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Cloud Gaming Services

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Abstract: This paper describes the functioning of cloud gaming services, their development, infrastructure, possibilities for advancement, and their application in Serbia.

Keywords: cloud gaming, latency, service, stream, virtualization.

1. Introduction

Similar to computers, the popularity of video games has also grown over time, having a significant influence on popular culture today. There have never been more diverse possibilities for playing the latest video games, whether on high-performance local computers, gaming consoles, or cloud gaming services. Existing literature mainly covers websites with information about cloud gaming relevant to specific time periods or specific research related to its performance. In contrast, this paper aims to clarify the origins, infrastructure, and operation of cloud gaming services, highlight the most advanced and popular services, and emphasize the importance of these technologies in the world of video games, both globally and in Serbia.

2. Operation of Cloud Gaming Services

Cloud gaming platforms operate in a similar manner to remote desktop software and video-on-demand services [1]. Video games are stored and executed remotely on the provider's hardware and streamed as video footage to the user's device through software located on the user's end. The software receives user commands, which are then sent back to the server and executed in the game [1]. Some cloud gaming services function as virtual machines, offering users the ability to virtualize a Windows environment, allowing them to download and install services and video games in the same way as on a local computer.

These technologies can be highly beneficial as they reduce the need to purchase expensive hardware and install video games directly on the local machine. They are applicable to a wide range of devices, including mobile devices such as smartphones, tablets, streaming devices, or thin clients, which are low-performance devices primarily used for connecting from remote locations [3]. Some services offer additional features, such as allowing viewers to join a session and temporarily control the game [4].

However, cloud gaming requires a reliable and fast internet connection. This can be a challenging aspect for people in areas where it is difficult to provide such conditions. Based on the experiences shared by people on various social media platforms and forums, we can confidently say that Serbia falls into such areas. Even with a reliable and fast internet connection, overloaded online traffic and other factors that affect network latency can impact cloud gaming performance [3]. Additionally, the costs of cloud gaming, compared to traditional distribution through physical and digital game copies, shift to data servers that run cloud gaming services. New cost structures are needed to cover these operational costs. Subscription models are commonly used, but the service also includes costs for purchasing games to be played on the cloud service, although the user does not own the game in the same way as if they had bought a physical or digital copy [3]. The framework of cloud gaming service operation can be seen in "Figure 1".

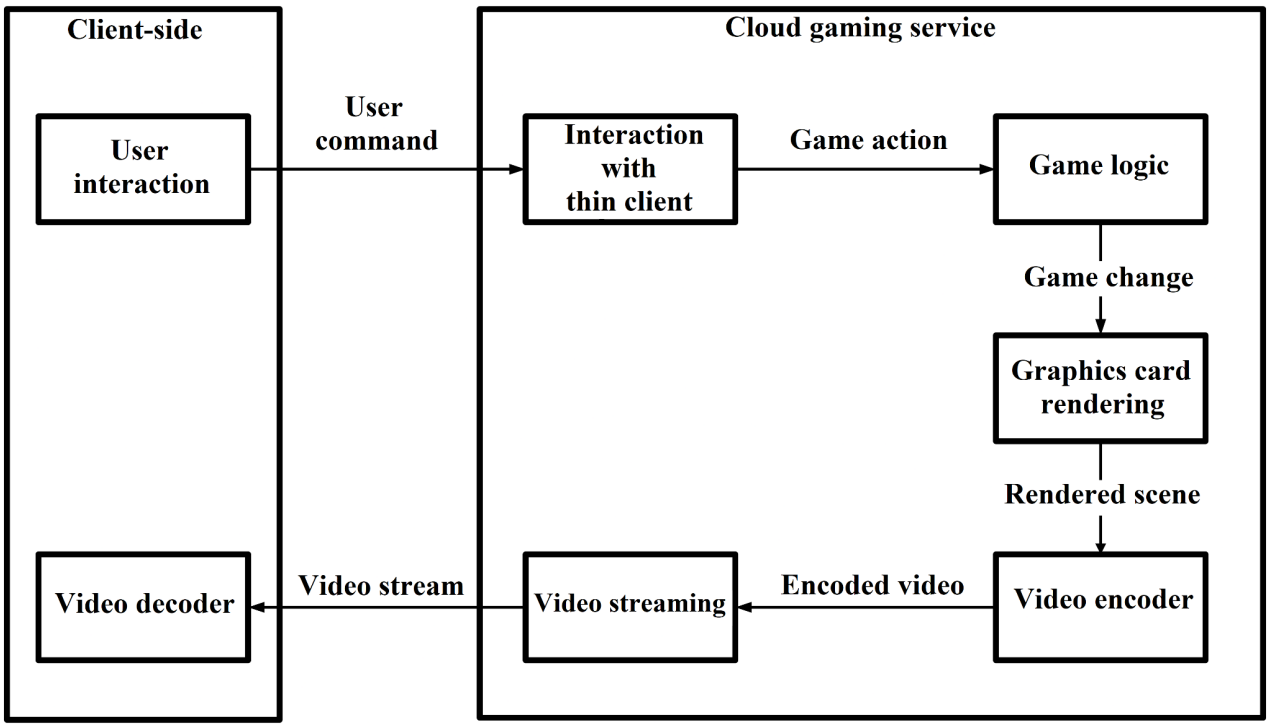

Figure 1. Framework of Cloud Gaming Service Operation [31].

The user issues a command and interacts with a thin client, which represents that command to the video game based on its logic. This reflects a change in the game itself, which is rendered, encoded as video footage, and sent to the video decoder via video streaming.

3. Infrastructure

These technologies require a well-designed infrastructure for services to work as intended, including data centers and server farms where games are executed. They also require an internet connection with high bandwidth and low latency to deliver a seamless stream to users without delay [5]. In the paper *On the Quality of Service of Cloud Gaming Systems*, it is mentioned that the infrastructure necessary for implementing cloud gaming was not available in many geographic locations for a long time. Although it is mentioned in the past tense, many users of these services from various parts of Serbia could testify that it is still the case. Due to the reliance on high-quality streamed video footage, some providers often limit the usage of services through data caps [6].

The key quality factor of a cloud gaming service is latency, the time period between a user issuing a command and that command being executed in the game. Latency can impact the gaming experience, especially for games that require fast user reactions, such as first-person shooters or fighting games [7].

The provider's hardware can be upgraded over time to support higher resolutions and frame rates during rendering and streaming [3].

Quality of Experience (QoE) is a measure of user satisfaction when using a service and should be considered during the development phase of cloud gaming [8].

4. History of Cloud Gaming Services

4.1. Initial Attempts

The startup company G-Cluster was the first to approach these technologies in 2000 and released its first product in 2003. Their initial model offered games for personal computers executed on their servers, with the help of Video on Demand service providers and Set-Top Box devices for signal reception and processing, as well as middleware providers to enable them to deliver their services to network operators. In this way, they provided video games to end users through enterprise portals, which are frameworks for integrating information, people, and processes, similar to web portals. By 2010, due to market changes, G-Cluster changed its operational model. They started collaborating with major server manufacturers to more easily deliver their services to network operators and end users. This change was prompted by the increasing availability of free games for personal computers, leading the company to focus on Internet Protocol Television (IPTV) users, with a target group of around three million users. In the same year, the G-Cluster gaming service was implemented in France [9]. In 2012, Orange entered the cloud gaming market. Both companies have been commercially successful since introducing these services for mobile and TV clients.

4.2. OnLive and Gaikai

Entrepreneur Steve Perlman stated in 2009 that with the advancements in data compression, video streaming, and the capabilities of smartphones, it was the right time to harness the potential of cloud gaming. OnLive, a cloud provider, officially launched in 2010. Users could play "Games on Demand" by paying a subscription fee along with additional costs for renting or

purchasing games. They had access to titles running at resolutions up to 720p and frame rates up to 60fps. They gained support from major publishers such as Ubisoft, 2K Games, and THQ. However, they struggled to attract other publishers [10].
Parallel to OnLive, David Perry founded a cloud provider called Gaikai. They opted for streaming game demos instead of full games, making their service a form of online advertising for video games. Gaikai gained much greater support from publishers, including Electronic Arts [10]. In July 2012, Sony acquired Gaikai for $340 million and by October of the same year, integrated PlayStation games into their offering. Eventually, the technology on which Gaikai was based became the foundation for PlayStation Now, a service introduced in 2014 [10].

OnLive was not profitable, and after a possible lawsuit from HP, the service failed. Their equipment was inherited by a newly formed entity called OL2. The new company attempted to change its business model to allow users to stream games they already owned, but it was not financially viable. In April 2015, Sony acquired the intellectual property of OnLive and OL2, only to shut them down about a month later [11]. According to The Verge, Sony's acquisition of Gaikai's and OnLive's intellectual property provided them access to a range of cloud gaming-related patents [11].

4.3. Recent Progress

In 2012, Nvidia announced its cloud gaming service, Nvidia Grid (later renamed GeForce Now). The service represented a combination of hardware, using Nvidia's processors, and software. Initially, Gaikai was intended to be the partner for providing games on the service [12]. Ubitus' GameCloud was introduced alongside Nvidia Grid, envisioned as a white-label service based on Nvidia Grid that other providers could use to offer services to their users [13].
In 2013, Grid was introduced as part of the Nvidia Shield device for Android TVs. The service was initially launched in North America in November 2014, with a limited number of games available. It expanded to personal computers in 2017, with the option to link users' Steam and Epic Games accounts [14]. The integration with other accounts faced criticism from many publishers such as Activision because game purchases were intended for personal computers and not for cloud gaming. Publishers forced Nvidia to withdraw those games from its service.
In Japan, in 2014, the video game Dragon Quest X appeared on Nintendo 3DS using Ubitus as the streaming technology [15].
In 2017, the French startup company Blade launched the Shadow service, where users had the ability to rent remote instances of Windows 10 in data centers and use Intel Xeon processors and Nvidia Quadro graphics cards. The service is geographically limited, depending on the proximity of the user to one of their data centers. It was initially launched in France but began expanding to the United States in 2019 [16].

In May 2018, Electronic Arts acquired equipment and staff from GameFly, an online video game rental service [17]. The company then announced "Project Atlas," a project focused on exploring the integration of artificial intelligence, machine learning, and Frostbite technology to create a "unified" platform for remote processing, streaming movies, HD video games with minimal latency, and discovering new possibilities for dynamic and cross-platform gaming [18]. In the same month, Google and Microsoft also revealed their ambitions for cloud gaming. Google initiated "Project Stream," including a closed beta test of the video game "Assassin's Creed Odyssey" that users could play through the Google Chrome browser [19]. Microsoft announced its work on Project xCloud, leveraging Microsoft Azure technology to a significant extent [20].
In 2019, Google officially unveiled its cloud gaming service called Stadia, which was launched in November of that year [4]. In May, Sony announced a partnership with Microsoft to collaborate on cloud solutions, including video games [21].
In mid-2020, Apple attempted to block cloud gaming apps on its platforms. They stated that cloud gaming services allowed developers to add games to the iOS system, bypassing the security checks conducted for each app before being added to the App Store, thereby violating their terms of service. However, in September of the same year, Apple changed its rules, allowing the execution of cloud gaming apps on iOS, with the limitation that each game must be offered as a separate download on the iOS store [22]. In November 2020, both GeForce Now and Stadia announced plans to release iOS versions of their services as progressive web applications that would run through the Google Chrome and Safari browsers on iOS devices [23], [24]. In early 2021, Microsoft also announced plans to use a similar approach to enable the use of xCloud technology on iOS devices through browsers [25].

In September 2020, Amazon introduced its cloud gaming service called Luna. Instead of a subscription that grants access to all content, Amazon implemented "channels" for various publishers, for which users would pay a monthly subscription fee [26].
In November 2020, Asus and Intel announced their ongoing collaboration in supplying hardware, researching, and optimizing software for the Boosteroid cloud gaming platform [27].

Currently, Nintendo has games on the Nintendo Switch that support cloud gaming, such as Control Ultimate Edition-Cloud Version, Hitman 3-Cloud Version, and Marvel's Guardians of the Galaxy: Cloud Version [28].

5. The most popular Cloud Gaming Services

When we look at the role of these technologies, all services essentially offer the same thing. However, they behave differently due to differences in their algorithms, where one service may perform better in one task but not necessarily in another. The research available at the link https://hal.inria.fr/hal-03421031/file/cloud_gamig_traffic_under_constraints_CR.pdf aims to determine which service most effectively adapts its traffic according to network constraints. The study was conducted for the four most popular services: GeForce Now, Stadia, PlayStation Now, and Xbox Cloud Gaming, considering various network constraints such as bandwidth, packet loss rate, latency, and jitter [32]. Overall, GeForce Now proved to be the most efficient service, while others faced occasional challenges in maintaining service continuity.

6. Cloud Gaming in Serbia

As mentioned in previous sections, a stable and fast internet connection is crucial for the quality usage of these services, and in that aspect, Serbia lags behind the most developed countries. However, according to user experiences, GeForce Now stands out as a service that performs quite well even with an unstable and slow internet connection.

Boosteroid and PlayStation Now have also shown good performance. Although PlayStation Now is theoretically not available in Serbia, it can be used with certain VPN software, offering users the opportunity to play specific PlayStation exclusives on their personal computers. It is assumed that the renaissance in this field is yet to come in Serbia, but even today, these services are useful and cost-effective considering the cost of hardware, gaming consoles, and the average salary in Serbia.

7. Potential improvements

7.1. Resource sharing

The proposed method for improving game streaming scalability is virtualization of graphics cards (Adaptive GPU resource scheduling) [29]. Most providers use a dedicated graphics card for each individual playing the game. This results in optimal performance but also resource wastage. With better algorithms for sharing graphics cards, if a game doesn't fully use a specific graphics card, it can be used as assistance for another user. In the past, this method was less used due to poor algorithm performance for virtualization. However, new algorithms have been devised that can use up to 90% of the graphics card's power even when it is shared among users [29].

7.2. Command prediction

Many algorithms can be used to predict the user's next actions, which could reduce the impact of latency on cloud gaming performance. Majd Bakar, the principal engineer working on the Stadia platform, envisions the possibility of using this concept to reduce latency to the point where it is practically non-existent, referring to it as "negative latency" [30].

8. Conclusion

Cloud gaming, like all cloud technologies, is a relatively new field but one that is rapidly evolving. It has numerous advantages and disadvantages, but efforts are being made to address these drawbacks, and it is only a matter of time before they diminish. This field has significant commercial potential, given the large gaming community, as evidenced by the involvement of almost all major companies in this form of business. Services are continuously growing and developing, and in the next few years, cloud gaming could become a commonplace phenomenon worldwide.

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