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Enhancing Quality of Experience (QoE) in Cloud Gaming: A survey

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***Abstract*----Cloud gaming, in its purest form, renders game scenes on powerful remote game servers located at the data center. These scenes are then transmitted over the internet to the players, and the players use thin clients installed on their device to interact with the game. Since the early 2000s, Cloud Gaming has allured a vast majority of industry and academia, thereby giving it the required uplift, it deserves. In this paper, we have discussed numerous advantages this state-of-the-art technology provides and also revealed some of the critical challenges that are needed to be addressed for it to become successful. We have also examined issues related to bandwidth requirement and the delay caused by high latency. This paper is an attempt to improve Quality of Experience (QoE) to augment user satisfaction, enjoyment and needs during online gaming.**

***Keywords*--- Cloud Gaming, Quality of Experience (QoE), Quality of Service (QoS), Video Streaming**

I. INTRODUCTION

Cloud gaming is a novel way of providing computer games to users. It uses the architecture in which the complex games are rendered on the powerful cloud servers [1-4]. After this, the processed game scenes are sent over the internet to players using thin clients on different devices. The thin client installed by the player is generally very light and requires very less processing power to run. The players get the option of playing multiple games because of the game client, which are present on the server. While playing, the control events made by the players from their input devices are then sent back to the servers.

In the late 2000s, many startups, such as OnLive [5], Gaikai [6], Gcluster [7], and Ubitus [8] began presenting cloud gaming services. Sony Interactive Entertainment acquired both OnLive [9] and Gaika [10] and used the assets of both the companies as the foundation of a cloud gaming service within its PlayStation product family, known as PlayStation Now [11]. In 2013, Nvidia announced GRID, now known as GeForce Now [12], a cloud gaming service with support to import a user's steam library. In 2019, Google at the Game Developers Conference introduced its cloud gaming service called Stadia [13]. Also, in the same year, Sony partnered with Microsoft to co-develop cloud gaming solutions [14].

Just like various software market segments, the adaptation of video games to the cloud computing environment can be considered as a boon to the gaming industry. Cloud computing rests on two main pillars of online storage and distributed computing. Making use of these two components, different types of games such as multiplayer games, browser-based games and other casual games have significantly benefitted and improved. With this in mind, we will discuss some of the significant advantages that the gaming industry endow because of Cloud Gaming: (i) Compatibility with different types of devices: the lower end devices lack the high memory requirements, processing power and graphic capacity that most of the games demand nowadays. Cloud Gaming tackles this problem by providing a highly scalable platform that allows games to be stored and processed, thus providing an exceptional gaming experience,

(ii) Security: the state-of-the-art security services provided by the cloud gaming companies avert any external intrusion such as hacking. Safety is enhanced as all the data is stored inside a virtual storage platform, (iii) Effortless access to multiple games: Without downloading, the player can access the games available on the cloud from any device and from any location, (iv) Bygone piracy: As the games are not stored on any physical computer owned by an individual, the chances of any unauthorized manipulation gets diminished, thereby maintaining the originality of the game, (v) Expeditious backend support: due to the immediate backend support, the updates are delivered to the users as soon as they log into their accounts. As a result, the gaming experience is augmented, keeping up the satisfaction level of the users.

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Fig. 1. Advantages of Cloud Gaming

Despite the numerous advantages of cloud gaming as shown in Fig.1., there are still many challenges that need to be addressed before it reaches its full potential. We outline some of the most critical challenges as follows: (i) Connectivity: Since cloud gaming relies mainly on cloud and connectivity, the biggest challenge is the network required to support the service. In the esports and multiplayer games, latency can be of great importance when competing against other players. Higher the latency, the more the disadvantage a player will have. So, cloud gaming providers need to maintain a low latency connection in order to provide a better gaming experience to players, (ii) Technology underpinning cloud gaming: games are becoming more and more demanding day by day, thereby presenting a challenge for the current cloud infrastructures to support such a hardware demand, (iii) Digital rights management: When an individual buys any game on a cloud gaming platform, they do not own the game in the same way as they did on the discs. The platform has to revoke the content if the publisher withdraws support for their platform. Even google on the launch of its cloud gaming platform stadia had to address this concern by announcing that all the purchased games with still be playable even if the publishers withdraw their support [15].

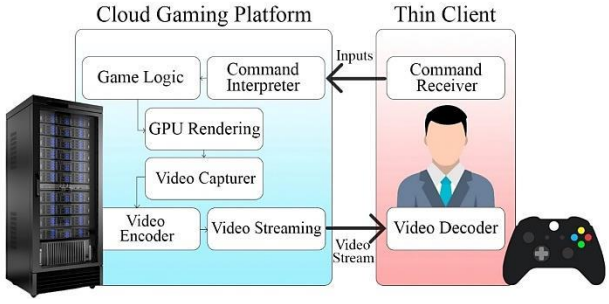

Fig. 2. Cloud gaming platform architecture

None of these concerns is insuperable, but also none of them can be ignored. We need to work on addressing these concerns in order to help cloud gaming reach its full potential.

After reviewing several aforementioned advantages and challenges, it would be correct to say that Cloud Gaming is a fascinating technology, but the challenges make it difficult for the Cloud Gaming companies to provide an immersive gaming experience to the players. Bandwidth and latency have a significant impact on Cloud Gaming as the latency poses added restrictions on the size of the frames. Also, factors such as, bit-rate and frame-rate affect the quality of the video that is streamed. Therefore, the literature examines these challenges in detail and provides appropriate solutions. The future of Cloud Gaming can be secured by traversing the pre-existing academic research and proliferating the development.

II. LITERATURE REVIEW

As Cloud Gaming seems to provide an intuitive future, it has attracted many researchers to write about and review this technology. Cloud Gaming platforms such as PlayStation Now [11] and GeForce Now [12], have allowed the players to cherish the gaming experience as it is meant to be. In this section, we review and summarize the pre-existing work in this field. This concise summary may provide a new insight to the interested readers and also to the general public.

A. Architecture and Performance

Ryan Shea [16] et al. have presented a detailed analysis of

cloud gaming, emphasising the distinctiveness of various cloud gaming platforms and their performance in different types of games. The paper begins by addressing the essential designs currently being considered by the cloud gaming providers. These designs include the cycle of collecting the player's actions, send them to the cloud to process and then render back the results into a video which is then displayed to the player. After this, the author talks about the thresholds for maximum interaction delay tolerance for different kinds of games. As the Quality of Experience [17] of games degrades with the increase in delay, this became a fundamental design challenge for the cloud gaming developers. Onlive and Gaikai, the industrial pioneers of cloud gaming, addressed this challenge by measuring the interaction delay and image quality for various kinds of games. The results obtained were tabulated and provided a distinct contrast between the threshold delay in different games. Therefore, the paper examines the design of the established cloud gaming platforms and the results obtained from these disclosed the potential of cloud gaming in the unforeseeable future.

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B. EdgeGame, a framework

Xu Zhang [18] et al. has introduced a framework called EdgeGame, which helped in enhancing the Cloud Gaming Experience by reducing network delay and bandwidth consumption. The framework comprises of mainly three components, namely, the game clients, the edge network and the cloud data center. The cloud data center contains all the data required to run the game. The edge network handles all the heavy GPU rendering, and the game client displays the video as well as collects the commands of the player and send it back to the edge network. As soon as the user requests to play a game, a vNode is initiated. It renders the game scenes and compiles them into videos, which are then displayed to the user. The video bitrates are altered in accordance with the change in the network dynamics enabling the user to perceive a quality gaming experience even on low bandwidth. Several other vital functions such as User Interaction Interface, GPU Rendering, Screen Compression, Game Logic and Game Log Uploading were also correctly implemented. EdgeGame endorses the sandbox technique, and as a result of this, multiple games can run on the same physical nodes. Overall, it was observed that EdgeGame [19] augmented the gaming experience of the users by 20 percent and took the edge off from network delay by 50 percent.

C. Adaptive residual streaming

De-Yu Chen [20] et al. has introduced a framework that uses progressive meshes, collaborative rendering, and 3D image warping techniques. This framework helps in augmenting the cloud gaming experience by addressing the issues of bandwidth requirement and latency. The fundamental idea of this framework is to utilize the local computing capacity available at the client-side, thereby reducing the bandwidth usage and also enhancing the quality of the game stream. The server works simultaneously on two application instances, one with the original Level of Detail (LOD) [21] and the other with the LOD set by the LOD Manager. Then, a residual frame is encoded by the server and is sent to the client-side where it is decoded to reproduce the original visual quality. However, in this approach of compressing residual images at the server, existing encoders might not be able to compress it optimally since these encoders are designed for regular images. Either we need to use a specific codec for this, or can also modify the current ones to make the encoding of residual images more efficient.

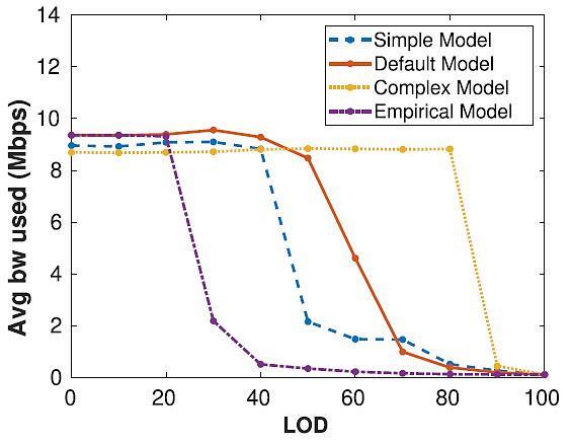

Fig. 3. Bandwidth comparison (all textured models) [20].

In this paper, the author also mentions the trade-off between latency and visual quality. The interaction latency can be reduced by using the 3D image warping technique, but then there will also be a reduction in the image quality.

D. Quality of Experience (QoE)

Asif Ali Laghari [22] et al. aims to improve Quality of Experience (QoE) by providing us with the Quality of Service (QoS) in accordance to the Service Level Agreement (SLA) thereby augmenting the user satisfaction level in cloud gaming. For the user to access cloud gaming services ubiquitously, QoS needs to have the support of applications, models and protocols. Several requirements should be met for enhancing the quality of cloud gaming communication such as small delay variance, low error rate, high bandwidth and low packet loss. With all these factors in mind, two types of approaches were analysed for cloud gaming, video streaming based and network-based approach. In video streaming, the video is compressed without sabotaging the quality of the video and provide the quality of service in accordance with the bandwidth and latency. Similarly, the network-based approach was also found to be efficient and provided additional responsiveness and better video quality. Cloud gaming platform, GamingAnywhere, was used to analyse the network-based approach. At last, it was concluded that factors such as bitrate, framerate and packet loss have a severe impact on the QoE of the user and still work can be done in order to improve the cloud gaming experience.

E. Frame rate and bit rate

Saman Zadtootaghaj [23] et al. in this paper aims to analyse the repercussions of two influencing factors, frame

rate and bit rate on the QoE of players in cloud gaming. It was noticed that when the frame rate was lowered in very low bit rates, the quality of the video improved. However, at some points, jerkiness became perceptible, which degraded the video quality and control over the game. In order to resolve this issue, a structural method was proposed to manage the QoE of the cloud gaming service. Two different games were used, and the order of the games was randomised. For the order, a Latin square design was used so as the minimise the learning effects. Now, based on the technical parameters, the quality features involved were estimated. The results revealed the differences between the assessed quality features under multiple encoding conditions of the same game. Bar plots were designed for the quality features, and the p-values were illustrated. The p-values gave significant differences between frame rate conditions. Finally, it was concluded that the two influencing factors, frame rate and bit rate, have a powerful impact on the QoE of players.

F. Foveated Video Encoding

Gazi Karam Illahi [24] et al. focuses on integrating a foveated video encoder with a gaze tracker device into a cloud gaming software, thereby mitigating the bandwidth requirements for cloud gaming. Foveated video encoding (FVE) is based on the human visual system (HVS): The region of the retina behind the eye lens is known as the fovea, and visual acuity of the eye is the highest in this region, dropping sharply with angular distance from the fovea [25]. In FVE, the video is encoded with a quality gradient similar to the acuity of HVS, resulting in a video with a lower bitrate compared to a video encoded using non-foveated encoding. This trade-off between the bandwidth requirement and the delivered video quality is known as adaptive bitrate streaming, in which the quality of the streaming video is varied in accordance with the bandwidth available. Cloud gaming platform, GamingAnywhere, was used to implement FVE for cloud gaming and has demonstrated that the implementation of FVE for games helped in reducing bandwidth significantly without sacrificing QoE. Overall, FVE enhanced the gaming experience of the users to a great extent by attenuating the bandwidth requirements for cloud gaming.

G. Content-aware Video Encoding (CAVE)

Mohamed Hegazy [26] et al. provides us with a model, namely CAVE, which works by improving the quality of streaming videos with specific bandwidth requirements. This point comes as a challenge because the requirements on latency pose added restrictions on the size of the frames in cloud gaming. Rate control was performed, and bits were allocated to various areas in the game frames and across the frames. However, the author makes it clear that CAVE is suitable for High-Efficiency Video Coding encoder, which itself is state-of-the-art and saves the bitrate substantially. CAVE was implemented in GamingAnywhere, which is an open-source cloud gaming platform. CAVE served as an additional module on the server-side and required no changes to be done on the client-side. Multiple experiments were performed on different video games, and several estimates such as quality fluctuations, rate control accuracy, CPU time and Video Multimethod Assessment Fusion (VMAF) were measured. The results were compared to the baseline HEVC encoder and showed that CAVE outstripped the closest work in the literature.

H. Quality certifications

Sascha Ladewig [27] et al. points out that the requirements that a cloud gaming service has to fulfil are still unclear as the pre-existing certifications are not of high quality when seen under that context of cloud gaming. Hence, the author manages a literature review to determine the requirements and analyse the existing certifications for could gaming services. In the paper, a two-fold contribution was provided to augment the assimilation of cloud gaming services. At first, a discussion was made on the requirements that the cloud gaming service providers need to fulfil in order to foster user satisfaction. Secondly, new criteria of certifications and ingenious ways to conduct the processes of certifications were also provided. It is shown that the QoE of the user is affected by two factors, video settings such as the used codec and video resolution and network factors such as packet loss and network bandwidth. These factors are also interdependent, and cloud gaming services need to consider these interdependencies in order to ensure a high-quality gaming experience. However, it was seen that the pre-existing cloud service certifications, although they provided a pragmatic criterion, they had a paucity of specific certifications that ensure high-performance gaming services.

III. OBSERVATIONS

In this paper, we have examined and summarized papers related to the pre-existing work done in this field. The papers introduced the general concept of cloud gaming and provided streamlined methods to overcome the challenges which are frequently faced. Designing frameworks such as EdgeGame [18] have not only reduced

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the latency delay and bandwidth consumption but have also given a boost to the cloud gaming experience. As great as this sounds, designs and frameworks can be further improved to obtain a much better result. Below are some of the key facets which still need to be addressed or further developed.

I. Lag

When playing on a PC or a console, all the data processing and image rendering is done on the local system itself. Due to this, there is a negligible lag or delay. However, while playing on a cloud gaming platform, if the player is situated far from the centralised cloud, then there might be some lag or delay. This delay provides an unfair advantage to the players who are located close to the cloud server where all the processing is being done.

J. Edge Computing

The data in cloud gaming is processed at a single centralised cloud. However, with the help of edge computing, application processes can be distributed at the edge of the network, as near as possible to the user. It is because of Edge computing that technologies like Mobile computing [28] and Internet of Things (IoT) [29] have been enabled. Firms are predicting that by 2025, a massive 75 percent of enterprise data would be processed at the edge.

K. High-end network requirements

Cloud gaming makes it possible to play graphic intensive games on low-end devices. However, it requires a high-end internet connection as all the information is sent over the internet. Other than an excellent internet connection, it also requires high physical requirements such as 4 GB system memory, Windows 7 (64-bit), 2.0GHz dual-core X86 CPU and a GPU that supports DirectX 11.

L. FPS games

At its best, Cloud Gaming can be an impeccable experience, almost indistinguishable from playing a game installed on a local machine. However, still, fast-paced first-person shooter games are susceptible to network, and even a small delay is enough to distract the user from the immersive gaming experience.

M. Other network Conditions

While frameworks and technologies have been designed to tackle the challenges posed by bandwidth and latency during cloud gaming, there are still factors such as packet loss and jitter which have a massive effect on gaming over the cloud [30] and still have not been worked on thoroughly.

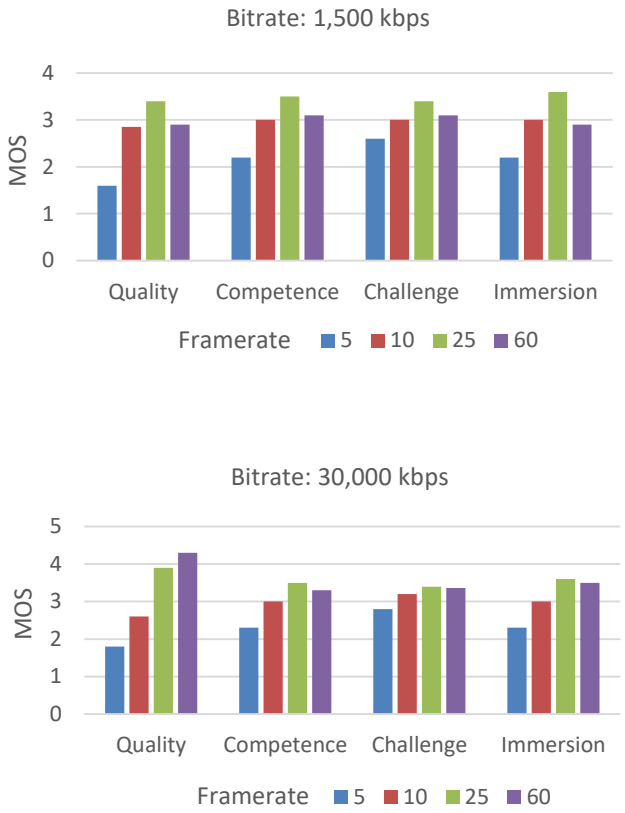

Fig. 4. Player experience dimensions for four framerates and both bitrates

The graphs above explicate the ratings for player experience dimensions for four frame rates and both, a high and a low bit-rate. In Fig. 4. at a lower bit-rate, the ratings declined when the frame rate was changed from 25 to 60. However, when the frame rate was changed from 5 to 10 fps, the ratings increased in all of the four dimensions. At a higher bit-rate, the ratings between 25 and 60 fps are very similar to each other. However, there is a significant difference in all four quality features between 5 and 10 fps. It can be observed that all of the four dimensions bear a resemblance to the overall quality, which is possible as of strong correlation between them.

IV. CONCLUSION

Our paper has provided a detailed survey of Cloud Gaming by discussing its various advantages and challenges. We have also examined some of the popular

Cloud Gaming Platforms such as GamingAnywhere, PlayStation Now and GeForce Now. The results indicated that as Cloud Gaming technology is capable of revolutionising the future, there are still some issues that need to be approached for an immersive cloud gaming experience. The issues regarding lag or delay provide an unfair advantage to the player situated closer to the operational data center. Also, we have shown that even though bandwidth and latency are some major factors affecting the cloud gaming experience, factors such as jitter and packet loss also need to be reassessed.

In summary, it will be correct to say that cloud gaming services needs a little bit of optimization. Due to the recent advancements in technologies, we are on the edge of a whole new era of gaming and the next-generation cloud gaming services will be imminent.

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