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The Role of Edge Computing in Future 6G Wireless Networks: A Literature Review

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Abstract. The rapid development of the Internet of Things (IoT), artificial intelligence (AI), autonomous systems, and immersive applications is creating new demands on wireless networks. Although 5G has improved data rates, latency, and device connectivity, applications such as autonomous driving, AI-enabled robotics, virtual reality (VR), augmented reality (AR), and smart healthcare require fast and intelligent processing as well as communication. Traditional cloud computing depends on centralised data centres, which can increase latency and core-network traffic when large amounts of data are produced at the edge. Edge computing addresses this limitation by moving computing resources closer to users and data sources. This paper reviews the role of edge computing in future sixth-generation (6G) wireless networks. It introduces the 6G vision and edge computing, compares edge and cloud computing, examines major benefits and applications, and discusses key challenges including security, resource management, energy efficiency, scalability, and service continuity. The paper argues that a device-edge-cloud architecture will be important for future intelligent wireless networks.

Keywords: 6G, Edge Computing, Mobile Edge Computing, Low Latency, Artificial Intelligence

1. Introduction

Wireless communication has evolved from the analogue voice services of 1G to the data-oriented and highly connected networks of 5G. 2G introduced digital communication, 3G accelerated mobile Internet, and 4G enabled large-scale services such as video streaming and mobile applications. 5G further introduced higher data rates, lower latency, and support for massive connectivity and industrial applications.

However, future networks will need more than faster communication. AI, IoT, autonomous vehicles, robotics, and extended reality require communication, computing, and sensing to work together. Research on 6G therefore emphasises autonomous systems, immersive applications, and the integration of communication, computing, AI, and sensing [1, 2].

The introduction of 5G represented a major transition in wireless communication, but emerging applications are creating requirements beyond conventional 5G services. Future networks must support heterogeneous devices and large volumes of data while maintaining low latency for real-time applications [1, 2].

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Consequently, the evolution towards 6G can be viewed as a transition from communication-oriented networks towards networks that integrate communication, computing, intelligence, and sensing. In this transition, edge computing is expected to play an important role.

Although 5G has significantly improved wireless connectivity, emerging applications create new requirements beyond conventional communication performance. The rapid growth of connected devices, including sensors, vehicles, robots, and wearable devices, increases the pressure on network and resource management. At the same time, applications such as autonomous driving, industrial control, and interactive AR require extremely low response latency, while AI-enabled applications place increasing computational demands on resource-constrained mobile and embedded devices [1, 2]. These requirements make it difficult for traditional cloud-centred architectures to provide efficient and timely services for all future applications [3, 4].

Edge computing provides a potential solution by placing computing and storage resources closer to users and data sources rather than relying entirely on remote cloud data centres [5]. By processing selected tasks closer to where data are generated, edge computing can reduce transmission delay, decrease unnecessary traffic through the core network, and support time-sensitive intelligent applications [4, 5]. Therefore, the integration of edge computing with 6G is expected to provide a more flexible architecture for applications that require low latency, high computational capability, and real-time decision-making.

This paper adopts a structured literature review and comparative analysis methodology to investigate the role of edge computing in future 6G wireless networks.

This review is significant for both industry and future research. From an application perspective, understanding the role of edge computing can support the development of low-latency and intelligent services in areas such as autonomous driving, robotics, smart manufacturing, and immersive applications. From a research perspective, this paper provides a structured overview of the major benefits, applications, and challenges of integrating edge computing with 6G, which may provide a useful reference for researchers investigating future intelligent wireless networks.

2. Background of 6G and edge computing

2.1. Overview of 6G wireless networks

2.1.1. Definition of 6G networks

Sixth-generation wireless communication (6G) is generally considered the next generation following 5G. Rather than simply increasing transmission speed, 6G is expected to integrate communication, computing, AI, and sensing into a more intelligent network architecture.

Saad et al. argue that 6G should support applications such as autonomous systems and extended reality while introducing new technologies and architectures [1]. Yang et al. similarly identify higher intelligence, massive connectivity, and new communication capabilities as important parts of the 6G vision [2]. Therefore, 6G can be viewed as a transition towards intelligent and distributed networks that provide both communication and computing services.

2.1.2. Key characteristics of 6G networks

Ultra-low latency is a key requirement because autonomous driving, industrial automation, and immersive applications require rapid communication and processing [1, 2].

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Massive connectivity is also important because future networks will connect large numbers of sensors, vehicles, robots, and intelligent devices [2].

AI-native networking is expected to make AI central to network optimisation, resource allocation, traffic prediction, and decision-making [1, 2].

Integrated sensing and communication (ISAC) may allow wireless systems to provide both communication and environmental sensing, supporting applications such as intelligent transportation and robotics.

2.2. Overview of edge computing

2.2.1. Definition of edge computing

Edge computing places computing and storage capabilities close to end users and data sources [5]. Its main purpose is to move selected computing functions towards the network edge.

In a traditional cloud model, data is sent to a remote data centre for processing and the result is returned to the user. Although this provides large computational capacity, the communication path can add latency.

Edge computing allows devices to offload tasks to nearby servers. Mobile edge computing research focuses on computation offloading, wireless resource allocation, and computing-resource management [3, 4].

Edge computing should not replace cloud computing. Instead, tasks can be distributed across end devices, edge servers, and cloud data centres according to workload, latency, and network conditions.

The relationship between end devices, edge servers, and cloud data centres in an edge computing architecture is illustrated in Figure 1.

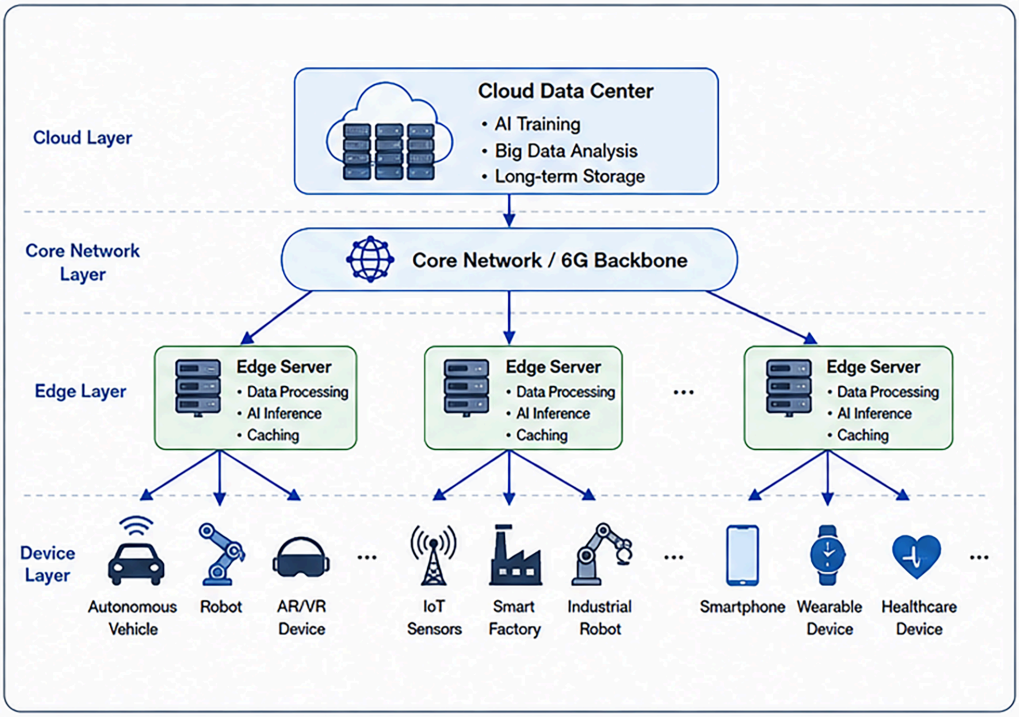


Figure 1. Architecture of edge computing-enabled 6G networks

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2.2.2. Edge computing and cloud computing comparison

Cloud computing relies mainly on centralised data centres, whereas edge computing distributes some resources throughout the network and places them closer to users [5].

Edge computing is generally more suitable for time-sensitive applications because data does not need to travel to a distant cloud server. Offloading workloads to nearby edge servers can reduce communication and processing delay [3, 4].

Processing data at the edge can also reduce traffic in core networks. Edge servers can filter or analyse data locally and send only necessary information to the cloud [6].

Cloud computing remains essential because it provides much greater computing and storage capacity. Future networks are therefore more likely to use a device-edge-cloud architecture rather than replacing cloud computing completely.

Figure 2 compares traditional cloud computing and edge computing under 6G. In traditional cloud systems, data travels a long path to remote cloud centers, bringing high latency and heavy core-network load. Edge computing adds local edge servers for nearby data processing, shortening transmission paths, cutting latency and easing core network traffic.

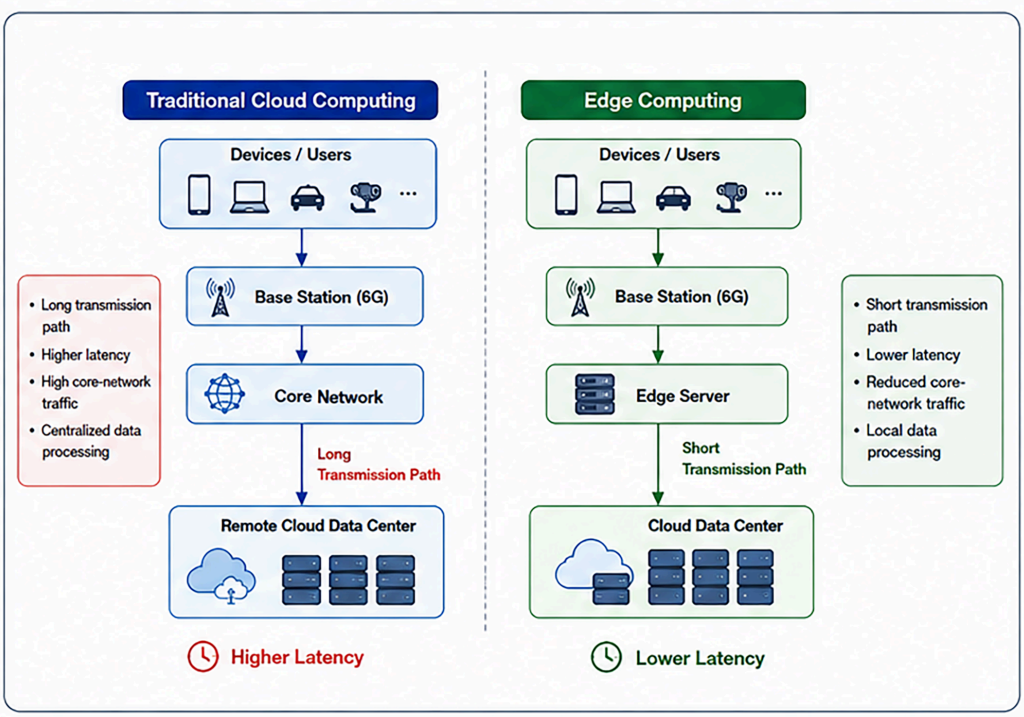


Figure 2. Comparison between cloud computing and edge computing

3. Importance of edge computing in 6G networks

3.1. Benefits of edge computing for 6G networks

3.1.1. Reducing communication latency

In cloud-based systems, user data may travel through access and core networks before reaching a remote server. Edge computing shortens this path by placing computing resources closer to users [4, 5].

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For example, autonomous vehicles can offload selected tasks to nearby edge servers, avoiding the need to send every task to a distant cloud data centre [3, 4].

3.1.2. Improving network efficiency

The growth of IoT and intelligent devices will generate enormous quantities of data. Sending all raw data to cloud data centres can increase traffic and congestion in core networks.

Edge computing allows data to be filtered and analysed closer to its source. This reduces unnecessary transmission and improves the use of communication resources [4, 6].

3.1.3. Supporting real-time applications

Future 6G networks will support applications requiring rapid processing and decision-making, including autonomous vehicles, AI-enabled robots, industrial automation, and AR/VR.

Edge Intelligence brings AI training or inference closer to the network edge, helping computationally constrained devices use nearby resources [7].

3.2. Edge computing applications in 6G networks

3.2.1. Autonomous driving applications

Autonomous vehicles continuously generate data from cameras, radar, lidar, and other sensors. This information must be processed rapidly to identify vehicles, pedestrians, road conditions, and hazards.

Sending all information to remote cloud servers can introduce extra latency. Edge servers near roads, base stations, or transportation infrastructure can process selected data locally [1, 4].

An edge server can combine information from multiple vehicles and provide traffic or road-condition information, supporting cooperative driving and intelligent transportation.

Edge computing cannot fully replace local vehicle computing. Safety-critical operations such as emergency braking may still require local decisions, so future systems are likely to combine local, edge, and cloud computing.

3.2.2. AI-enabled robotics applications

AI-enabled robots increasingly require computer vision, environmental perception, path planning, and decision-making.

However, mobile robots are often limited by computing capacity and battery energy, making it inefficient to run all AI models locally.

Edge Intelligence allows AI inference and other computing functions to be deployed on nearby edge servers [7, 8].

A robot could send sensor or image data to an edge server through a 6G network, receive processed results, and reduce its own computational burden.

3.2.3. Virtual reality and augmented reality applications

VR and AR applications require high data rates and highly responsive interaction.

AR devices may need to analyse the surrounding environment and generate virtual content in real time. Excessive delay can reduce the quality of the user experience.

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Nearby edge servers can process selected image, video, and AI workloads, reducing the time required to exchange data with remote cloud servers [1, 4].

3.2.4. Smart factory applications

Smart factories contain large numbers of sensors, robots, cameras, and automated machines that continuously generate data and often require rapid responses.

Edge servers can process industrial data close to production lines. For example, they can analyse vibration data and identify potential equipment failures without sending all raw data to the cloud.

This supports real-time monitoring, predictive maintenance, and industrial automation. Research on MEC and IoT highlights the value of computing close to data-generating devices [6, 9].

3.2.5. Smart healthcare applications

Modern medical systems generate large amounts of information, including medical images, patient-monitoring data, and connected-device data.

Edge servers near hospitals or medical devices can process selected information locally while more demanding tasks are transferred to the cloud.

Because healthcare data is sensitive, local or edge processing can also reduce the amount of raw patient data transmitted across networks [9, 10].

3.3. Technical challenges of edge computing in 6G networks

3.3.1. Security and privacy issues

Edge computing involves many distributed nodes, increasing the number of potential attack targets. A compromised edge node may affect connected users and devices.

User data may also move between end devices, edge servers, and cloud platforms, making authentication, access control, and privacy protection more complex.

Research has identified data protection, authentication, access control, and privacy as important security issues in MEC [10, 11].

Future 6G edge networks therefore need strong encryption, authentication, privacy-preserving techniques, and secure resource management.

3.3.2. Resource management and task scheduling

Edge servers have more resources than end devices but fewer than large cloud data centres, while serving many users at the same time. This makes resource allocation a major challenge.

Efficient allocation of computing, storage, and communication resources is essential [4, 6].

For each task, the system must decide whether it should run locally, be offloaded to an edge server, or be sent to the cloud.

The decision depends on workload, network conditions, server load, energy consumption, and latency requirements [3, 4].

Intelligent and dynamic task-offloading algorithms will therefore be important for 6G edge networks.

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3.3.3. Energy efficiency and power consumption

Deploying many edge servers increases infrastructure energy consumption, while mobile devices are limited by battery capacity.

Edge systems must balance computational performance and energy use. Task allocation can consider device battery level, server load, and network conditions.

Green mobile edge computing is already an important research direction [4]. Future 6G systems will need energy-aware resource management and intelligent workload allocation.

3.3.4. Network scalability and deployment complexity

The large number of devices and edge nodes expected in 6G will increase network management complexity.

Different edge servers may have different computing, storage, and network capabilities, requiring effective coordination and orchestration [6].

Deployment and maintenance of large numbers of edge servers also create infrastructure and operational costs.

3.3.5. Reliability and service continuity

Many future 6G users will be mobile, including vehicles, drones, and mobile robots.

When a user moves between edge-node coverage areas, the original server may no longer be the best location for processing tasks.

This creates task-migration and service-continuity challenges. Mobility management and computation migration are important MEC research issues [5].

4. Conclusion

This review concludes that edge computing plays an important role in future 6G wireless networks. It can reduce communication latency, relieve network congestion, and support real-time applications such as autonomous driving, smart manufacturing, and intelligent healthcare. The combination of edge and cloud computing can provide a more flexible and efficient network architecture for future 6G services.

However, this paper mainly relies on literature review and lacks simulation and real-world experimental validation. Future research could focus on specific task-offloading and resource-allocation algorithms, while further investigating security, energy efficiency, and network scalability to provide more practical evidence for 6G edge computing.

Future 6G is therefore unlikely to rely exclusively on cloud or edge computing. A device-edge-cloud architecture is more suitable: latency-sensitive tasks can be executed locally or at the edge, while complex computation and large-scale storage can remain in the cloud. Overall, edge computing is an important component of future 6G and can help provide faster, more efficient, and more intelligent wireless services.

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