e-ISSN: 2582-52 08
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:05/May-2024 Impact Factor- 7.868 www.irjmets.com

RESEARCH AND SURVEY OUTLOOK ON MOBILE EDGE COMPUTING

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DOI : https://www.doi.org/10.56726/IRJMETS56423

ABSTRACT

In recent years, there has been a big change in how we use mobile technology, thanks to new ideas like the Internet of Things and 5G communication. Instead of relying on big cloud servers far away, Mobile Edge Computing (MEC) brings the computing power closer to us, right at the network's edge like base stations and access points.

This shift allows for faster, more efficient processing on our devices while saving energy. Researchers and companies are working hard to make MEC a reality by combining wireless communication and mobile computing in new ways. By managing resources smartly, MEC can offer faster speeds, better battery life, and open up exciting new possibilities.

Looking to the future, advancements in areas like system deployment, cache optimization, and privacy protection will bring MEC out of the lab and into our everyday lives. Exciting times are ahead as standardization efforts and practical applications of MEC start to take shape.

Keywords- Mobile edge computing, fog computing, mobile cloud computing, computation offloading, resource management.

I. INTRODUCTION

Mobile Edge Computing (MEC) [12]-[15] revolutionizes the way we interact with data by bringing computational power closer to users and devices. The introduction of the paper delves into the evolving landscape of edge computing, with a specific focus on Mobile Edge Computing (MEC) as a transformative technology within the mobile access network. It outlines the fundamental concept of MEC, which involves migrating intensive computing tasks from Mobile Users (MUs) to Edge Servers (ESs) located in close proximity, thereby enhancing Quality of Service (QoS) and Quality of Experience (QoE) for users. Moreover, the introduction discusses the technical challenges faced in MEC adoption, such as decision-making processes, resource allocation [4]-[6], mobility management, and service migration.

It emphasizes the importance of addressing these challenges to ensure efficient offloading of tasks and optimal resource utilization in the MEC environment. Additionally, the introduction highlights key technical indicators in ES-oriented service provision, including expenditure management, load balancing, ES placement, and resource allocation strategies. It underscores the significance of efficient resource allocation [4]-[6] in cloudlet-based and base station-based MEC systems to maximize resource utilization, minimize power consumption, and enhance user experience. Furthermore, the introduction touches upon the applications of MEC, such as Mobile Edge Internet of Things (MEIoT) architecture for efficient IoT data processing and video streaming in smart cities using MEC for enhanced video delivery and reduced congestion.

Overall, the introduction sets the stage for exploring the intricacies of MEC, its technical challenges, applications, and the potential it holds for revolutionizing mobile network computing by bringing cloud resources closer to users and optimizing system performance.

II. OVERVIEW OF MOBILE EDGE COMPUTING

A. Definition

MEC is described as a new network paradigm that offers information technology services and cloud computing capabilities within the mobile access network of Mobile Users (MUs). It is positioned as a technology that can migrate intensive computing tasks of MUs to nearby Edge Servers (ESs), thereby reducing latency and improving Quality of Service (QoS) and Quality of Experience (QoE).

B. Service of Mobile Edge Comppuling

Mobile Edge Computing provides a range of services and capabilities within the mobile access network, enabling MUs to offload computation and data tasks to ESs located at the edge of the network. By leveraging MEC, MUs can access cloud resources closer to their location, reducing the need for data transmission to distant cloud servers and minimizing network delays.

C. Architecture

Mobile Edge Computing is typically located within the Radio Access Network (RAN) and is in close proximity to MUs. This proximity allows MEC to achieve higher bandwidth with lower latency, enhancing the overall user experience. The European Telecommunications Standards Institute (ETSI) has played a role in standardizing MEC, emphasizing its potential to create a new ecosystem and value chain for computing tasks.

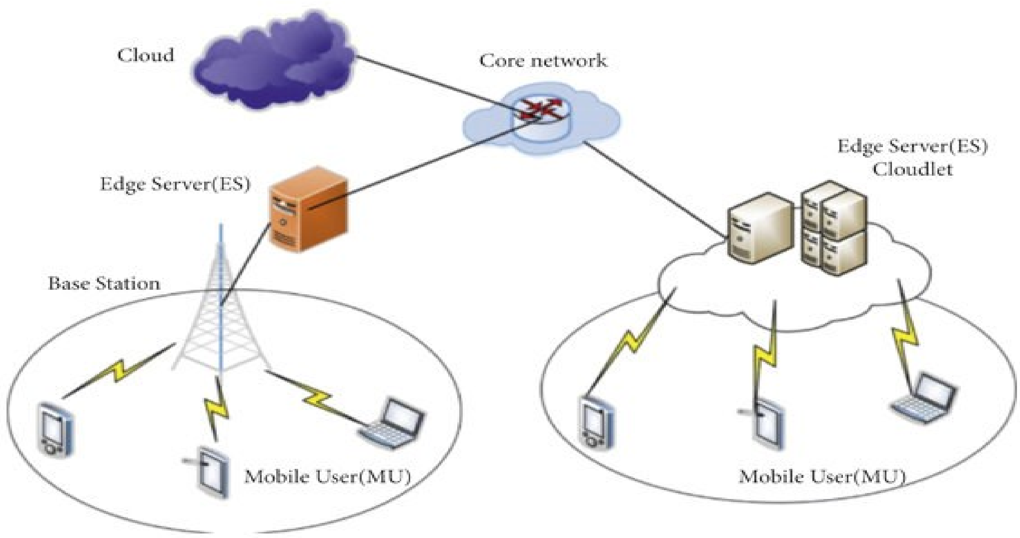

Figure 1: Mobile edge computing (MEC) architecture

III. SIMILAR TERMS

D. Mobile Cloud Computing(MCC):

MCC refers to a concept where mobile devices offload computation tasks to cloud resources. It involves integrating cloud services with mobile networks to enhance computing capabilities for mobile users.

E. Fog Computing(FC):

Fog computing is another computing paradigm that extends cloud computing to the edge of the network. It focuses on distributing computing tasks closer to the data source to reduce latency and improve efficiency

F. Cloudlets:

Cloudlets [7] are small-scale cloud data centers [1]-[3] located at the edge of the network. They serve as intermediaries between mobile devices and the cloud, enabling faster data processing and reduced latency for mobile applications

IV. MOBILE USERS ORIENTED SERVICE ADOPTION

G. Offloading:

One of the key aspects of MUs-oriented service adoption is offloading, where MUs transfer computation and data tasks to Edge Servers (ESs) located at the edge of the network. This offloading process aims to improve application performance, reduce latency, and optimize resource utilization

H. Computation Offloading:

The study on offloading is divided into computation offloading and data offloading [4]-[6]. Computation offloading involves transferring computational tasks from MUs to ESs for efficient execution. This process helps in enhancing the performance of mobile applications and meeting latency requirements.

I. Single MU Offloading Scheme and Multi-MU Offloading Scheme

The offloading schemes are further categorized into single MU offloading and multi-MU offloading schemes. These schemes determine how individual MUs or multiple MUs offload their tasks to ESs for processing, considering factors like application requirements and network conditions

J. Service Adoption Challenges

MUs-oriented service adoption faces challenges related to decision making, resource allocation [4]-[6], and mobility management. These challenges need to be addressed to ensure effective offloading of tasks and optimal utilization of resources in the MEC environment.

V. EDGE SERVER- (ES-) ORIENTED SERVICE PROVISION

K. Technical Indicators-

ES-oriented service provision involves considering various technical indicators to optimize the performance and efficiency of the MEC system. These indicators include factors such as expenditure, load balancing, cloudlet placement, resource scheduling, ES placement, and VM migration.

L. Expenditure

Managing the cost and resources of ESs is crucial in ES-oriented service provision. Strategies such as incentive-compatible auction mechanisms, stochastic control algorithms, and profit maximization policies are proposed to optimize resource allocation [4]-[6] and pricing between MUs and Ess

M. Load Balancing

Load balancing techniques are employed to optimize the distribution of computational tasks among ESs to enhance mobile application performance. Balancing the workload and optimizing mobile application performance are key objectives in ES-oriented service provision.

N. ES Placement:

Determining the optimal placement of ESs in different scenarios, such as WLAN and WMAN, is essential for efficient service provision. Strategies for cloudlet placement, server deployment, and power-aware selection of ESs contribute to improving network performance and user experience.

O. Resource Allocation:

Efficient resource allocation in cloudlet-based MEC systems and base station-based MEC systems is crucial for maximizing the utilization of resources and minimizing power consumption. Algorithms for resource allocation [4]-[6] aim to enhance computation offloading profit, reduce completion time, and optimize energy consumption.

VI. APPLICATIONS ON MEC

P. Mobile Edge Internet of Things (MEIoT)

Ansari et al. proposed a Mobile Edge Internet of Things architecture [14] that brings computing and storage resources closer to IoT devices. This architecture enables efficient processing of IoT data at the edge of the network, reducing latency and improving IoT application performance.

Q. Video Streaming in Smart Cities

MEC can be utilized for video streaming applications in smart cities, where edge servers process and deliver video content to users in real-time. By deploying services at the edge of the network, MEC reduces congestion and ensures timely delivery of video streams to users.

R. Wearable Devices and Cloud Integration

MEC facilitates the integration of wearable devices with cloud services in realistic setups. By offloading computation tasks to edge servers, wearable devices can enhance their functionality, improve energy efficiency, and provide seamless user experiences.

S. UAV-Based Mobile Cloud ComputingSystem

A UAV-based Mobile Cloud Computing system leverages MEC capabilities to support applications involving Unmanned Aerial Vehicles (UAVs). By deploying edge servers on UAVs, real-time data processing and communication tasks can be efficiently handled, enabling diverse UAV applications.

T. OCR-Like Applications

MEC can support OCR-like applications that involve processing and analyzing text or images in real-time. By utilizing edge computing resources, OCR applications can achieve low latency and high performance, making them suitable for various use cases.

VII. OPEN ISSUES

U. Service Micration Algorithm:

Further research is needed to develop efficient service migration algorithms in MEC systems. Service migration plays a crucial role in optimizing resource utilization, load balancing, and ensuring seamless service continuity in dynamic network environments.

V. Security Concerns:

Security is a critical issue in MEC environments, and there is a need to analyze security threats, challenges, and mechanisms inherent in edge computing paradigms. Researchers are exploring fog-based storage technologies and cybersecurity measures to mitigate cyber threats and safeguard data in MEC systems.

W. Resource Allocation Challenges:

Resource allocation in base station-based MEC systems requires joint consideration of computation offloading and resource management [8]-[11]. Developing effective resource allocation [4]-[6] strategies is essential for optimizing system performance, minimizing completion time, and enhancing user experience in MEC environments.

X. Multi-Cloudlet Collabration:

Exploring methods for multi-cloudlet collaboration is an open research issue in MEC. Efficient collaboration among multiple cloudlets [7] and virtual machines is crucial for enhancing resource utilization, improving scalability, and meeting the diverse service requirements of mobile users.

Y. Algorithm Optimization:

Designing and optimizing algorithms for cloudlet placement, resource scheduling, and load balancing are ongoing challenges in MEC research. Developing low-complexity algorithms for cloudlet placement and scheduling is essential for managing the dynamic nature of mobile applications and network conditions.

Z. Simulation Tools:

The development of simulation tools tailored for MEC environments is essential for evaluating system performance, testing algorithms, and validating research findings. Researchers are exploring the use of simulation tools to analyze the impact of different parameters on MEC systems and optimize system design.

VIII. TECHNICAL CHALLENGES AND REQUIREMENTS

Network Integration:

MEC platforms need to seamlessly integrate with existing communication networks, such as 3rd Generation Partnership Project (3GPP) architectures. This integration should not significantly impact the current network specifications and operations

Application Portability:

MEC applications should be portable across different MEC servers deployed by various vendors. This requires standardized mechanisms for packaging, deploying, and managing applications to ensure compatibility and optimization across different platforms

Security:

Security is a critical aspect of MEC systems due to the integration of computing and IT services. MEC platforms must address security challenges by ensuring data privacy, protecting against unauthorized access, and implementing measures to prevent both logical and physical intrusions

Performance:

MEC systems must deliver optimal performance without compromising network throughput, latency, or packet loss. Adequate capacity provisioning is essential to handle user traffic efficiently, especially for applications with low latency requirements or intensive hardware resource usage

Resilience:

MEC platforms should exhibit resilience and high availability to meet the operational demands of network operators. Fault-tolerant capabilities are necessary to prevent disruptions and ensure continuous service delivery

Operation:

The management framework [16]-[18] of MEC systems should support virtualization and cloud technologies, allowing multiple parties to participate in system management. The framework should accommodate diverse deployment scenarios and operational requirements

Regulatory and Legal Considerations:

Compliance with regulatory and legal requirements, such as privacy regulations and charging policies, is essential for the development and deployment of MEC systems. Ensuring data protection and adherence to relevant laws is crucial for maintaining trust and compliance

IX. SECURITY AND PRIVACY

Trust and Autentication Mechanism

Establishing trust and authentication mechanisms is essential in MEC systems to verify the identity of entities interacting within the network. Due to the heterogeneity of edge servers and mobile devices in MEC, conventional trust models designed for Cloud Computing may not be directly applicable. A unified trust and authentication mechanism is needed to assess the reliability of edge servers and prevent trust threats.

Networking Security:

MEC systems rely on communication technologies like WiFi, LTE, and 5G, each with its security protocols. Challenges arise in distributing credentials across different trust domains, making it difficult to ensure privacy and data integrity in communications. Cryptographic attributes can be used to exchange session keys and address these challenges.

PrivacyEnhancement:

MEC offers enhanced privacy and security compared to traditional Cloud Computing [1]-[3] by deploying proximate edge servers that are less susceptible to attacks. Private-owned cloudlets can mitigate concerns about data leakage, especially for sensitive applications requiring secure information exchange between end-users and servers.

Data Encryption:

Encrypting data in transit and at rest is crucial to protect sensitive information from unauthorized access. Strong encryption algorithms and secure key management practices should be implemented to safeguard data confidentiality in MEC environments.

Access Control:

Implementing robust access control mechanisms ensures that only authorized users and devices can access MEC resources. Role-based access control, authentication protocols, and secure APIs help enforce access policies and prevent unauthorized access

Security Monitoring:

Continuous monitoring of MEC systems for security threats, anomalies, and unauthorized activities is essential. Intrusion detection systems, log monitoring, and security audits can help identify and respond to security incidents in a timely manner

Complains and Regulations:

Adhering to data protection regulations, industry standards, and privacy laws is critical for MEC deployments. Compliance with regulations such as GDPR, HIPAA, or industry-specific standards ensures that data handling practices in MEC systems are lawful and ethical

Table 1: Edge computing vs Cloud computing

Edge Computing	Cloud Computing
Edge computing is a distributed computing architecture that brings computing and data storage closer to the source of data, enabling processing at the edge of the network, near the devices generating the data.	Cloud computing involves delivering computing services over the internet, where data analysis and processing are typically done at centralized data centers.
Processing happens closer to the data source or the "edge" of the network, typically on devices like smartphones, IoT devices, or local servers. This reduces the latency and bandwidth usage by processing data locally.	Processing occurs on remote servers (data centers) maintained by cloud service providers. Users access computing resources and store data over the internet
Low latency is a significant advantage as data processing occurs locally, reducing the time taken to transmit data to a centralized location for processing. This is crucial for applications requiring real-time or near-real-time processing.	While cloud services have improved in reducing latency, there's still a delay in transmitting data to and from remote servers, which may not be suitable for latency-sensitive applications.
Limited scalability due to the constraints of edge devices. Each device has its processing capacity, and scaling may require adding more physical hardware.	Highly scalable as cloud providers can allocate resources dynamically based on demand. Users can easily scale up or down resources such as computing power, storage, and bandwidth.
Resources are limited by the capabilities of individual edge devices. Processing power, storage, and memory are constrained compared to the vast resources available in cloud data centers.	Offers virtually unlimited computing resources and storage capacity compared to edge devices. Users can access resources on-demand and pay only for what they use.
Data processing and storage occur locally, which can enhance security and privacy by keeping sensitive data closer to its source and reducing the exposure to potential security threats during data transmission over the network.	Security measures are implemented at the data center level, often with robust encryption, firewalls, and access controls. However, concerns regarding data privacy and compliance may arise, especially when data is stored on remote servers.
Well-suited for applications requiring real-time data processing and analysis at the source, such as industrial IoT, autonomous vehicles, smart cities, and augmented reality (AR)/virtual reality (VR) applications.	Ideal for applications that do not require real-time processing, such as web hosting, big data analytics, software development, and enterprise resource planning (ERP) systems.

X. CONCLUSIONS

The conclusion of the research paper discusses the security challenges encountered in edge paradigms like fog computing, mobile edge computing, and mobile cloud computing.

It identifies common issues and explores various threats targeting these paradigms, along with existing security measures. Furthermore, the conclusion delves into Mobile Edge Computing (MEC) as a solution to address latency issues for delay-sensitive applications accessing cloud resources.

It presents different definitions of MEC, discusses its motivations through real-world examples, and highlights the opportunities it brings for readers and service providers Moreover, the conclusion mentions research challenges in implementing MEC, providing insights for future developments in the field of edge computing. It emphasizes the importance of understanding and mitigating security risks while leveraging the benefits of MEC for enhancing application performance and user experience

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