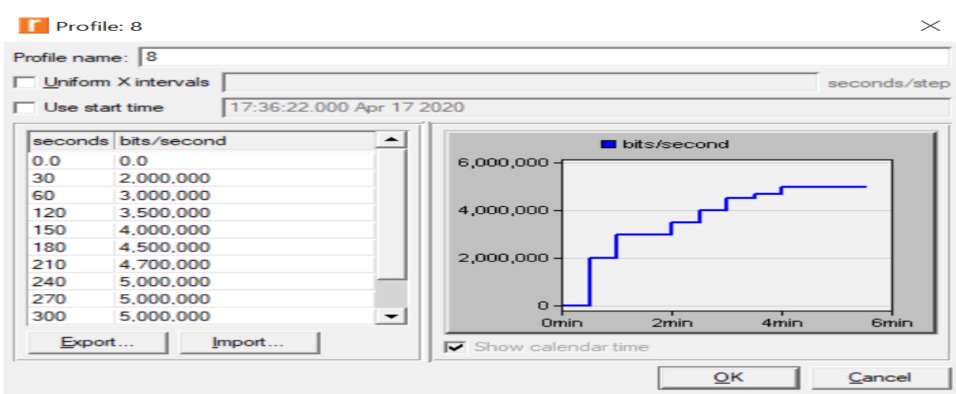
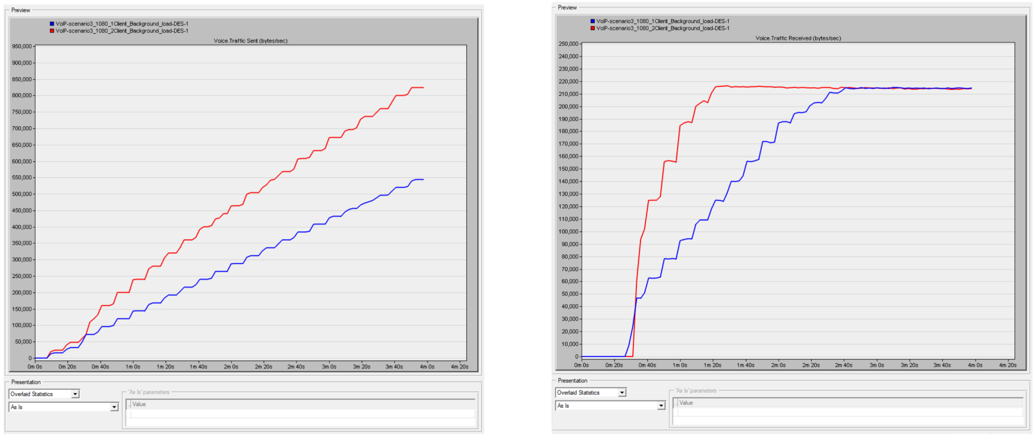


Figure 14: Adding background load to the link

Simulating our topology with a background load we will see how the load at different rates will affect the traffic received and sent at different times after simulation. The figure 14 demonstrate the traffic sent and received from the voice and the video profiles.

The end to end delay and jitter for this scenario is almost similar to the results in scenario one.



(a) Voice traffic sent for 1 client (blue) and 2 clients (red)

(b) Voice traffic received for 1 client (blue) and 2 clients (red)

Figure 15: Voice traffic sent and received

5.3.1 Voice traffic sent and received

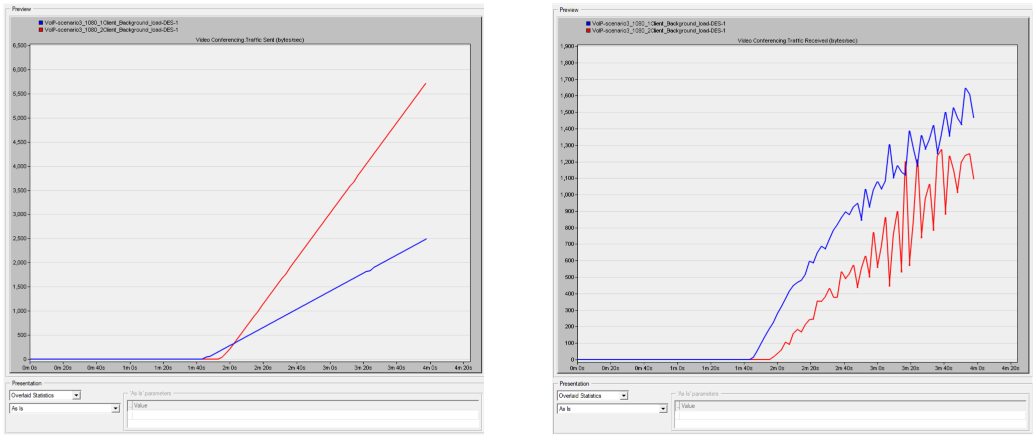
The presence of a background load affects the voice traffic received and sent by the gamers. This load forms ripples in the traffic at the time instances where we have added a background load similar to the figure 14. The results can be seen in the figure 15.

In the figure 15 (a) it can be observed that the number of bytes sent by the client to the server increases linearly with time for the voice over IP services. The number of bytes sent by 2 gamers is more (825,000 bps) than the single user (550,000 bps) at the end of the simulation. This trend shows that more traffic is sent from two gamers as compared to only one gamer. This also infers that a 45 Mbps link capacity is a viable option for a good quality of experience for voice services even when we add a background load to our topology.

For the receiver side in figure 15 (b) it can be observed that the traffic received increases is a step-like fashion for two gamers/clients, whereas the increase is ramp-like for only one gamer. After two minutes and thirty seconds, the two cases settle for a constant value of 215,000 bps. This trend shows that for the given configuration between the client and the server, it takes more than a couple of minutes to reach stability in the network and the gamers can observe constant traffic after this time. This results in minimal fluctuations in the traffic received and a better quality of experience by the users.

5.3.2 Video traffic sent and received

The same background load as shown in figure 13 was used for video conferencing services. The results for this case in the scenario can be seen in figure 16 (a) and (b).



(a) Video traffic sent for 1 client (blue) and 2 clients (red)

(b) Video traffic received for 1 client (blue) and 2 clients (red)

Figure 16: Video traffic sent and received

In figure 16 (a) it can be observed that the video conferencing starts at 100 seconds after the simulation begins. This has been in the Profile configurations. The number of bytes sent from the client to the server increases linearly with time. The number of bytes sent by 2 gamers/clients in a subnet is more (5,700 bps) when compared to a single user (2,500 bps) at the end of the simulation. This is expected behavior for a single user when compared to multiple users.

For the receiver side, the increase is also linear but this increase is inconsistent over time. This inconsistency is because of the background load that we have added to the network at different time steps as shown in figure 16 (b).

Conclusion

By observing the trends in consoles and now, Cloud Gaming since the 1980's we can see that the majority of the companies such as SONY and Microsoft as well as other independent gaming companies such as Gaikai will be investing more into Cloud Gaming functionality. It is predicted that after the 9th Generation of consoles, which is the PlayStation 5 (PS5) and X Box Series X, developers will invest their energy and research into cloud gaming only.

In our report, several parameters were tested such as end-to-end delay, Jitter, and traffic for both voice and video. Results based on our hypothesis that more data would be transmitted if we added a voice configuration to the already video data being transmitted to the server and back to the client was conducted by Riverbed modeler Academic Version and the scenarios shown in our results. Moreover, we added in a load to all our experiments to make these more realistic and portray better results.

For future experiments, we can add in more users in different cities and continents as well as add in several more servers to portray a more life-like environment. It must be noted that Riverbed Modeler Academic version 17.5 is limited to the resources and number of nodes it can configure.

Acknowledgement

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