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A Comparative Study on the Development of Edge Computing using 5G/6G Technology

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Abstract: ***Technology is changing the world around. The data which was confine to a system or a network is now easily available everywhere through cloud computing technology. It is a technology that Enables the use of computing resources and services from the internet instead of owning physical hardware or infrastructure. Cloud computing provides on-demand delivery of services and resources like database and servers. But now the rapid development of devices connected to the internet is resulting in large-scale of data which is arising a problems like low bandwidth, slow response time, lack of security and privacy in classical cloud computing models. Due to today's techno savvy society and heavy data flow, Cloud computing is no more significance. As a solution of which Edge computing is emerging in Internet of Things. Edge computing generate one layer between cloud and users.***

Keywords: cloud computing, edge computing, Internet of Things, latency reduction, 6G technology

1. Introduction

1.1 Cloud Computing

Cloud Computing Is about storing and accessing data and programs on remote servers which is hosted on Cloud Rather then owning a physical hardware or infrastructure. Cloud computing is also called as Internet-based computing. With the help of cloud computing we can use resources as a service using internet. We can store any storable file like image, documents and etc. We can also perform operations like recovery of data, retrieve software on demand, building a new application or software, Streaming videos and audios online. Cloud computing is a Membership-based service where you can use cloud storage space and cloud resources as a service. Cloud computing can be distributed system and Centralized system. The distributed system where all data are spread across multiple data centres and all data centres in the network can handle requests. It means the load of processing data are not on the single computer, but on the entire cloud. In other hand the Centralized system is the only system where all the data are stored. All processing will be done in single device. Only this device or system is responsible for process all request and store data. With the help of cloud computing we don't need to pay for space that are not used by user, Cloud computing provides us a pay-as-you-go service that means we pay for the space what we actually use. The best example in the real world is E-mail service. Your email is not housed on your device instead of the all resources are on cloud and with the use of internet you can demand it anytime and anywhere. In short cloud computing is the better option then the traditional on-premises infrastructure or storage and it also provides Global Accessibility, flexibility, innovation and speed to market.

1.2 Need for Edge Computing

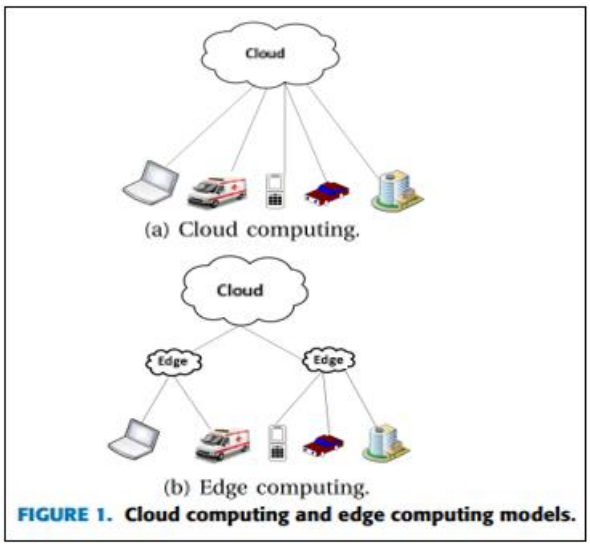


FIGURE 1. Cloud computing and edge computing models.

Cloud Computing is working well in compare to on-site server and storage. With rapid development Of Internet Of Thing (IOT) the data flow is much more then expected. Since IOT has been becoming more popular, IHS Markit estimates the total number of connected device of the internet in 2030 is around 125 billions so the Internet traffic is predicted to increasing rapidly in cloud computing future. It is causing in large-scale of data which is arising a problems like low bandwidth, slow response time ,lack of security and privacy in classical cloud computing models. Due to today's techno savvy society and heavy data flow, Cloud computing is not only sufficient. So as a solution Edge computing concept emerged in IT industry. Edge computing overcomes the problems of cloud computing using different models.it is more efficient in compare to cloud computing. With the rapid development of the Internet of Everything (IoE), the number

of smart devices connected to the Internet is increasing, resulting in large-scale data, which has caused problems such as bandwidth load, slow response speed, poor security, and poor privacy in traditional cloud computing models.[2]

1.3 Edge Computing:

It is a new computing paradigm for performing calculations at the edge of the network. Unlike cloud computing, it emphasizes closer to the user and closer to the source of the data.[2] Edge Computing is mediatory of Cloud and Internet of thing (IOT). Edge computing enables data to be analysed , processed & transferred at the edge of a network rather then being transmitted to a centralised data centre (Cloud).Edge Computing is a real time data processing method where data are stored and process and analysed at the edge first and only necessary data are transmit to cloud. Edge computing reduce the load of Cloud computing. Edge computing is different from classical cloud computing. It is a new computing paradigm that accomplish computing at the edge of the network. Edge Computing have the characteristics of cloud computing. Edge computing minimize the distance from cloud computing and user by getting place in middle, in simple terms, edge computing moves some portion of storage and compute resources out of data servers and closer to user or where the request begins. Rather then transmit the all data continuously and making cloud server heavy, we can use edge computing to analysed and pass only the useful data to the cloud. With this we can reduce the load of cloud and remove the unnecessary data. Also we can overcome the other problems like high latency, low bandwidth, slow response time. Edge devices also downgrade the information that might be needed for user device in future. This feature also make reliable service for client. Nowadays end-users using services like CCTV Surveillance , virtual reality and traffic monitoring generate big data which is require speedy-processing and quick response time. End-users usually run these application on their device meanwhile the services and processing execute on the cloud. There is various edge devices like routers, access point, base station which is connects the cloud to the end-user. Developer can use the edge computing service by expanding Users services closer to them. The services in edge computing are located into the edge of network. Edge computing uses a distributed model. Edge computing have limited scope of users. Edge computing works on a edge of the network means edge devices are as close as possible. It also helps to reduce latency and fast processing and retrieving data. Edge computing bring a extra security layer that protects data with higher security. Edge computing does not process data at the public data centre which makes it more secure. It also enhance real time data streaming. In short edge computing process the raw data and generate processed data and only the processed data will be go further for storing in cloud data canters. It generate a layer between cloud and end-devices. Edge computing also retrieve data from cloud centres and make them ready to send to end devices. We also improve more efficiency by embedding 6th generation networking to Edge computing. It helps to reduce latency, high bandwidth, fast response time and etc. we learn about this more in next topic. Edge Computing brings the service and utilities of cloud computing closer to the end user and is characterized by fast processing and quick application response time [1].

1.4 Limitation of edge computing with 5g

with the advancement of smart devices and Internet of Things (IoT) technology, as well as diversified applications (e.g., smart city, mobile augmented reality, face recognition, and autonomous driving), 5G networks cannot completely meet future rapidly growing traffic demands. [5] So we can say that 5g might not meet the requirement of today's or future heavy data transfer or processing load. Edge Intelligence (EI), powered by Artificial Intelligence (AI) techniques (e.g. machine learning, deep neural networks etc.), is already being considered to be one of the key missing elements in 5G networks and will most likely represent a key enabling factor for future 6G networks, to support their performance, their new functions, and their new services. Consequently, this paper aims to provide an overarching understanding on why edge intelligence is an important aspect in 6G and what are the leading design principles and technological advancements that are guiding the work towards the edge intelligence for 6G [3].

1.5 How 6g overcomes the limitation of edge computing with 5g

Edge computing and cloud computing are two complementary paradigms in the field of distributed computing. While cloud computing centralizes processing and storage in data centre edge computing brings computation closer to the data source, typically at the "edge" of the network, closer to where data is generated and consumed. Edge computing is an emerging technology that enables the evolution to 5G/6G by bringing cloud capabilities near to the end users (or user equipment, UEs) in order to overcome the intrinsic problems of the traditional cloud, such as high latency and the lack of security. [4] The 6G networks are widely projected to provide an increase of 100× in volumetric spectral and energy efficiency (in bps/Hz/m3) relative to the 5G networks and they will have a very complex structure incurred from massive connectivity.[6] The fully intelligent network orchestration and management for providing innovative services will only be realized in Beyond 5G (B5G) or 6g networks.[6] 6G network is expected to effectively support high-quality services and unlimited connectivity for a large number of intelligent devices.[5]

2. Literature Review

2.1 Evolution of Edge Computing with 5G Technology:

Edge computing has emerged as a transformative paradigm, merging telecommunications and IT services to offer cloud computing capabilities at the edge of the network.[9] Its primary objective is to reduce latency for mobile end-users while optimizing network resources, particularly in the context of 5G technology.[10] Through the convergence of edge computing and 5G, computational capabilities are brought closer to data sources, thereby addressing latency issues and enhancing application performance. Cloud-native technologies like software-defined networking and virtualization have played a pivotal role in facilitating the integration of edge computing within the framework of 5G networks.[11] This integration has not only improved the efficiency of mobile services but also streamlined network

operations, laying the groundwork for future advancements in edge computing.[12]

2.2 6G-Enabled Edge Computing Use Cases:

The anticipation of 6G technology has brought forth new possibilities for edge computing, envisioning it as a built-in service with cloud-native concepts.[13] 6G networks are expected to support a diverse range of applications, including IoT, aerial networks, satellite access, and underwater communication.[14] These networks will heavily rely on edge computing to meet stringent requirements such as ultra-low latency, mission-critical reliability, and high mobility.[14] Moreover, the integration of artificial intelligence and machine learning technologies will further enhance the capabilities of edge computing in 6G networks, enabling intelligent network operations and management.[15] The seamless integration of edge computing within 6G networks promises to revolutionize various industry verticals and drive innovation in the digital landscape.[16]

2.3 Anticipated Improvements with 6G Technology:

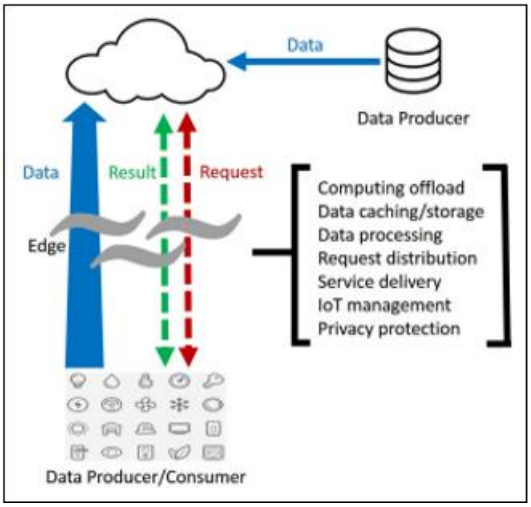


Figure 2: Edge Computing Paradigm [30]

The advent of 6G technology heralds significant improvements in edge computing, particularly in terms of performance, reliability, and mobility.[17] 6G networks are envisioned to offer ultra-low latency, enabling real-time applications and services that were previously unattainable. Mission-critical reliability will be a hallmark of 6G networks, ensuring the seamless operation of essential services across diverse environments. High mobility capabilities will enable ubiquitous connectivity, extending the reach of edge computing to remote and dynamic settings.[17] Artificial intelligence and machine learning will play a crucial role in optimizing network operations and management, further enhancing the capabilities of edge computing in the 6G era.[18] These anticipated improvements underscore the transformative potential of 6G technology in advancing edge computing and reshaping the digital landscape.[19]

2.4 Future Directions and Challenges:

While the prospects of edge computing in 6G networks are promising, challenges persist in its deployment and implementation.[20] Limited insights into deployment strategies and architectures pose significant hurdles in realizing the full potential of edge computing in 6G networks.[21] Standardization efforts and technological advancements will be crucial in shaping the future direction of edge computing in the context of 6G technology. Additionally, defining appropriate business models and addressing security concerns will be imperative in ensuring the successful implementation of edge computing solutions in 6G networks. [22] Despite these challenges, the transformative potential of edge computing in 6G networks underscores its importance in driving innovation and enabling transformative applications across various industry verticals.[23]

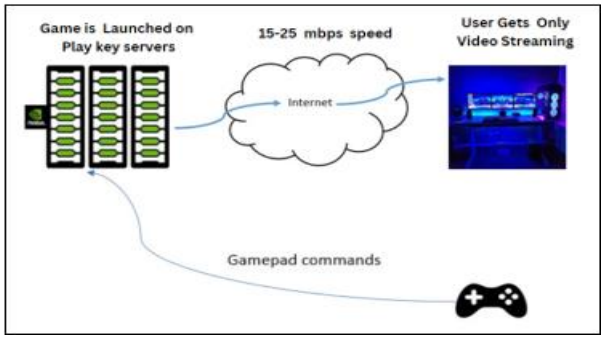
2.5 Comparative Analysis and Decision Framework:

Table 1: Comparative Aspects of 5G versus 6G

Aspect	5G	6G(Expected)
Speed and Bandwidth	lower latency	Even more higher speeds
Capacity and Scalability	Increased capacity and scalability	supporting a vast number of IoT devices and applications
Spectrum and Frequency	Operates in sub-6GHz and mmWave bands	Utilization of higher frequency bands
Network Architecture	Introduction of network slicing, enabling tailored network instances for edge computing	potentially introducing holographic communication and decentralized edge computing models
Edge Computing Integration	Provides foundation for edge computing deployments,	enabling more distributed and decentralized edge computing models with enhanced capabilities

Edge computing, with its ability to reduce data transmission and traffic by processing data at the network's edge, offers several advantages over traditional architectures.[24] It optimizes resource utilization in cloud computing systems, reduces network traffic, and enhances security by encrypting information close to the network kernel.[25] While edge computing shares security concerns with cloud computing, it offers fewer restrictions and physical access control.[26] However, challenges remain in defining architectures and business models for edge computing in 6G networks.[27] Comparative analysis and decision frameworks will be crucial in navigating these challenges and realizing the full potential of edge computing in the context of 6G technology.[28]

2.6 Reducing Latency of Cloud Gaming with Edge Computing 6g



Cloud gaming in edge computing refers to the utilization of edge computing infrastructure to deliver gaming services to users over the internet. Edge computing involves placing computational resources closer to end-users, reducing latency and improving the overall user experience. When applied to cloud gaming, this architecture can address some of the challenges associated with traditional cloud gaming platforms, such as high latency and network congestion.

- Reduced Latency: Edge computing brings processing resources closer to the user's location. This proximity reduces the round-trip time for data to travel between the user's device and the server, resulting in lower latency. In gaming, low latency is crucial for responsive gameplay and real-time interactions.
- Improved User Experience: Lower latency leads to a better gaming experience, especially for fast-paced games that require quick reactions. Players experience less input lag, smoother gameplay, and reduced instances of stuttering or buffering.
- Scalability: Edge computing can offer scalable resources based on demand. As more users access cloud gaming services simultaneously, edge servers can dynamically allocate resources to ensure consistent performance for all players.
- Resource Efficiency: By leveraging edge computing, cloud gaming providers can optimize resource utilization. Computing resources are distributed across multiple edge locations, balancing the workload and minimizing the strain on central data centers.
- Geographical Reach: Edge computing enables cloud gaming services to reach users in diverse geographic locations more effectively. This is particularly beneficial for global gaming platforms, as it helps in providing a consistent experience regardless of the user's location.
- Network Optimization: Edge servers can perform network optimizations, such as traffic shaping and prioritization, to ensure a stable connection for gaming data. This helps in reducing packet loss and maintaining a reliable gaming experience.
- Edge Device Compatibility: Cloud gaming in edge computing can support a wide range of devices, including smartphones, tablets, PCs, and smart TVs. Users can access games from various devices without compromising performance.
- Security and Privacy: Edge computing can enhance security and privacy by processing sensitive data closer to the user's device. This approach minimizes the exposure of data during transit over the network.

3. Conclusion

Cloud computing has transformed data storage and access by leveraging remote servers, offering scalability and flexibility. However, the increasing demand for faster data processing and the rise of Internet of Things IoT devices have highlighted the limitations of traditional cloud models, such as latency and bandwidth constraints. As a solution, edge computing brings computation closer to the data source, reducing latency and improving responsiveness, especially for real time applications. The integration of 5G and future 6G technologies will further enhance edge computing by enabling faster speeds and better connectivity, ensuring smooth operations for applications like cloud gaming, surveillance, and smart cities. Although challenges remain, such as security and deployment complexities, the combined potential of cloud, edge, and future network technologies points toward a highly efficient, secure, and responsive digital future.

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