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Cloud Gaming: Future of Computer Games

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ABSTRACT

Cloud gaming is a new way to deliver the high-end gaming experience to users anywhere and anytime in the world. In cloud gaming, high developed game software runs on powerful servers in data centers, rendered games are streamed to users over the Internet in real-time, and gamers use light-weight software executed on heterogeneous devices to play the games. Due to the rise of high-speed network and cloud computing, cloud gaming has attracted good attentions in both the academic as well as industry since late 2000's. In this research, we studied the latest cloud gaming research from different approach, assessing over cloud gaming platform, best techniques, and commercial gaming services over cloud. Those who read this survey will learn basic understanding of cloud gaming research and know about recent advances in this field.

Keywords-Cloud, gaming, video games, distributed computing, video gaming, quality of services

1. INTRODUCTION

Cloud gaming refers to a latest technology to deliver computer video games to gamers, where high-end games are played on powerful cloud servers, the rendered game scenes are played over the Internet to users with thin clients on their devices, and the controlled events from input devices are sent again to cloud servers for interaction. In the cloud, a cloud gaming platform is executed on cloud servers in one or different data centers. The cloud gaming platform runs computer games, which can be divided into two components: (i) game logic that is responsible to convert gamer's instruction into game interactions, and (ii) scene renderer that generates game scenes in real-time in-game. Cloud gaming is a relatively new technology that enables users to play high-quality computer games without the need for expensive hardware. Instead, the games are processed and rendered on powerful cloud servers, and the user interacts with the game through a thin client on their device. This thin client only requires a low-complexity instruction receiver and video decoder, and the communication between the client and the cloud gaming platform is carried out over the internet. Cloud gaming platforms handle two main components of the gaming experience: the game logic, which is responsible for converting the user's input into game interactions, and the scene renderer, which generates the game scenes in real-time. The resulting video frames are sent to the user's device, while the user's inputs are sent back to the cloud server for processing..

The popularity of cloud gaming can be attributed to different potential advantages to consumers, game developers, and the service providers. For consumers, cloud gaming enables them to: (i) have access to their users anywhere and anytime, (ii) buy or rent the games on-demand, (iii) avoid regularly upgrading the

hardware (iv) enjoy unique specifications such as migrating across user's computers during gaming sessions, observing ongoing tournaments, and sharing game replays with your friends. For game developers, cloud gaming allows developers to: (i) concentrate on one platform, which will reduce the porting and testing costs, (ii) bypass retailers for high profit margins, (iii) reach out to more users, and (iv) avoid piracy as the game software is never downloaded on client computers. For service providers, cloud gaming: (i) leads to different business models, (ii) creates more demands on already-deployed cloud resources, and (iii) demonstrates the potential of new remote execution applications, since cloud gaming has the strict constraints on different computing and networking resources. Despite of the big opportunities of cloud gaming, various crucial challenges must be addressed by the research community before it reaches its complete potential to attract more users, game developers, and service providers.

Scope and Classification-

In the current research paper, we are surveying the cloud gaming literature. We firstly have to collect representative cloud gaming papers, and have to group them into various classifications. We highlight that only a particular set of papers are surveyed, in order to provide the users to better understand the landscape of the cloud gaming research. Upon selecting the representative papers, we propose. More details on the classification system follow.

1) Cloud Gaming Overview: We survey the overview, papers on either general cloud gaming, or particular topics, like mobile cloud gaming and Game-as-a-Service (GaaS).

2) Cloud Gaming Platforms: We consider the papers that builds basic cloud gaming platforms, which support various performance ehancement methodologies. These studies can be further categorized into three different groups: system integration, QoS evaluations, and QoE evaluations.

3) Optimizing Cloud Gaming Platforms: We consider papers that optimize cloud gaming platforms from particular aspects; generally each work focuses on developing one or a few components. Such studies can be later categorized into two different groups: cloud server infrastructure and communications.

4) Commercial Cloud Gaming Services: We will survey the representative commercial cloud gaming services, and classify them along various aspects. We also discuss the pros and cons of several cloud gaming services.

2. CLOUD GAMING PLATFORMS

This topic presents the work associated to cloud gaming platforms in three different steps: (i) integrated cloud gaming platforms for complete demo systems, (ii) measurement studies on Quality of Services metrics (iii) measurement studies on QoE metrics.

A. System Integration

Providing an easy-to-use platform for (cloud) game developers is very difficult. This is because of the complicated, distributed, and diverse nature of the cloud gaming platforms. In fact, there is a clear trade off between development convolution and optimization room. Platforms opt for very low (or even no) additional development complications may suffer from few room for enhancement, which are termed as transparent platforms that run unmodified games. In contrast, various platforms opt for more enhanced performance at the cost of requiring more development complications, such as code expansion and recompilation, which are called non-transparent platforms. These two different classes of cloud gaming platforms have pros and cons

B. Quality of Service Evaluations

Performing Quality of Services measurements is critical for measuring the performance of the cloud gaming platforms. Moreover, doing it in real-time allows us to successfully troubleshoot and even to dynamically enhance the cloud gaming platforms. The QoS related cloud gaming papers are roughly classified into two different classes: (i) energy consumption (ii) network metrics. They are surveyed in the following.

Energy Consumption: Games have been known to let the consumer computing platforms to their high capacity. In traditional systems such as desktop computers, it is generally expected and accepted that Game applications will push a computer system to its limits. However, mobile environments are in a different environment as they have thefixed power reserves. A fully used mobile device may have a more reduced running time, thus it is important to minimizing the complications of these game applications for mobile devices. Cloud gaming

systems issue a likely way forward by offloading complex processing services such as 3D rendering and physics calculations to high-end cloud servers. However, cares must be taken because the decoding of video, especially high quality video is far from a trivial work.

Network Metrics: Like other distributed multimedia softwares, consumer's experience mostly depends on network conditions. Therefore, evaluating various network metrics in cloud gaming is critical, and we have provided detailed research below. Clay pool measures the contents variety of various game genres in depth. 28 games from 4 perspectives, including First-Person Linear, Third-Person Linear, Third-Person Isometric, and Omnipresent, are selected for analyzing their scene complications and movements, indicated by average Intra-coded Block Size (IBS) and Percentage of Forward/backward or Intra-coded Macro blocks (PFIM), respectively. Analysis performed by the author suggest that Microsoft's remote desktop achieves good bit rate than No Machine's NX client, while NX client has high frame rate. A following work finds out On Live network specifications, such as the data size and frequency being sent and the overall downlink and uplink bit rates. The authors reveal that the high downlink bit rates of On Live games are almost similar to those of live videos, nevertheless, On Live uplink bit rates are much more average, which can be compared to the traditional game uplink traffic. They also notify that the game traffic features are same for three different types of game genres, including First-Person, Third-Person, and Omnipresent, while the total bit rates can differ. Another important finding is that On Live does not perform its ability in adapting bit rate and frame rates to network latency.

3. OPTIMIZING CLOUD GAMING PLATFORMS

This topic surveys enhancement studies on cloud gaming platforms, which are then segmented into two different classes: (i) cloud server infrastructure (ii) communications.

A. Cloud Server Infrastructure

To manage with the surprise demands from the huge number of cloud gaming gamers, carefully-designed cloud server infrastructures are needed for high-quality, powerful, and viable cloud gaming services. Cloud server infrastructures can be enhanced by: (i) intelligently allocating resources among servers (ii) creating innovative distributed structures. We describe these two different types of task in the following.

1) Resource Allocation: The number of resources allocated to high performance multimedia softwares such as cloud gaming is continuesly growing in both public as well as private data centers. The high in demand and utilization patterns of these platforms make the smart issuing of the resources more important to the organization of both public as well private clouds. From Virtual Machine (VM) placement to shared GPUs, researchers from various areas have been finding how to make efficientuse of the cloud to host cloud gaming platforms. We now explore the key work done in this field to facilitate efficient deploy the cloud gaming platforms.

3) *Distributed Architectures:*

Due to the large geographical distribution of the cloud gaming users the structure of distributed architectures is of crucial importance to the deployment of the cloud gaming systems. The structure of these systems must be carefully enhanced to ensure that a cloud gaming system can sufficiently cover its expected users. Next, to maintain the extreme low latency tolerance need for high QoE even the placement of various server components must be enhanced for the lowest possible delay. These innovative distributed architectures have been found in the literature.

B. Communications

Due to the distributed nature of cloud gaming services, the effificiency and robustness of the communication channels between cloud gaming servers and clients are crucial and have been studied. These studies can be classified Into two groups: (i) the data compression algorithms to reduce the network traffic amount and (ii) the transmission adaptation algorithms to cope with network dynamics. We survey the work in these two groups in the following.

1) Data Compression: After game scenes are computed on cloud servers, they have to be captured in proper representations and compressed before being streamed over networks. This can be done in one of the three data compression schemes: (i) *video compression*, which encodes 2D rendered videos and potentially

auxiliary videos (such as depth videos) for client side post rendering operations, (ii) *graphics compression*, which encodes 3D structures and 2D textures, and (iii) *hybrid compression*, which combines both video and graphics compression. Upon cloud gaming servers produce compressed data streams, the servers send the streams to client computers over communication channels.

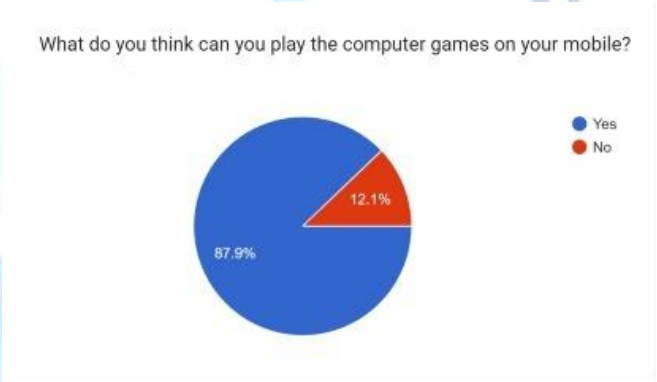
2) Adaptive Transmission: Even though data compression techniques have been applied to reduce the network transmission rate, the fluctuating network provisioning still results in unstable service quality to the gamers in cloud gaming system. These unpredictable factors include bandwidth, roundtrip time, jitter, and etc. Under this circumstance, adaptive transmission is introduced to further optimize gamers QoE. The foundation of these studies is based on a common sense: gamers would prefer to scarify video quality to gain smoother

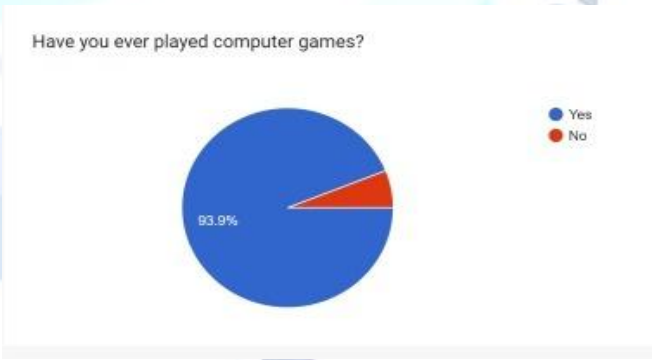
4. COMMERCIAL CLOUD GAMING SERVICES

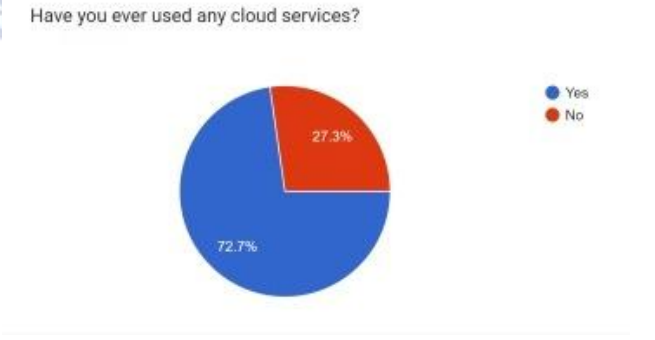
In addition to the technical problems discussed in prior sections, commercialization and business models of cloud gaming services are critical to their success. We survey the commercialization efforts starting from a short history on cloud gaming services. G-cluster starts building cloud gaming services since early 2000's. In particular, G-cluster publicly demonstrated live game streaming1 over WiFi to a PDA in 2001, and a commercial game-on-demand service in 2004. G-cluster's service is tightly coupled with several third-party companies, including game developers, network operators, and game portals. This can be partially attributed to the less mature Internet connectivity and data centers, which force G-cluster to rely on network QoS supports from network operators. Ojala and Tyrvainen presents the evolution of G-cluster's business model, and observe that the number of G-cluster's third-party companies is reduced over years. The number of households having access to G-cluster's IPTV-based cloud gaming service increased from 15,000 to 3,000,000 between 2005 and 2010.

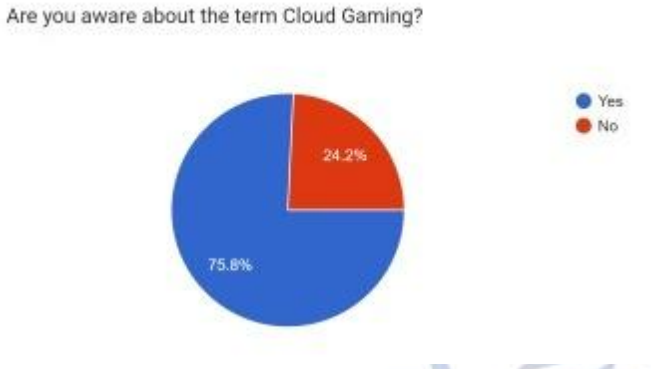
In late 2000's, emerging cloud computing companies start offering Over-The-Top (OTT) cloud gaming services, represented by On Live, Gaikai, and Game Now. OTT refers to delivering multimedia content over the Internet above arbitrary network operators to end users, which trades QoS supports for ubiquitous access to cloud games. On Live was made public in 2009, and was a well-known cloud gaming service, probably because of its investors including Warner Bros, AT&T, Ubisoft, and Atrari. On Live provided subscription based service, and hosted its servers in several States within the US, to control the latency due to geographical distances. On Live ran into financial difficulty in 2012, and ceased operations in 2015 after selling their patents to Sony. Gaikai offered cloud gaming service for using some different business model. Gaikai accepted cloud gaming to allow users to try new games without purchasing and installing software on their own hardware. At the end of each gameplay, gamers are given options to buy the game.

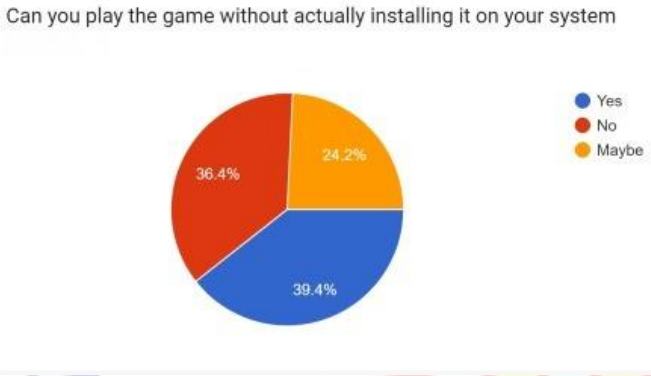
Figuresand Survey Results-

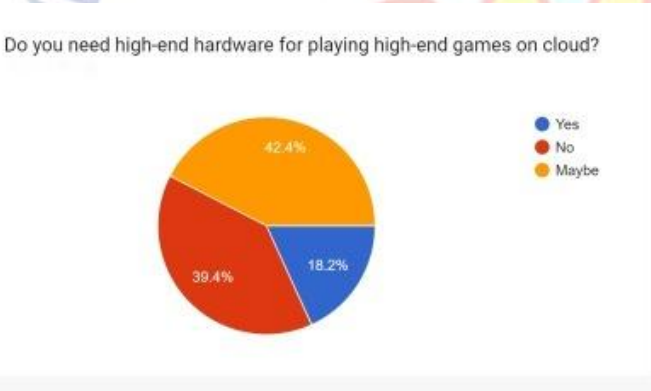












Descriptive Statistics-

1) Have you ever played computer games?

Mean	1.0625
Standard Error	0.043475521
Median	1
Mode	1
Standard Deviation	0.245934688
Sample Variance	0.060483871
Kurtosis	13.22666667
Skewness	3.795045503
Range	1
Minimum	1
Maximum	2
Sum	34
Largest(1)	2
Smallest(1)	1
Confidence Level(95.0%)	0.088668911

2) Can you play the game without actually installing it on your system?

Mean	1.875
Standard Error	0.140204344
Median	2
Mode	1
Standard Deviation	0.793115539
Sample Variance	0.629032258
Kurtosis	-1.349384479
Skewness	0.232772371
Range	2
Minimum	1
Maximum	3
Sum	60
Largest(1)	3
Smallest(1)	1
Confidence Level(95.0%)	0.285948645

3) Have you ever used any cloud services?

Mean	1.28125
Standard Error	0.080752197
Median	1
Mode	1
Standard Deviation	0.456803409
Sample Variance	0.208669355
Kurtosis	-1.024554389
Skewness	1.021591908
Range	1
Minimum	1
Maximum	2
Sum	41
Largest(1)	2
Smallest(1)	1
Confidence Level(95.0%)	0.164695192

4) Are you aware about the term Cloud Gaming?

Mean	1.25
Standard Error	0.077771377
Median	1
Mode	1
Standard Deviation	0.439941345
Sample Variance	0.193548387

Kurtosis	-0.570114943
Skewness	1.212282818
Range	1
Minimum	1
Maximum	2
Sum	40
Largest(1)	2
Smallest(1)	1
Confidence Level(95.0%)	0.158615769

5) Do you need high-end hardware for playing high-end games on cloud?

Mean	2.25
Standard Error	0.134703977
Median	2
Mode	3
Standard Deviation	0.762000762
Sample Variance	0.580645161
Kurtosis	-1.092720307
Skewness	-0.466607874
Range	2
Minimum	1
Maximum	3
Sum	72
Largest(1)	3
Smallest(1)	1
Confidence Level(95.0%)	0.274730571

6) What do you think can you play the computer games on your mobile?

Mean	1.125
Standard Error	0.05939887
Median	1
Mode	1
Standard Deviation	0.336010753
Sample Variance	0.112903226
Kurtosis	3.909359606
Skewness	2.380876189
Range	1
Minimum	1
Maximum	2
Sum	36
Largest(1)	2
Smallest(1)	1
Confidence Level(95.0%)	0.121144795

5. CONCLUSION

In this research, we categorized the existing cloud gaming research into four classifications: (i) overview, (ii) platform, (iii) optimization, and (iv) commercialization. In 2nd section, We included papers that introducing general and detailed cloud gaming. In 3rd section, we presented the basic cloud gaming platforms that support forassess able table performance measurements. More specifically, we considered: (i) Quality of Services evaluations, such as energy consumption and network metrics, and (ii) QoE evaluations, such as user experience. In 4th section, we presented the two different major enhancement directions: (i) cloud server structure, such as resource allotment and spread out architecture, and (ii) communications, such as data compression and adaptive communication. In 5th section, we gave the history of cloud gaming services, followed by the infrastructure decisions made by representative commercial cloud gaming services. Minimizing the cost on cloud and networking resources while achieving best gaming experience requires careful enhacement like the approaches explored in this research. Without these enhancements, service provider cannot combine enough cloud gaming users to each physical hardware. This will lead to much less profits, and can cause the service provider out of business. Some early industry pioneers such as On Live has left the market. Latest cloud gaming services such as PS Now and Game Now are good more optimized and will be more competitive in the current market. As commercial cloud gaming services become financiallystable, the new cloud gaming ecosystem will graduallygrow, will lead to more investments and technologies to improve these services. Most of the innovation needed to push cloud gaming to the another level may reside in creating new programming paradigms to support the different needs of these complicated systems. Most latest cloud gaming platforms work like ”black box” simply wrapping a traditionally programmed game in a support system to start cloud gaming. Although, the original black box model of cloud gaming has led to many real world implementations a more integrated approach may be necessary. It is likely that using in-game contexts or whole new programmingmodel may resolve some of cloud gaming barriers. Future cloud gaming aware programmingmodel will help facilitate both better gaming experience and resource usage. This will allow

more new invention, yet demanding ideas to be implemented, which in turn results in crucial momentum towards building the new generation

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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