Cloud Gaming: Architecture and Performance

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***Abstract*— Cloud gaming is the process of implementing a cloud computing scheme to the realm of online video games. Cloud computing is utilized worldwide by thousands of corporations for the purpose of processing large sums of data without having to shell out the money for the hardware to do so. Since the introduction of the internet in 1991, video games have evolved into an online universe where gamers can achieve what was previously impossible in the reality they reside within. Video games have evolved into a 25 billion dollar industry that continues to grow year after year and does not seem to be slowing down. Over the past 30 years graphics cards have gone from having approximately 32KB of memory to 6GB of memory.[10] That's a rate of approximately 200MB a year of improvement on memory alone. Hardware requirements for modern gaming grow at an extremely rapid rate. High end hardware is extremely expensive, so in order for users to stay up to date and play their new favorite games at high performance they require a significant amount of consistent PC upgrades. With further reading, this paper discusses the (II) Historical Implementations of cloud gaming, the (III) Modern Implementations of cloud gaming, the (IV) Networking Architecture that accomplishes this, the (V) Effectiveness and Performance of cloud gaming, the (VI) Prospective Applications of this technology, and the (VII) Economic Impact on the "Gaming" Industry. This paper serves to be an exploration of the technology and ideologies associated with cloud gaming, while taking a colloquial look into the software and hardware configurations needed to implement such technology.**

***Keywords*—**

Rendering: The automatic process of generating a photorealistic or non-photorealistic image from a 2D or 3D model by means of computer programs.

Framerate: Frequency at which consecutive images called frames are displayed in an animated display.

Latency: How much time it takes for a packet of data to get from one designated point to another.

Host: A network host may offer information resources, services, and applications to users or other nodes on the network.

Virtual Reality: The computer-generated simulation of a 3D image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment.

Software as a service: A software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted.

I. Introduction

Reliability is important in the modern world, and there isn't a more reliable methodology for processing data than through the cloud. For years cloud providers such as Microsoft and Amazon have leased out cloud servers for quantitative computing purposes. Allowing entities with large sums of data to quickly complete a computation faster than they would otherwise be able to.

As some time has passed and the cloud has displayed its longevity, the idea of using the cloud as a gaming platform has come into scope. The driving force behind the concept lies within modern gamings increasingly growing workload. As digital leisure activities continue to grow in popularity, so does their complexity. Modern day games, including those utilizing virtual reality, are a computationally heavy process that not many home computers can handle. Using the cloud as a platform, even those with economically basic devices would be able to experience state of the art, high end games.

There are overwhelming benefits to this architecture, one of the most enticing is the potential for complete mobility of all games. Previously, the only games that could be taken with a consumer were mobile applications, but with the cloud as a platform the user can now take all games with them as they only need a display device to be able to play. As a result, the

cloud provides platform uniformity, meaning that all games can now be played from any operating system, eliminating operating system dependencies and giving users a chance to play their favorite games without limitation.

Platform uniformity is a game changing element of game development for leading studios. Patching released software is always a delicate process because there are many different operating systems and hardwares of varying specification to interact with. Simplifying this process allows these increasingly busy studios to focus on the progression of the game, instead of the intricacies of patching across all platforms. Simultaneously, the residence of the game solely on the cloud allows for the elimination of the digital property rights dilemma. The game would be significantly harder to steal if its only presence was in the cloud, resulting in increasing profits across the industry. The rise of gaming is the most prevalent in the 21st century, and as progression continues games will rise into the clouds.

II. Historical Implementations

In this section, we discuss when and how Cloud gaming came about. Today's implementation all began with one company making an effort to allow consumers to play games without needing to have the most high tech machines.

The first instance of Cloud gaming to come about was created by a private company, OnLive, founded in 2003 in Mountain View, California. The company premise was to rent and demo video games without the need for an installation. OnLive delivered the games through their software as a streaming video that was rendered by the OnLive servers.

With the OnLive servers doing all of the rendering, users no longer have to render the games onto their home machine. Along with this, there came about a new feature for the user to be able to record and spectate games. Now users could play games that were too intensive for the client's hardware to run, advancing the world of cloud gaming.

A major issue that OnLive could not find a solution for was input lag, which deterred users from using this new service as a substitute to playing video games. This issue amounted to the defuncting of OnLive in 2015, and Sony Computer Entertainment purchasing of their patents [1].

After the introduction to cloud gaming, the new genre began to spread along other platforms such as the XBOX and PlayStation consoles. Both of these consoles have already established their name and popularity, that their enterprises had the resources to invest and popularize Cloud gaming. In the 2015 CES (Consumer Electronics Show), Sony introduced a game streaming service, PlayStation Now, with their new patents from OnLive. The new service had many of the same features as OnLive's streaming service, but with a better quality and reliability. reliability

PlayStation Now uses Gaikai Cloud technology as it's driving force. Gaikai's Cloud technology was established in 2008, and has improved and revolutionized Cloud gaming and next generation video game technologies. Although Gaikai was bought out by Sony and shut down, the foundation of the technology powers SCE video game streaming services alongside Remote Play by Sony to allow the PlayStation 4 to interact with the PlayStation Vita handheld system [4].

As the technology behind Cloud gaming gains in popularity, so does the knowledge of the implementation it needs. This has resulted in developers pushing towards mobile application and browser based gaming. One of the first successful and popular mobile applications originated in 2015. The Agar.io game was developed by nineteen-year-old student Matheus Valadares and quickly skyrocketed after the link to the game was released on 4chan. The game had become so popular because there was no need to download anything and there was no complicated tutorials [3]. Users could easily start a game with the other modern gaming users in the community.

Agar.io has resulted in the stem of many new .io games. Not all of them have been just as successful, but Slither.io has been. The simplicity of the game and the ease of access make for a great mobile application, which has expanded Cloud computing further in the last few years.

With much more to learn about how to improve the structure and performance of Cloud gaming, as well as the shear playbase of video games today, there is no doubt that the technologies will continue to advance. Cloud gaming is allowing massive amounts of players to access games at the same time, and developers of these games are finding it easier to maintain and patch with more accessibility.

III. Modern Implementations

Here, we summarize the current state of Cloud games. There are the platforms that are succeeding the most as well as the actual numbers when it comes to running a cloud game on your own system today.

The current implementation of cloud gaming starts with Liquid Sky, an elite cloud provider. For a windows PC, the user only needs 250MB of storage space, an Intel 4000+ graphics card, and 2G of RAM. Most users with an average client already have 250MB of storage space, and the simplest clients contain at least 2G of RAM which eases the access to cloud games to many.

Liquid Sky has multiple data centers to help with the latency of gaming. Latency is the delay of data sending after a command is made. Cloud games, unlike videos and music do not have time to buffer beforehand, so all commands are happening in real time. This is one of the largest problems that comes with cloud gaming as the games are more prone to freezing while the user waits for a command to go through the database and by interpreted and sent back. Liquid Sky has placed a data center in California, Texas, and Washington DC in the United States alone, and this has helped with the latency issue. Players are able to be spread amongst the data centers in

order to get a better experience, so not all players are having to wait for a single data center to interpret their commands to the game.

Although Liquid Sky has established great advancements among the Cloud gaming industry, further advancement is continuing to be difficult. The gaming industry has been working towards converting to the cloud, but high latency, closed-catalogs, piracy and costly infrastructure have made it difficult to keep advancing the gaming hardware needed [11].

The most popular game managing services today include: Steam, Uplay and Battle.net. The management platforms, with the help of Liquid Sky, allow users to store and play videogames on a majority of computing devices. This means that a user does not need to purchase a game more than once to play across multiple devices, and is yet another reason that cloud gaming is increasing its user database.

As long as the user's internet connection has 3-5Mbps to stream a 1080p, 30 fps game, cloud gaming with Liquid Sky and the managing services is possible [12]. This is the current baseline that has been giving the player database an opportunity for an experience with high end gaming without the bulk cost of a state of the art computer.

IV. Networking Architecture

It takes a large amount of technology and thought to make a game work in the cloud, and here we go over just what it takes with some of the modern implementations of a Cloud Gaming System.

The architecture of a Cloud Gaming System is still one being discussed. There a many considerations to make, and improvements that could be made on the current state. Figure 1 illustrates how cloud gaming services work currently. In essence, the user runs the game on their client and their requests to the game are interpreted by the game's logic. The game then sends back the new video that the user's client can decode and present to the user [14].

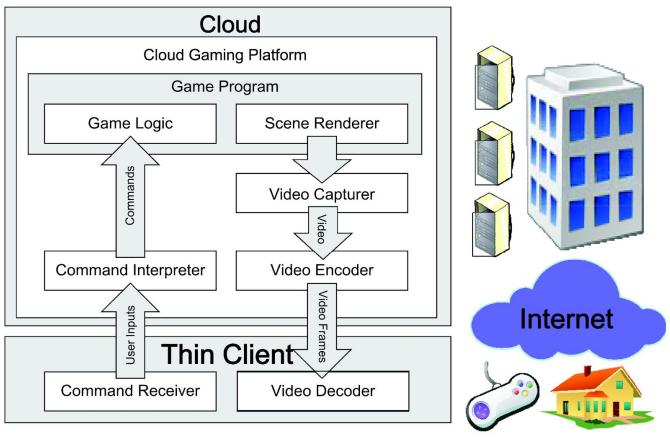

Fig. 1 Typical Cloud Gaming architecture.

The cloud functions by hosting the cloud gaming platform on cloud servers in either one or many data centers. The platform's job is to both interpret the user's command to the game and to render the game scenes in real time. This combination is what makes it difficult to communicate cloud games with the user (The struggle that led to OnLive's defuncting).

The basic architecture in Figure 1 is what most developers are using to increase the rendering speeds of games, and new ideas are being suggested and tested frequently. What is known to work in producing a working cloud game is structures such as a DNS, authentication, CDN (Content Delivery Network), cache, data storage, traffic manager and load balancer, and a web app server. Traffic will move through each of these structures, being routed and rerouted to successfully create a cloud gaming platform [15]. There are many other structures being considered, and with the advancement in cloud gaming technology, we should see a more solid idea of just how cloud gaming architecture works.

V. Effectiveness and Performance

The cloud has proven to be an effective platform for server based processing. It provides higher performance characteristics and can achieve synonymous performance to a top tier machine. Current industry leaders are capable of providing a high performance standard even with minimal internet download speeds. The providers can supply high definition gaming with smooth framerates to all of their subscribers regardless of their current machine specifications.

Input lag has been the main problem cloud gaming has faced through development. Latency is the speed it takes for instructions to be sent from the user to the server and back. Given current state of the art hardware the primary issue is essentially resolved. The platform is capable of providing response times of 30-50ms depending on the distance between the user and the server. The infrastructure has now been laid for there to be servers across the country allowing users in various locations in the country to have reasonable response times.

With the centralized characteristic of the cloud gaming infrastructure, developers are able to service a large amount of users with a compact networked system. This system introduces a stable and controlled environment for the developers to work in. Streamlining the development and maintenance process translates into a more profitable and usable system overall.

VI. Prospective Applications

The future of Cloud Gaming is not one that is slowing down. The growth and ideas that come along with the different streaming services are going to continue to expand. This section will highlight some of the future projects

currently at work, and how they will change the face of Cloud Gaming with their release.

Virtual Reality (VR) is also on the verge of expanding, which Liquid Sky will be a front-runner for as a service provider. VR combining with cloud gaming means that the high cost can decrease, and the user database can grow. Games would be rendered in data centers, as they are currently, and will lead to livestreaming the output right to the user's headset.

The current state of VR requires users to buy powerful and costly hardware to enjoy the new idea, that will continue to need an upgrade as the knowledge and implementation of VR increases. Cloud gaming will eliminate this need and open another door for it's growing use. Although how companies plan to use cloud gaming for VR in the future is still being questioned, there are plans in place.

GameFace Labs in San Francisco revealed their current plan to create a VR headset that will not need any connection to a PC to function or any downloads. They have claimed that their new headset will have "twice the power of an Xbox 360, strapped to your face" [16].

Although Virtual Reality is relatively new and exciting, it is not the only future element of cloud gaming. WebGL powered HTML5 is making a huge leap towards web games being delivered with an even higher graphics quality [17]. The newer WebGL standard has allowed web browser games to gain the hardware acceleration they did not have before. Local computers are now able to have local computing rather than server hardware, which saves users more money when it comes to gaming.

The issue with HTML5 is that there is scarce amount of high quality games available. The hope is that with the continuing growth of "pure" HTML5 operating system platforms, such as Firefox and Chrome OS, the quality of available games will begin fixing itself [17]. A benefit of the HTML5 OS's is that any platform that can run these internet browsers will have access to the same games.

The streaming quality of HTML5 is one that is a positive move for cloud gaming, and the bandwidth that comes along with this particular method is more modest. This is allowing more users with an average advanced broadband (a minimum of at least 25 Mpbs) to play these cloud games [18].

One of the major issues with HTML5 is the audio portion of games. Yes, graphics are extremely important when it comes to a quality game, but audio quality also plays are part in users experience. There is bugs with audio among all of the platforms that use HTML5, and the fix of this will be another step for browser based cloud gaming [18].

On the developer end, HTML5 is free to use. This is an improvement from attempting to develop with Flash games and other technologies costs the developer. HTML5 has shown so much growth thus far, that it is no surprise that it is surpassing Flash in its use. The graph in figure 2 shows how even the browser search between Flash games and HTML5 games has changed.

Games available in HTML5 are continuing to grow, as well as the interest in using is as a platform for gaming and developing, so it will be interesting to see what changes and developments will be made as more discoveries about cloud gaming/computing are made.

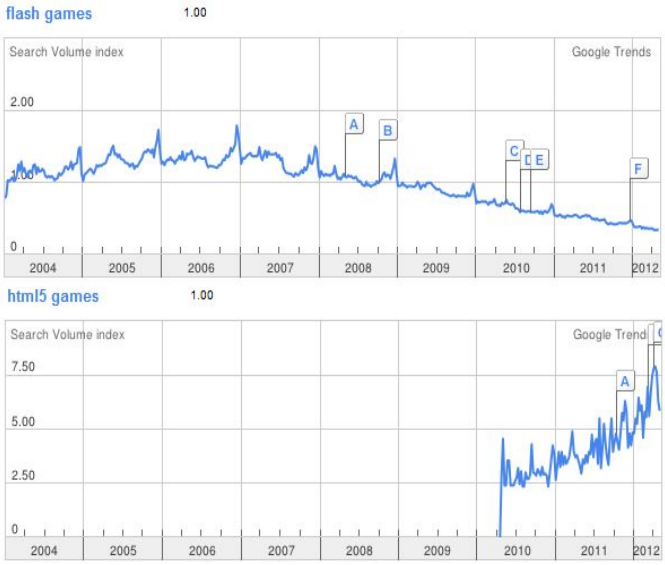

Fig. 2 Google trends for the search terms "flash games" and "HTML5 games" [19].

VII. Economic Impact of Cloud Gaming

The relationship between producer and consumer has always been affected by technology in one way or another. Technology has the ability to make it more affordable for producers to develop and create products, as well as make it more enjoyable for users to operate and purchase products. The trend continues with cloud gaming as developments in technology has made it more convenient for consumers to purchase and play games. Developers benefit from this technology by not having to keep client side operations in mind when creating or maintaining their products. These benefits to both parties makes the industry of cloud gaming enticing for new entrepreneuring groups. This section will detail the economic impacts that cloud gaming has on the consumers and producers in this industry.

A. Consumer

One can argue that consumers control the market and what does and does not become successful products. There are a multitude of factors that affect the decisions of consumers, but as seen in Dennis W. Rook and Robert J. Fisher's paper titled "Normative Influences on Impulsive Buying Behavior",[20] we can see that the most susceptible people to impulse

purchases are influenced by “negative normative evaluations” when subconsciously deciding whether to buy a product or not. Therefore convenience of less computation/storage requirements and increased usability function as positive evaluations that will increase the purchasing rates for a majority of consumers.

Another deciding factor for the consumers’ experience is the price of a product. With increased ease of development, there is an argument that the product price can possibly decrease as development costs decrease. In an ideal environment, this is the perfect storm for a product. As development cost decreases, and product price decreases, producers get to save money and a lower cost enables more edge consumers to make a decision to purchase the product. Both parties benefit.

That being said, there are negative evaluations that cloud gaming does introduce into the market due to current technological limitations. These evaluations can come in the form of network latency, community of users, and volume of product selections. Network latency has been and still is an issue for cloud gaming. Most gaming enthusiasts tend to hold performance at a high standard when looking at products. This is a divisive issue as most “gamers” would say that a game with high latency is “unplayable”. There is a subset of games that will overlook this quality due to necessity because of not meeting system requirements for the most sought after games. This a contributor to the community aspect of cloud gaming. Due to cloud gaming in its current state being more catered to consumers with lower end hardware, the community around cloud gaming is relatively small. This is changing as larger corporations are implementing cloud gaming into their infrastructure. This issue will change with time due to gaming communities being comparable to living, moving beings.

With such a niche community surrounding cloud gaming at the moment, there isn’t much incentive to produce games that are tailored to the cloud gaming system. This low volume of games, and other performance factors mentioned earlier, decreases the likelihood of the gaming community adopting this new style of gaming.

There is a few solutions to increasing the popularity of cloud gaming with consumers. First is mitigating the performance issues due to still developing technologies. The most effective solution to this problem is time. The technology will continue to develop in order to make cloud gaming more effective. Second problem is the amount of content related to cloud gaming. This will be solved as developers continue to produce content for these cloud infrastructures.

B. Producer

Cloud gaming as opened up new avenues for producers to increase their earnings and even structure themselves to models that may not have been possible in the past. Cloud gaming has impacted the traditional business model of developing a product and selling it to consumers who think there is value in the product. But it has also created a model for developers that rely on “Ad Revenue” to fuel their success. No matter the business model, cloud gaming introduces benefits to producers.

As mentioned in the consumer section, cloud gaming introduces more straight forward development process. Instead of having to develop their products to be compatible with many operating systems and hardware, the producers only need to develop for the specifications of the centralized host. This cuts down on development time by eliminating redundant code. This centralized structure also simplifies the maintenance process required for the products. In a traditional gaming model, developers would need to send out “patches” to the client systems in order to synchronize all the consumer programs. In a cloud gaming environment, the developers only “patch” the host system that is being accessed by the clients. These are improvements to the development process that are independent of the producer's business model.

A business model that was popularized by the increasing use of the internet is one that’s dependant on “Ad Revenue”. This concept of attracting traffic to websites that host advertisements on them has made a significant impact in the development of free cloud gaming. This is a tactic that many producers have capitalized on in recent years. With the increased popularity of “.io” games. These are identified by their URL addresses ending in “.io”. Developers of these games rely on attracting as many consumers to their webpage as possible in order to increase their average traffic. They due this because other businesses will pay money to the website owner based on how many people will see their advertisements. Cloud gaming provides a platform that increases the convenience of the user as they don't have to download or install any content. For the consumer they can experience gaming instantly by navigating to a website. As mentioned before, it has been shown that these games and others implementing similar techniques can be very prosperous to the producer.

Although there are a lot of benefits to the producer when developing for cloud gaming, there are a few setbacks that make the industry difficult to enter into. To name a couple, these challenges include quality of the games produced, and

the hardware requirements to host cloud gaming. Due to the current technologies of cloud gaming, it can be difficult to produce a games that have precision or low latency requirements. This limits the producers to make games that may not be up to their performance based standards. On top of this, developers must meet the hardware requirements discussed in the Networking Architecture section above. This is a detriment to any developer that may lack the resources to build or rent the infrastructure needed. This lack of developers with the hosting ability contributes greatly to the low volume of products in the cloud gaming space.

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