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A Study on Edge Computing for Cloud Gaming

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Abstract: The idea of Cloud gaming involves allowing users to play games from anywhere while being connected to a network without worrying about the hardware and software requirements of the game. This is achieved by running the game on high end devices located far away and streaming the video to the user while accepting his commands. The system faces issues like latency which degrades the Quality of Experience. However, with advancements in 5G technology and Edge Computing the problem of delay, bandwidth utilization can be solved to achieve a smooth user experience. The coming days will only attract more users to the already popular Cloud gaming area so, the existing system must keep improving to provide service indistinguishable from conventional gaming. This paper presents a survey on utilizing Edge Computing for improving Cloud Gaming systems. The study of the edge based system is done using two Cloud Gaming systems namely EdgeGame and GamingAnywhere. The paper highlights some of the prospects of Edge Computing that can be used to improve Cloud Gaming. The Edge Computing technologies can be used to reduce latency, bandwidth usage and congestion to improve overall user experience in Cloud Gaming. The paper also presents the opportunities and potential challenges faced in the area of cloud gaming.

Keywords: Cloud Gaming, Edge Computing, Edge nodes, Cloud Data Center, Quality of Experience, Latency, Bandwidth.

I. INTRODUCTION

The era of the internet has revolutionized gaming and made it immensely popular not just among kids but also among youths. Gaming industry is nearly worth over $200 billion and is making a contribution to the world economy. Games range from simple 2D representations to complex Virtual Reality based experience. The games were mainly played on Desktop Computers until the last decade however in the modern day games are played on consoles, smartphones, smart TVs, laptops which has now made game developers to produce games for a particular platform. The popular AAA games or simply the high-end games demand expensive hardware equipment like GPUs, 4K screens with higher refresh rate, 32 GB of RAM, SSD for an outstanding gaming experience. These expensive pre-requisites are not affordable by everyone and this has made gaming confined to the elite class. Thus, there is a need to make Gaming available to all at a much lower expense and diminish the need for regular hardware upgrade and this made way for Cloud Gaming to provide Gaming as a Service (GaaS) [12].

Cloud Gaming has been around for quite a long time now but it's getting recognition only recently. Cloud Gaming or Game streaming is all about running the game on powerful machines located somewhere far from the user which streams the video to their device. This reduces if not eliminates the user's device dependency as the game's requirements are satisfied by the Cloud device and the user must only have a device capable of playing the video and accepting inputs. The idea of Cloud Gaming is becoming more and more popular as it provides an opportunity to average classes of public to explore AAA games. The pioneer in the Cloud Gaming industry was OnLive, which offered the first Cloud Gaming services in the United States of America. This idea was later taken ahead by the likes of Gaikai and StreamMyGame who developed a better business model to successfully operate this venture. The advantages of Cloud Gaming are (i) No need for constant hardware upgradation to enjoy latest games (ii) games can now be played on any platform with a good internet connection (iii) allow users to explore more games and maybe sometimes available for free. The advantages are not just confined to the gamers but also to the game developers. Cloud gaming allows them to develop games that can support multiple platforms like console, PC, smartphone etc.

The idea of Cloud gaming has begun to attract Entrepreneurs, Researcher, venture capitalists and Businessmen. The platforms such as G-Cluster, OTOY and T5-Labs are examples of how steeply this technology is developing. The Cloud gaming industry has also seen the entries of Tech giants with the likes of Google, Microsoft and Sony, which evidently shows its scope in the near future. However, Cloud Gaming still suffers from a few issues that is curbing its popularity. The current 4G equipment is not able to produce speeds sufficient for an enjoyable gaming experience. The entire idea

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of Cloud Gaming revolves around making the games device agnostic and to achieve that computationally expensive tasks must be processed at a powerful device other than the user's device. However rendering HD frames, running game logic to be performed on the device would come at the expense of draining battery which is undesirable. The issues such as latency is reducing the Quality of Experience (QoE) making it difficult for the Gaming services to offer streaming AAA games which are particularly sensitive to such issues [6]. The industry then looked for ways to develop systems with lower latency and ways to efficiently utilize the available bandwidth and this is where Edge Computing comes into picture.

Edge Computing is the technology of processing data at the edge of the network, usually at or close to the place it is generated. Edge Computing was initially used to handle the rising data due to Internet of Things (IoT) applications but because of its ability to process data closer to the source its use cases simply skyrocketed [11]. Today, Edge Computing is finding applications in Real-time data processing and analytics, development of smart cities, autonomous vehicles etc. Some of the commonly used alternatives for Edge Computing are “Fog Computing”, “Cloudlet Computing” etc but the term “Edge Computing” will be used in the rest of this paper. Edge network is made up of edge nodes and the devices that generate data are referred to as edge devices. Base stations, routers, switches and gateway are some of the commonly observed edge nodes. The edge devices are mainly the ones connected to the Internet and send the data to these edge nodes, Laptops, Computers, Smartphones, SmartTv, wearable gadgets etc are a few examples. Edge Computing is used to mitigate the problems encountered in conventional Cloud Gaming systems. As the data from end devices go to the Edge nodes and is processed there, the system will have a lower latency. Cloud Gaming also involves video streaming and multimedia transportation through the network which will consume a lot of bandwidth. Edge Computing can be used to minimize the bandwidth consumed as video encoding can be made to perform at the edges rather than the Data server, this will lead to lesser bandwidth consumption and also decrease congestion in the network. The rise of 5G for faster wireless technology has boosted the Edge Computing domain and will continue to do so in the future, providing a promising solution to tackle issues in Cloud Gaming and provide the users with experience indistinguishable from that of running games locally [16]. The edge network can be used to run computationally expensive tasks on the edge nodes rather than running them on edge devices. The edge nodes will be only a few hops away from the end devices and will have relatively lower latency as compared to computation on the cloud server. The paper discusses the usage of Edge Computing to support the Cloud Gaming system and highlights the tasks that can be performed on the edge nodes. However with growing opportunities comes greater challenges to successfully implement gaming on cloud. Although the industry is looking to improve gaming experience, it must also find a way to sustainably achieve this goal. There are constant trade offs being made between providing better service to the users and reducing costs on hardware and software equipment to obtain higher profits. The paper also visits a few challenges the Cloud Gaming service is and most likely to face.

The following lines briefly describe the content that will be covered in this paper. In Section 2, the works related to Cloud gaming and the role of Edge Computing in development is discussed. Section 3 describes the structure of the Cloud gaming ecosystem based on the study of two Open-Source gaming platforms EdgeGame and GamingAnywhere. Section 4 explores the Challenges in the growing domain of Cloud gaming and Section 5 discusses the upcoming opportunities in development of Cloud Gaming.

II. RELATED WORK

A. Cloud Gaming Systems

A study on papers explaining the structure of Cloud gaming was conducted to know more about the existing works in the field. In [4] the gaming systems were classified into three categories based on how they divide the workload between cloud servers and clients. The categories were: (i) 3D graphics streaming, (ii) video streaming, and (iii) video streaming with post-rendering operations. The paper on the future of Cloud gaming [2] further classifies cloud gaming platforms into three types: (i) Blackbox solution in which the game renders audio/video to the Cloud Gaming server (ii) Augmented game which is integrated with the game server and the game exposes the camera location and orientation to improve latency and graphics quality, and (iii) Type Cloud Gaming system that demands new programming paradigms where games are expected to be written using advanced software development kits (SDKs). It is shown that by using the in-game contexts, cloud gaming servers can perform more efficient video compression through wrapped video frames and accelerated motion estimation. The studies have shown a modularized approach for making games keeping in mind the opportunities in containerization that are specialized for cloud gaming can contribute to its improvement. The trade-offs between: 1) time-to-market and room for optimization; and 2) hardware and software costs were explored while another kind of trade-off between improving Quality of Experience (QoE) and generating profit to the organization was discussed in [2]. The gaming systems were also distinguished based on accessibility and differentiate them as public cloud gaming services and closed cloud gaming services, e.g., in hotels, Shopping malls, Internet cafes, and amusement parks. The quality of video stream available to the users also plays a key role in advanced gaming and there is a high demand for

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producing a 360-degree view for gaming purposes [8]. The metrics to evaluate performance of Cloud gaming services help in a comprehensive understanding of the existing platforms and some of the key metrics are Latency, Delay, Quality of Service and Quality of Performance. These metrics not just help in performance evaluation but also assist in efficient utilization of bandwidth, better allocation of resources etc.

B. Edge Computing

In [7], a study was conducted on the correlations of the gaming videos in multiplayer cloud gaming systems and a cloudlet-assisted multiplayer cloud gaming systems was proposed. The correlation of video frames was also studied for transmission through edge nodes. The Edge Computing based system known as EdgeGame was introduced that takes advantage of the edge network to reduce network delay and save bandwidth cost. Moreover, EdgeGame also used reinforcement learning in the edge to increase end-user's QoE [1]. It was also shown that it can achieve a flexible trade-off between different operations such as computation, caching and communication resources by optimistically using edge nodes. In order to reduce network delay and the bandwidth consumption from the cloud, the 2D/3D graphic rendering is placed at the edge [1]. The challenge of maximizing the cloud gaming provider's total profit while achieving good enough QoE was studied to sustain the businesses of gaming service providers [9]. The problem of efficiently consolidating multiple cloud gaming servers on a physical machine using modern virtual machines (VMs) was studied and the results put forth quite satisfactorily showed a good enough QoE can be provided in a cost-effective way. The authors referred to the problem as a provider-centric problem and their study was focused on dealing with the sustainability of business with respect to the service providers [9].

The need to provide better service to users has driven researchers to find ways to reduce the latency and network delay. The path from the Data center to the user devices usually involves routing across various nodes and hence adds to the innate delay. The techniques of Edge Computing have been promising to improve the delay and make efficient utilization of the bandwidth. The interactions from the thin client must be processed in the Data center and the response must be rendered in the form of video streaming. The correlations of the gaming videos in multiplayer cloud gaming systems with video frames rendering have been studied and an attempt to optimize the system by cloudlets and a cloudlet-assisted multiplayer cloud gaming system has been proposed [7]. The cloudlet based gaming systems have been developed as an android application to achieve lower latency [17]. The less important computing tasks are being performed at the edges such as routers, switches and mobile phones that are bringing down network delay and minimising network congestion.

III. STRUCTURE OF CLOUD GAMING SYSTEM

The system overview is based on the study of two cloud gaming frameworks EdgeGame[1] and GamingAnywhere [4]. The section suggests the possible usage of Edge Computing ideas and brings in the positive aspects of the two systems to enhance the existing performance of the architecture. EdgeGame uses edge resources efficiently for caching, computing and communication. For multi-player games,the edge nodes involved must be well synchronized. The edge nodes upload the game log to the cloud data center for having the users gameplay information in cases when the game needs to be resumed. The system places computation intensive tasks such as 2D or 3D rendering on the edge nodes resulting in lower network delay and better bandwidth consumption. The system also uses Reinforcement based learning for routing. The three components of an Edge Computing based system are (1) Cloud Data Center (2) Edge Nodes (3) Thin Client. Figure 1 depicts an abstract view of a cloud gaming system, where the end devices interact with the edge network, which in turn interacts with the Data center. All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

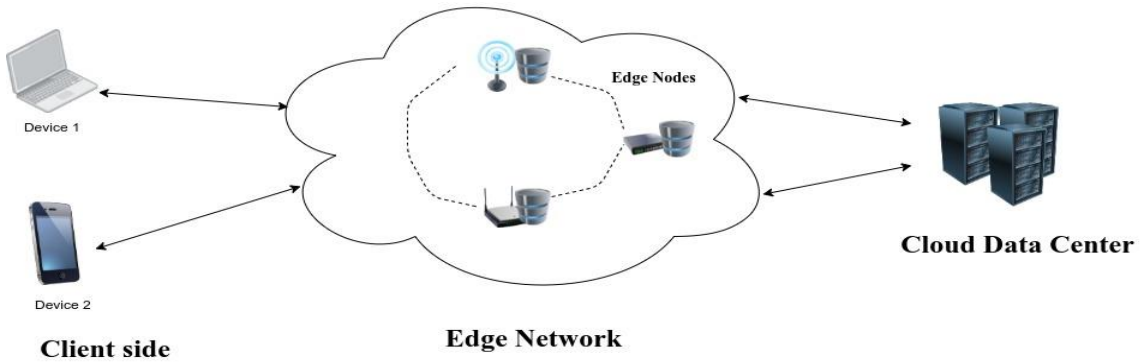

Fig. 1 An Edge based Cloud Gaming System

A. Cloud Data Center (CDC)

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It acts as a monitoring system, database portal for user authentication and registration. Also responsible for looking among the edge nodes near the user's address selecting the best edge node that provides lesser network delay and efficient bandwidth utilization to serve the user and improve the QoE and selection is done based on factors such as load balancing and service cost. If no suitable node is available the CDC must be in the position to serve the user itself. The CDC can be further used as a Video Encoding Server which acts as a gateway and Ad Hoc cloudlet. The Ad Hoc principle is based on sharing video frames among other devices connected to the wifi and with tuning the encoding techniques the computationally less expensive tasks can be performed at the edge nodes [7].

B. Edge Network

The Edge Computing based solution tries to bring computation-intensive services to edge nodes which are just one hop away from the users. The idea is to have virtual nodes(Vnodes) at the physical nodes, so that each Vnode can host a different game when needed. These Vnodes also help in achieving abstraction by having a separate ground for each game and making sure the data or game logic doesn't interfere with other games. A daemon process is running at the nodes that is in constant communication with the CDC and monitors the Vnodes. The Vnode is launched when a player requests the game on the node alloted by the CDC. When the user is playing the game, the Vnode is responsible for accepting the commands, updating the game logic, rendering the scenes and sending the compressed game videos that would be decoded at the user device. In terms of video rendering, the video encoder is purely based on the centrality of the cloud server, so integrating it with Edge-computing technology is a bit difficult. The encoding involves selection of one of the video frames as an intra-video P-frame which might be performed on the edge nodes. However, a multi-hop decoding problem may arise when the selected intra P-frames act as a prerequisite for other players involved in multiplayer games [8]. To avoid this One-hop Inter video encoding can be used which is computationally less expensive and could be performed on edges.

C. Client

The user client is a lightweight program or an application often regarded as the thin client, that hosts the available game titles. Users can select the desired game and the request is sent to the CDC. Upon allocating an edge node to the user, its address is sent to the thin client. The thin client is also responsible for accepting the user commands and sending them to the allocated node, and rendering gaming video at the user end.

Figure 2. shows the flow of important steps in an Edge based system. In step 1, the user logs in to the system and the authentication request is sent to the CDC where user identity is verified. The CDC allocates a physical node considering factors such as network delay, bandwidth, congestion and service cost (step 2). The address of the node selected is sent to the client. The users select the game they want to play and a virtual node is set up in the physical node (step 3). The vnode looks into the tasks for allowing GPU, running game logic, updating game log and encoding the video frames as shown in steps 4, 5 and 6 respectively. The CDC is responsible for monitoring the game log, edge node status and taking appropriate actions when adverse conditions occur (step 7). The encoded video frames are continuously sent to the client (step 8), where they are decoded and the game streaming is completed (step 9). The procedures take place continuously till the user decides to quit the game or a pre-defined time period of service is reached.

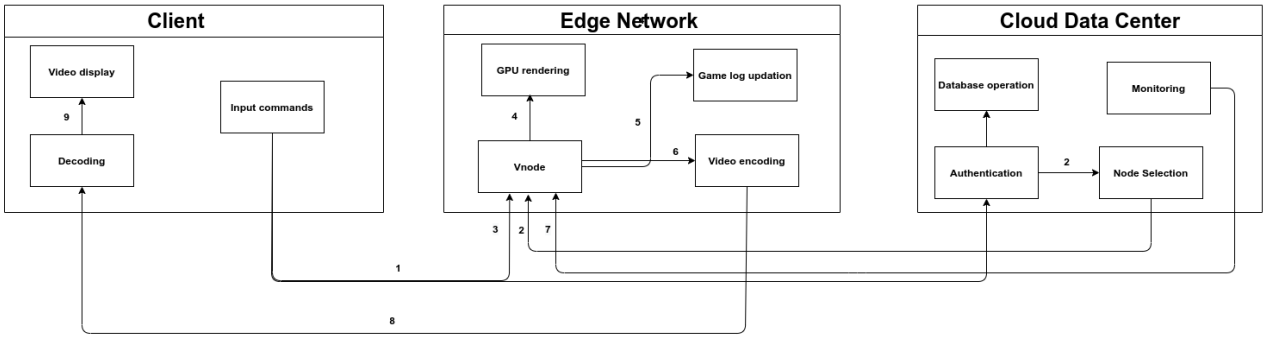

Fig. 2 The workflow of various activities taking place in Edge based Cloud Gaming system.

IV. CHALLENGES

The Cloud Gaming system still needs a lot of improvement and as this technology is finding interests starting from Entrepreneurs to Multinational Companies, the expectations are already high. The popularity of Cloud Gaming will only increase in coming days as more and more users start exploring it. This will bring in a lot of challenges to maintain,

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sustain and improve the gaming system. This section describes some of the existing challenges and the ones which are likely to arise as the engagement of Cloud Gaming increases in the near future.

A. Handling Resources at the Edge

The edge nodes like base stations, routers, gateways etc have limited resources for computation. The edge devices typically have x86 or ARM architecture, with a main memory of nearly 128 MB and 1 GB of storage. This makes computationally expensive tasks very difficult to run on them, so there is a need to establish high-end devices as edge servers to run these kinds of operations. This will also make way to run AAA games on cloud architecture. However, with the infrastructures by Content delivery Network (CDN) providers, the powerful servers would be available more closer to the users, and this will make way for faster gaming networks.

B. Applications adapting to Edge Network

As the data is being processed on edges rather than a centralized data center, the security aspects of edge nodes become important. The game development must focus more on modular approach and deploying them as containers over edge devices will ensure a more secure edge networking. The container engines such as Docker are continuously working on increasing the security needed for cloud applications. The games offered by Cloud Gaming Services in future must be designed in a specific manner to facilitate working with edge networks. There is also a need to modify existing gaming applications so as to fit the edge computing based systems and with advancements in 5G communication the games must also adapt to the changing protocols in Networking.

C. Business Sustainability

The challenge of maintaining the business while offering user experience of the highest quality is not just confined to the Gaming sector but can be generalized to every other business in this world. The pioneer in Cloud Gaming service OnLive terminated operations due to its inability to sustain the business. While this may not be a major problem to Multinational Companies indulged in this business, but for entrepreneurs this problem is of topmost priority. The industry may want to look into buying cheaper hardware that can produce comparable service to the costlier counterparts [9]. The selection of regions with high network traffic to establish edge servers could just be some of the ways to reduce the cost but finding a perfect trade off between Quality of Experience and Service costs will remain a tough challenge.

D. Reducing Energy Expenditure

It is estimated that Cloud Data Centers would consume three times more energy than it has consumed in this decade. This is an ongoing area of research and is often referred to as Green Cloud Computing aimed to reduce energy requirements in the Cloud based ecosystem and promote sustainable development. Cloud gaming does shift computationally expensive tasks to the cloud and thus saving resources of end devices and eventually saving battery power. But to sustain the Cloud or edge network a considerable energy is required and attempts are being made to reduce the energy expenditure [13].

E. Running AAA games on Cloud Gaming

Cloud Gaming will face challenges in handling AAA games or simply high end games. These are often multiplayer games with complex game logic. These games are sensitive to network delay and factors such as congestion, jitter can severely affect the gameplay and lead to poor QoE. This will make users lose interest in that platform and the service provider may eventually run out of business. Seeing the current popularity of these games, gamers won't hesitate to spend a lot of money upgrading their existing devices which will shake the entire idea of Cloud Gaming to its core. Thus, this is one of the major challenges to the industry in which a lot of research is being undertaken.

V. OPPORTUNITIES

The increasing research in developing 5G infrastructure has made way for higher speed in data transmission. The growing area of Edge Computing has brought in ways to reduce several issues such as latency, bandwidth usage and data storage. By using Edge Computing in Cloud Gaming architecture several existing issues have been tackled and have also produced a lot of opportunities to improve the service to get one step closer in achieving the Gaming as a Service model. This section presents a few of the opportunities in developing Edge Computing based Cloud Gaming Systems.

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A. Closed Gaming Setup

The Cloud Gaming setup can be installed in places like five-star hotels, Shopping malls, Gaming arena, Tech Parks etc as a closed circuit system to allow the users to play different games in sessions. These setups can be owned by the organization or be established in collaboration with the Service providers. They can then set up additional edge nodes to specifically increase quality of the service and also improve the overall cloud network. In addition to this, high computational edge servers can be established to perform computationally expensive tasks. However, the service cost factor must be kept in mind as these servers and nodes may need constant maintenance and have high energy needs.

B. Containerizing Applications

The games can be developed in such a way that they can be deployed as containers on a server. The edge nodes capable of hosting them are then identified by the CDC and then these edges serve the users. Containers offer better service than that of using VM to host the game [18]. Docker containers can be deployed on edges which can then start upon request of the user, the booting is faster than VM and uses less resources than VM [5]. Containerized applications also help in achieving isolation from other applications running on the same edge. The service providers need to encourage game development to embrace containerized approaches and deploy modules on edges using containers. This will bring the gaming service more closer to the user end.

C. Real Time Operating Systems

Real Time Operating Systems(RTOS) is a kind of Operating System(OS) that is meant to serve any real-time requests. In Cloud Gaming too, the user input commands come as real-time requests and an RTOS run hardware could be quick enough to serve them [15]. RTOS are lightweight than conventional OS and are suitable to control edge nodes such as base stations. However, existing RTOS are proprietary software and hence provide a limited opportunity for research. The open source RTOS must be developed to promote future works to enable further improvement in the Cloud Gaming area.

VI. CONCLUSION

The paper produces a survey on using Edge Computing to improve Cloud Gaming Systems. The study is based on two Cloud Gaming platforms namely, EdgeGame and GamingAnywhere. The need for Cloud Gaming and the role of Edge Computing in achieving lower latency and efficiently utilizing the bandwidth with the works related to its development has been briefed in the paper. The growing area of Cloud gaming still faces challenges that need to be addressed for improving this technology. Also with rapid development of 5G infrastructure and using Edge Computing makes way for a number of opportunities in the future.

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