

Beyond Reality: Diving into the Immersive Experience of Computer Gaming

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Abstract: Players may now receive top-notch gaming experiences from cloud gaming, no matter where they are or when they play. According to this paradigm, powerful servers housed in data centers run complex game software, and the resulting game scenes are transmitted in real time to players via the internet. Players interact with these games via little apps that are installed on various devices.

Ever since the late 2000s, cloud gaming has attracted significant interest from the academic and industrial communities, driven by the increasing accessibility of high-speed networks and the pervasiveness of cloud computing.

This manuscript undertakes a comprehensive investigation of current research in the field of cloud gaming, covering a wide range of topics including platforms for cloud gaming, optimization strategies, and commercial cloud gaming services. The most recent developments in this rapidly developing subject will be introduced to readers, who will also acquire insights into the state of cloud gaming research today.

Keywords: Cloud gaming, Network, Market trend

I. INTRODUCTION

The swiftly advancing realm of cloud gaming is a technology that enables gamers to enjoy their preferred video games via the internet, eliminating the necessity for a high-performance gaming PC or console. Operating as a variant of online gaming, cloud gaming involves the execution of games on remote servers, with the video and audio streams transmitted to the player's device—be it a laptop, desktop, tablet, or smartphone. This innovation liberates players from the constraints of device specifications, offering a flexible and accessible gaming experience over the internet. This technology has revolutionized the gaming industry by offering gamers the ability to play high-quality games on almost any device with an internet connection, providing a more accessible and affordable way to access the latest games without investing in expensive hardware. Cloud gaming has gained a lot of popularity in recent years and is

expected to continue to grow as more game developers and publishers move towards cloud-based gaming [1].

The origins of cloud gaming can be traced back to the early 2000s when the concept of cloud computing started to gain popularity. The idea of delivering software and services over the internet, rather than through physical installations or downloads, was seen as a potential solution to many of the challenges faced by the gaming industry, such as the high costs of developing and distributing games, and the need for powerful hardware to run the latest games [2].

The first commercial cloud gaming service was launched in 2010 by OnLive, a company founded by Steve Perlman. OnLive's platform allowed gamers to play high-quality games on a variety of devices, including laptops, desktops, and smart TVs, by streaming the games from remote servers. OnLive's service received positive reviews from critics and gamers alike, but the company faced financial challenges and ultimately went bankrupt in 2015.

Since then, several other companies have entered the cloud gaming market, including Google with Stadia, Microsoft with Xbox Cloud Gaming (formerly known as Project xCloud), and NVIDIA with GeForce Now. These services have expanded the availability of cloud gaming to a wider audience and offered new features, such as integration with existing gaming ecosystems and the ability to play games on mobile devices.

In the current context, cloud gaming is a rapidly growing business that is expected to reach a market value of more than \$8 billion by 2025. This technology has the power to completely transform the gaming industry by giving players a more affordable and convenient way to play the newest titles. At the same time, it provides publishers and game creators with new opportunities to reach a wider audience. The gaming industry is undergoing a revolutionary shift, with cloud gaming expected to grow rapidly. This movement emphasizes cost and accessibility for gamers while offering industry stakeholders a favorable landscape.

II. TECHNOLOGY USED

Technology Used:

1. **Cloud Computing Infrastructure:** Cloud gaming services rely on powerful remote servers located in data centers around the world. These servers provide the processing power and storage necessary to run the games and stream them to players over the internet.
2. **Video Encoding and Streaming:** In cloud gaming, video and audio are streamed from the remote servers to the player's device. This requires high-quality video encoding and streaming technologies, such as H.264, VP9, or AV1, that can compress the video data and transmit it over the internet with minimal latency and buffering [3].
3. **Network Infrastructure:** For cloud gaming to be successful and to ensure a responsive and uninterrupted gaming experience, there needs to be a fast and reliable internet connection. Cloud gaming companies work closely with content delivery networks (CDNs) and internet service providers (ISPs) to optimize their network architecture. The goal is to reduce latency and packet loss as much as possible to maximize user experience when gaming. This strategic partnership between cloud gaming providers and network entities highlights how important it is to have a strong and effective network infrastructure in order to give customers with the smooth and excellent gaming experiences they need [4].
4. **Input Latency Reduction:** Cloud gaming introduces additional latency due to the time it takes for the player's inputs to be transmitted to the remote server and for the server's response to be transmitted back to the player's device. To reduce input latency, cloud gaming providers use techniques such as prediction, client-side interpolation, and server-side interpolation.
5. **Edge Computing:** Edge computing is a technology that allows computation and data processing to be performed closer to the end-user, reducing latency and improving performance. Cloud gaming providers use edge computing to distribute processing tasks between the remote servers and local devices, improving overall performance and reducing latency.

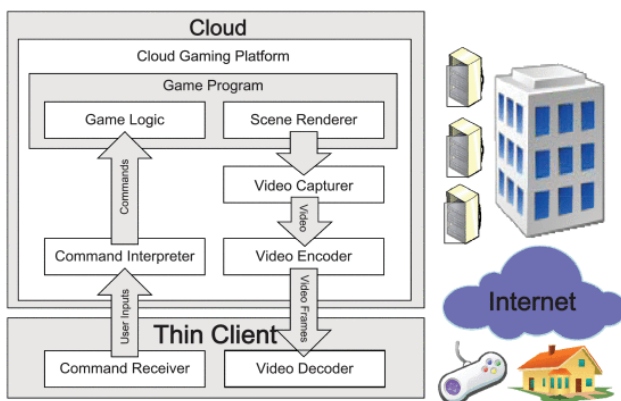


Fig. 1.

III. CHALLENGES

1. **Latency:** Latency refers to the time it takes for a player's input to be processed by the remote server and for the server's response to be transmitted back to the player's device. High latency can result in a laggy and unresponsive gaming experience, making it difficult to control the game. Cloud gaming providers must work to minimize latency by optimizing their network infrastructure and using techniques such as prediction and interpolation.
2. **Internet Connection:** Cloud gaming requires a fast and stable internet connection to ensure a smooth and responsive gaming experience. However, not all players have access to high-speed internet, and some may experience issues such as buffering, stuttering, or loss of connection. Cloud gaming providers must work to optimize their services for players with different internet speeds and connectivity.
3. **Bandwidth:** Cloud gaming requires a significant amount of bandwidth to stream high-quality video and audio data to the player's device. This can be a challenge for players with limited data plans or slow internet speeds. Cloud gaming providers must work to optimize their data compression and transmission protocols to reduce the amount of bandwidth required to play games.
4. **Content Availability:** While cloud gaming services offer a large and growing library of games, not all games are available on all platforms or in all regions. This can be frustrating for players who want to play a specific game but cannot access it through their chosen cloud gaming service [17].
5. **Subscription Costs:** While cloud gaming can be more affordable than purchasing a high-end gaming PC or console, the cost of a subscription to a cloud gaming service can add up over time. Additionally, some cloud gaming services require players to purchase games separately, which can be an added cost.

Overall, these challenges are not insurmountable, and cloud gaming providers are continually working to improve their services to address them.

IV. LITERATURE REVIEW

Research into cloud gaming has been ongoing for several years, with many studies exploring various aspects of the technology, including latency, bandwidth requirements, and player experience. Here are a few examples of recent research in cloud gaming:

1. A study conducted by researchers at Carnegie Mellon University found that cloud gaming can reduce energy consumption compared to traditional gaming setups. The study found that cloud gaming servers use less energy than gaming PCs and consoles, and that the energy savings can be significant over time [6].
2. Another study published in the IEEE Journal of Selected Topics in Signal Processing found that cloud gaming can benefit from a technique called "edge computing." Edge computing involves offloading processing tasks to local devices or edge

servers to reduce latency and improve performance. The study found that using edge computing can reduce latency in cloud gaming by up to 50%.

3. A study conducted by researchers at the University of York found that cloud gaming can have a positive impact on players' social experiences. The study found that players who used cloud gaming services were more likely to play games with friends and family than those who used traditional gaming setups.
4. A study published in the International Journal of Human-Computer Interaction found that players generally have a positive experience with cloud gaming, but that there are some challenges related to latency and image quality. The study found that players generally preferred cloud gaming to traditional gaming setups, but that latency and image quality were the most significant factors affecting the player experience.

Overall, these studies highlight the potential benefits and challenges of cloud gaming and demonstrate the ongoing research efforts to improve the technology and the player experience [5].

V. CLOUD GAMING PLATFORMS

The nature of cloud gaming platforms, with their complexity, distribution, and heterogeneity, poses a significant challenge to providing an easy-to-use platform for game developers. Transparent platforms, which run unmodified games, may have limited optimization potential, while non-transparent platforms, which require code augmentation and recompilation, may be time-consuming and expensive. QoS measurements are crucial for quantifying platform performance, and real-time measurements enable effective troubleshooting and optimization. Mobile environments have limited power reserves, and reducing game software complexity is important for maintaining device performance. Network metrics are also important in evaluating user experience in cloud gaming. Measuring QoE is subjective and requires tedious and expensive user studies, followed by the proposal, training, and evaluation of practical models relating QoS and QoE metrics. Large datasets are necessary to validate these models for use in actual cloud gaming platforms [12].

Recognizing the intrinsic complexity of cloud gaming platforms is a prerequisite for tackling the problem of developing an intuitive platform for cloud game developers. These platforms are distinguished by their variety, distributed architecture, and intrinsic complexity. Because cloud gaming infrastructure is so complex, providing developers with a smooth and easy-to-use experience presents special problems. A deep comprehension of the nuances involved in the creation and management of cloud gaming platforms is necessary to successfully navigate these challenges, highlighting the demand for specialized solutions that address the many and complex facets of this technology [15]. They require a different set of skills and knowledge from those needed for traditional game development. The transparency of the platform, or lack thereof, can greatly affect the ease of deployment and optimization. Transparent platforms offer simplicity in terms of deployment, as they require no modification of existing games, but they may not achieve the best performance. Non-transparent platforms, on

the other hand, may require additional development complexity, but they can potentially offer better performance by leveraging unique features of the cloud gaming platform [16]. Therefore, game developers need to weigh the benefits and drawbacks of each platform type when deciding which one to use

Finally, it's important to note that cloud gaming on mobile devices faces unique challenges due to their limited power reserves. Game software that is optimized for traditional desktop computers may not perform optimally on mobile devices, as it may consume too much power and drain the battery quickly. Therefore, it's important to reduce the complexity of game software for mobile devices while maintaining optimal performance. This requires a different set of skills and knowledge from those needed for traditional game development, as well as a deep understanding of the unique characteristics of mobile devices.

VI. OPTIMISING GAMING PLATFORMS

Optimizing gaming platforms is a crucial aspect of ensuring a smooth and enjoyable gaming experience for players. There are several strategies that game developers and platform providers can use to optimize their gaming platforms, including:

1. **Reducing Latency:** Latency is one of the most significant factors affecting the gaming experience. To reduce latency, game developers and platform providers can use predictive algorithms, caching, and compression techniques to reduce the amount of time it takes for game data to travel between the player's device and the game server.
2. **Optimizing Bandwidth Usage:** Bandwidth is another critical factor in gaming performance. Game developers and platform providers can use data compression techniques, such as video encoding and image compression, to reduce the amount of data that needs to be transmitted between the player's device and the game server.
3. **Hardware Optimization:** Game developers can optimize their games for specific hardware configurations, such as gaming consoles or mobile devices, to ensure the best possible performance on each platform. This can include optimizing graphics settings, frame rates, and other performance metrics to ensure the game runs smoothly on each platform.
4. **Server Optimization:** Game servers play a crucial role in delivering a seamless gaming experience. Platform providers can optimize their server infrastructure by using load balancing, caching, and other techniques to ensure the server can handle high volumes of traffic and provide fast response times.
5. **Testing and Optimization:** Game developers and platform providers can use data analytics and user testing to identify areas of their platform that need optimization. By analyzing player behavior and performance metrics, they can identify areas where performance is lagging and work to optimize these areas to improve the gaming experience.

VII. COMMERCIAL CLOUD GAMING SERVICES

Commercial cloud gaming services are platforms that allow users to stream and play games on-demand without needing to own expensive hardware or physical copies of the games. Some of the most popular commercial cloud gaming services currently available include:

1. **Google Stadia:** Introduced in 2019, Google Stadia stands as a cloud gaming service offering users the flexibility to play games across an array of devices, ranging from Chromecast and laptops to desktops and smartphones. Adopting a subscription-based model, the service requires users to pay a monthly fee granting access to a curated library of games available for streaming over the internet. This approach not only caters to diverse user preferences by enabling gameplay on various devices but also aligns with the evolving landscape of subscription-based gaming services that provide users with a convenient and expansive gaming experience [7] [8].
2. **GeForce NOW:** Developed by NVIDIA, GeForce NOW is a cloud gaming service that allows users to play games on a variety of devices, including PCs, Macs, and NVIDIA Shield TV. The service offers a library of games that users can access by linking their Steam or other digital game libraries to their account.
3. **Xbox Game Pass Ultimate:** Xbox Game Pass Ultimate is a subscription service that offers access to a library of games that can be played on Xbox consoles and Windows PCs. The service also includes access to Xbox Live Gold, which allows users to play games online with friends.
4. **PlayStation Now:** Sony created PlayStation Now, a cloud gaming service that lets customers stream games on a range of gadgets, such as PCs, PlayStation consoles, and some Sony TVs. The service offers a library of games that can be streamed over the internet.

VIII. ANALYSING THE BUSINESS OF COMPUTER GAMING

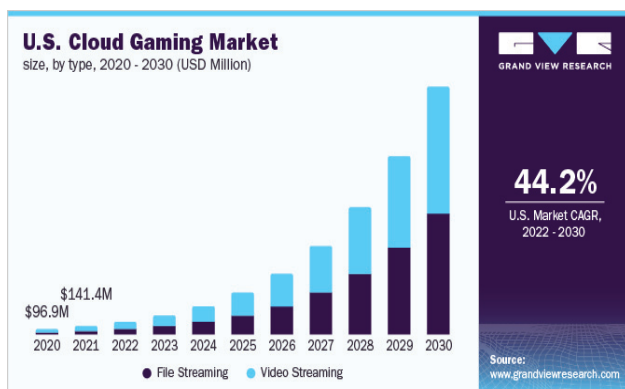


Fig. 2. U.S. Cloud Gaming Market

The cloud gaming market has been experiencing significant growth in recent years, with the market size expected to reach USD 7.24 billion by 2027. The market is expected to continue to grow in the coming decade, with several trends and factors driving this growth.

From 2020 to 2030, we can expect to see several developments in the cloud gaming market. One of the most significant trends is the continued growth of 5G technology. As 5G networks become more widely available, it will enable faster and more reliable internet connections, making it easier to stream games over the internet. This is likely to drive the adoption of cloud gaming services, as users can access games from a variety of devices, including smartphones and tablets.

Another trend driving the growth of the cloud gaming market is the increasing popularity of subscription-based services. Subscription-based models are becoming more prevalent in the gaming industry, with services like Xbox Game Pass and PlayStation Now offering users access to a library of games for a monthly fee. Cloud gaming services like Google Stadia and Amazon Luna are also adopting this model, with users paying a monthly fee to access a library of games that they can stream over the internet [8].

In addition, advancements in cloud technology are likely to lead to improvements in the overall gaming experience. Cloud gaming services are investing in new technologies like artificial intelligence (AI) and machine learning (ML) to optimize gaming performance and reduce latency. As these technologies continue to develop, we can expect to see significant improvements in the overall gaming experience for cloud gaming users [14].

Finally, we can expect to see more competition in the cloud gaming market, with new players entering the market and existing players expanding their services. This competition is likely to lead to innovations and improvements in cloud gaming technology, as companies strive to differentiate themselves from their competitors.

A. Latest Updates:

The market growth of cloud gaming services was accelerated by the outbreak of COVID-19, as people were forced to spend more time indoors with limited outdoor activities and social interactions. As a result, major companies capitalized on the increasing interest in video games and launched affordable cloud gaming services, thus expanding the overall gaming market. For example, in November 2021, Intel acquired RemoteMyApp, a cloud gaming service, as part of its entry into the market. This acquisition provided Intel with access to RemoteMyApp's team of skilled cloud service designers.

B. Type Insights:

It is anticipated that the file streaming market will experience a rapid CAGR of more than 46% from 2022 to 2030 due to its cost-effectiveness for game developers. Implementing file streaming can reduce expenses related to media production and patch distribution to gamers. As a result, numerous gaming brands have started to adopt cloud streaming, and this trend is expected to persist in the years ahead. Additionally, some enterprises opt for private clouds to host their games, which provides exclusive access and improved protection for users.

C. Device Insights:

Device insights on cloud gaming refer to the types of devices that users are using to access cloud gaming services. Understanding device insights is important for cloud gaming

providers, as it can help them optimize their services to ensure a smooth and seamless gaming experience for users.

The fact that cloud gaming is accessible on a variety of devices—from laptops and desktop computers to smartphones and tablets—is one of its benefits. This allows users to play games on their preferred devices without needing to purchase expensive hardware or consoles [18].

Recent data suggests that mobile devices are becoming an increasingly popular platform for cloud gaming. According to a report by App Annie, mobile gaming accounted for 51% of total gaming revenue in 2020, with cloud gaming services like Google Stadia and Microsoft xCloud helping to drive this growth.

However, desktop and laptop computers remain a popular choice for cloud gaming as well, particularly among hardcore gamers who prioritize performance and graphics quality [19]. In addition, the rise of remote work and virtual events during the COVID-19 pandemic has led to an increased demand for cloud gaming on laptops and desktops, as users look for ways to stay entertained while working or attending virtual meetings.

Console gaming remains popular as well, but cloud gaming services are starting to compete with traditional consoles like the PlayStation and Xbox [9]. Companies like Microsoft and Google are investing heavily in their cloud gaming services to provide an alternative to traditional console gaming, with the added benefits of portability and accessibility across multiple devices [10].

IX. GLOBAL GAMING MARKET

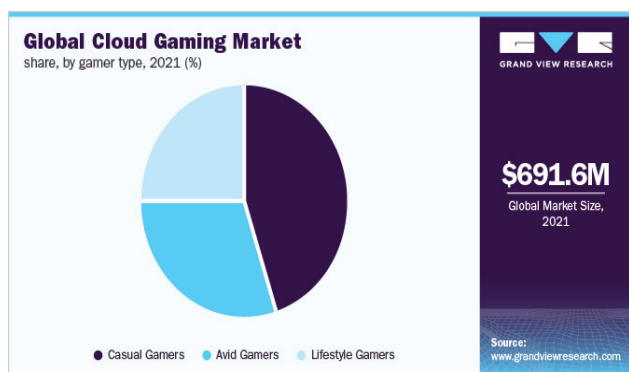


Fig. 3. Global Cloud Gaming Market

As of 2021, more than half of the market share is occupied by casual gamers, and it is anticipated to experience a compound annual growth rate (CAGR) of over 40%. The hyper-casual gaming genre is currently the most popular, with the most extensive viewership, and may generate revenue when monetized. Voodoo's hyper-casual games have received over 2 billion downloads, exemplifying their popularity.

The second largest market share is held by the avid gamers segment, with the lifestyle gamers segment following behind [20]. Avid gamers are influential in the gaming community, often encouraging others to try out new games. On the other hand, lifestyle gamers have a strong passion for gaming and enjoy developing their skills and knowledge in various games. As these traits become more prevalent, both

segments are projected to experience consistent growth rates from 2023 to 2030.

A. Regional Insights:

Cloud gaming regions refer to the geographic locations where cloud gaming servers are located. These regions play a crucial role in the performance and latency of cloud gaming services, as the distance between the user and the server can affect the quality of the gaming experience [13]. Cloud gaming providers typically have multiple data centers located in different regions around the world to ensure optimal performance for users in different locations. The number of regions and data centers varies depending on the provider, but some of the major cloud gaming providers have a global presence with multiple regions [11].

Here are some examples of cloud gaming regions and providers:

1. Google Stadia: Google Stadia has data centers in the United States, Europe, and Asia, with multiple locations within each region. This allows users to access the service from different parts of the world with minimal latency.
2. Amazon Luna: Amazon Luna currently has data centers in the United States, with plans to expand to other regions in the future.
3. NVIDIA GeForce NOW: NVIDIA GeForce NOW has data centers in North America and Europe, with plans to expand to other regions in the future.
4. Microsoft xCloud: Microsoft xCloud has data centers in the United States, Europe, and Asia, with plans to expand to other regions in the future.
5. PlayStation Now: Sony PlayStation Now has data centers in North America, Europe, and Asia, allowing users to access the service from different parts of the world. Some other notable players in the market include:
 - Apple Inc.
 - Electronic Arts, Inc.
 - Intel Corporation
 - International Business Machines Corporation (known as IBM)
 - Ubitus Inc.
 - Tencent Holdings Ltd.

X. CLOUD GAMING MARKET SCOPE:

TABLE I. CLOUD GAMING MARKET SCOPE:

Report Attribute	Details
Market Value size in 2022	USD 1.02 Billion
Revenue forecast in 2030	USD 20.94 Billion
Growth Rate	CAGR of 45.8% from 2018 to 2030
Base year of estimation	2021

Historical Data	2018 to 2030
Forecast Period	2022 to 2030
Quantitative Units	Revenue in USD million and CAGR from 2018 to 2030
Report Coverage	Forecast of revenue, Rankings of companies, Competitive landscape, growth factors, and Emerging trends
Segments Covered	Type, device, gamer type, region
Regional Scope	North America, Europe, Asia Pacific, Latin America, MEA
Country Scope	US, Canada, UK, Germany, China, India, Brazil, Japan
Key Companies Profiled	Sony Interactive Entertainment, Ubitus Inc., Tencent Holdings Ltd., Amazon Inc., Apple Inc., Electronic Arts, Google Inc., Intel Corporation, IBM, Microsoft Corporation, NVIDIA.
Customisation Scope	Free Customization of Report upon Purchase. Extension or modification of the national, regional, and sectoral purview
Pricing and purchase options	Take advantage of customized alternatives to match your precise study requirements.

XI. CONCLUSION

In conclusion, cloud gaming has revolutionized the gaming industry by enabling players to access high-quality games on a wide range of devices, regardless of their hardware specifications. Cloud gaming services offer many benefits, including seamless gaming experiences, lower costs, and reduced hardware requirements. Moreover, cloud gaming also allows for easier sharing of games and multiplayer capabilities across different platforms.

While cloud gaming has faced some challenges, such as latency and network stability issues, improvements in internet infrastructure and advancements in technology have made cloud gaming more accessible and reliable than ever before. As the technology continues to develop, cloud gaming is poised to become even more popular in the coming years, offering gamers greater flexibility, convenience, and access to a vast library of games. Overall, cloud gaming represents a promising future for the gaming industry and its players.

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