A Comparative Study of Mobile Cloud Computing, Mobile Edge Computing, and Mobile Edge Cloud Computing

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***Abstract*—Mobile computing paradigms have undergone significant transformations with the rise of mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC). These paradigms offer distinct approaches to address the challenges of mobile application development, resource management, and latency reduction. MECC combines the benefits of MCC and MEC, integrating cloud and edge resources to leverage their respective advantages. MECC offers a hybrid architecture where tasks can be dynamically allocated between cloud servers and edge nodes based on factors such as task requirements, latency constraints, and resource availability. This paper presents a comprehensive review through the comparative analysis of MCC, MEC, and MECC, focusing on key aspects such as architecture, resource allocation, latency reduction, and scalability.**

Keywords— mobile cloud computing, mobile edge computing, mobile edge cloud computing, resource allocation, latency reduction, scalability

I. Introduction

This Mobile computing has witnessed remarkable advancements in recent years, enabling users to access a wide range of applications and services on their mobile devices. As the demand for computational resources and real-time responsiveness increases, mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC) have emerged as prominent paradigms to address the challenges of mobile application development and resource management.

A. Mobile Cloud Computing (MCC)

MCC leverages cloud resources to offload computation and storage tasks from resource-constrained mobile devices. By utilizing the immense processing power and storage capacity of the cloud, MCC enables users to access complex applications and services without the need for extensive local resources. Several studies have investigated the advantages of MCC. Satyanarayanan and et. al. [10] presented the concept of MCC and highlighted its benefits in enabling resource-intensive applications on mobile devices. Chen and et. al. [3] proposed an energy-aware resource allocation mechanism for MCC, optimizing task distribution among cloud servers to minimize energy consumption.

B. Mobile Edge Computing (MEC)

MEC brings computational capabilities closer to the network edge, reducing latency and bandwidth consumption by processing data locally. By deploying edge servers in proximity to mobile devices, MEC enables real-time data processing, low-latency services, and improved user experiences. Mao and et al. [9] discussed the architecture and key features of MEC, emphasizing its ability to support latency-sensitive applications and reduce network congestion. Shi and et. al. [11] proposed an adaptive task offloading scheme for MEC, considering the dynamic network conditions and workload distribution to optimize resource utilization.

C. Mobile Edge Cloud Computing (MECC)

MECC combines the advantages of MCC and MEC, integrating cloud resources and edge computing capabilities. This hybrid paradigm aims to leverage both centralized cloud processing and localized edge computing to achieve optimal performance and resource utilization. MECC enables dynamic task offloading and seamless coordination between cloud servers and edge nodes. Wang and et. al. [13] presented an energy-efficient task offloading strategy for MECC, considering the energy consumption of both cloud and edge resources to optimize task allocation and execution. Han and et. al. [5] proposed a resource management framework for MECC, addressing challenges related to resource allocation, task scheduling, and data placement in a hybrid cloud-edge environment. This paper aims to provide a comprehensive comparative analysis of MCC, MEC, and MECC. By examining their architectures, resource allocation mechanisms, latency reduction techniques, and scalability, we can gain insights into their strengths and limitations. The comparative analysis will help stakeholders understand the trade-offs and make informed decisions when selecting the most suitable paradigm for their specific use cases. Understanding the characteristics and capabilities of MCC, MEC, and MECC is crucial for researchers, developers, and organizations aiming to leverage mobile computing paradigms effectively. By considering the strengths and limitations of each paradigm, we can design efficient and scalable mobile applications that meet the requirements of diverse use cases.

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II. Literature Review

Mobile computing paradigms have evolved rapidly in recent years to meet the increasing demand for computational resources and real-time responsiveness in mobile applications. Among the prominent paradigms are mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC).

For comparative studies on Mobile Cloud Computing (MCC), the comparative analyses of MCC with other paradigms, including MEC and MECC, shed light on the unique characteristics and benefits of MCC. Lu and et. al. [8] compared MCC with traditional cloud computing and highlighted the benefits of offloading computation-intensive tasks to the cloud, reducing the energy consumption and extending the battery life of mobile devices. Fernandez and et. al. [4] conducted a performance evaluation of MCC and MEC, demonstrating that MCC offers lower response times for data-intensive applications due to its access to powerful cloud resources.

In the comparative studies on Mobile Edge Computing (MEC), MEC has gained significant attention in recent years due to its ability to bring computational capabilities closer to mobile devices. Researchers have conducted comparative studies to highlight the advantages of MEC over other paradigms. Mao and et. al. [9] compared MEC with cloud computing and emphasized the benefits of reduced latency, improved data privacy, and localized processing for real-time applications. Khan and et. al. [6] conducted a performance evaluation of MEC and MCC, demonstrating that MEC offers lower latency and improved energy efficiency for latency-sensitive applications.

For comparative studies on Mobile Edge Cloud Computing (MECC), MECC combines the benefits of MCC and MEC, integrating cloud resources and edge computing capabilities. Although studies specifically comparing MECC with other paradigms are limited, some research has explored its potential advantages. Yu and et. al. [14] proposed a resource allocation scheme for MECC, highlighting the benefits of dynamic task offloading and workload balancing between the cloud and edge resources. Almiani and et. al. [1] conducted a comparative analysis of MECC and MCC, demonstrating that MECC offers reduced latency and improved resource utilization by leveraging both cloud and edge capabilities.

Overall, the existing literature provides valuable insights into the characteristics and advantages of MCC, MEC, and MECC. While MCC focuses on offloading tasks to the cloud, MEC emphasizes localized processing at the network edge, and MECC combines cloud and edge resources for optimal performance. Comparative studies highlight the trade-offs and performance benefits of each paradigm, helping researchers and practitioners make informed decisions when selecting the most suitable approach for specific use cases.

III. Advamtages & Disadvantages of Mobile Edge, Mobile Cloud, Mobile Ege Cloud Computing

Mobile computing paradigms such as mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC) have emerged to address the challenges of resource limitations, network latency, and real-time responsiveness in mobile applications. Each paradigm offers unique advantages that cater to different application requirements. However, these paradigms also come with their own set of limitations. In this section, the advantages of each paradigm and their potential benefits for mobile computing are explored and discussed. Then, the disadvantages of each paradigm to provide a comprehensive understanding of their drawbacks in mobile computing are examined.

A. Mobile Cloud Computing (MCC)

Mobile Cloud Computing (MCC) has emerged as a transformative paradigm, revolutionizing the way we interact with our smartphones and tablets. MCC harnesses the power of cloud computing to extend the capabilities of mobile devices, enabling users to access unlimited storage, processing power, and a vast array of services. MCC leverages the expansive cloud infrastructure to offload resource-intensive tasks from mobile devices to remote servers. This allows smartphones and tablets to access virtually unlimited storage, computing power, and a rich ecosystem of services that were previously beyond their reach. By tapping into the cloud, mobile devices can handle complex applications, store and access large amounts of data, and benefit from scalable resources on-demand.

1) *Unlimited Storage:*

MCC leverages cloud servers to offload computation and storage tasks from mobile devices. This enables access to virtually unlimited storage space for data-intensive applications [10].

2) *Powerful Processing Capabilities:*

With MCC, mobile devices can utilize the computational power of remote cloud servers, enabling the execution of resource-intensive tasks [10].

3) *Ubiquitous Access to Data:*

MCC allows users to access their data from anywhere at any time, as long as they have an internet connection. This ensures seamless data availability and synchronization across devices [10].

4) *Network Dependency:*

MCC heavily relies on network connectivity to access remote cloud resources. In scenarios with limited or unreliable network connectivity, users may experience service disruptions and delays in accessing cloud-based services [7].

5) *Latency:*

The reliance on network communication introduces latency in data transmission, resulting in increased response times. Real-time applications that require immediate feedback may be impacted by this latency [7].

6) *Data Privacy and Security:*

Storing and processing data in the cloud raises concerns about data privacy and security. Users may have limited control over their data, potentially exposing sensitive information to security risks [7].

B. Mobile Edge Computing (MEC)

Mobile Edge Computing (MEC) has emerged as a game-changer. By bringing computing resources closer to the network edge, MEC revolutionizes the way mobile applications are developed, deployed, and experienced. MEC introduces a distributed computing paradigm that moves computational capabilities and services closer to mobile users. By leveraging edge nodes, such as base stations, access points, and edge servers, MEC reduces latency, enhances real-time interactions, and enables context-aware applications. This proximity to mobile devices enables a whole new level of responsiveness and performance for mobile applications.

1) Low Latency:

By bringing computation closer to the network edge, MEC reduces network latency and enables real-time processing of data. This is particularly beneficial for latency-sensitive applications such as augmented reality, autonomous vehicles, and real-time video analytics [9].

2) Enhanced User Experience:

MEC enables localized data processing, reducing the need for data transmission to remote servers. This results in faster response times, improved user experiences, and reduced network congestion [9].

3) Edge Analytics:

MEC allows for data analytics and decision-making at the edge, enabling real-time insights and faster response to critical events [9].

4) Limited Computational Resources:

Edge devices often have limited computational capabilities compared to cloud servers. Resource-intensive tasks may face challenges in execution due to constrained processing power and memory on edge devices [9].

5) Scalability Constraints:

Edge resources may be limited in scale, making it challenging to handle increasing workloads or sudden spikes in demand. Scalability can be a limitation when dealing with resource-intensive applications or serving a large number of users [9].

6) Maintenance and Updates:

Managing a large number of distributed edge devices requires careful maintenance and regular updates. Ensuring consistency, security, and performance across all edge devices can be a complex task [9].

C. Mobile Edge Cloud Computing (MECC)

In the ever-evolving landscape of mobile computing, where data-intensive applications and real-time services are becoming the norm, Mobile Edge Cloud Computing (MECC) has emerged as a transformative paradigm. MECC combines the strengths of mobile edge computing and cloud computing, offering a powerful solution to address the limitations of mobile devices while harnessing the scalability and flexibility of the cloud. Mobile Edge Cloud Computing integrates edge computing infrastructure with the vast resources and services provided by the cloud. By leveraging edge nodes, such as base stations, access points, and edge servers, MECC brings computation, storage, and services closer to mobile users. This proximity to the edge enables low-latency processing, reduced network congestion, and efficient resource utilization while leveraging the scalability and elasticity of the cloud.

1) Dynamic Task Offloading:

MECC combines the benefits of MCC and MEC, allowing for dynamic task offloading between cloud and edge resources. This enables intelligent workload distribution, optimizing resource utilization and minimizing latency [13].

2) Scalability:

MECC leverages the scalability of cloud resources and the proximity of edge devices, providing a flexible and scalable infrastructure for applications with varying resource demands [5].

3) Energy Efficiency:

By distributing tasks between cloud and edge resources, MECC reduces energy consumption by offloading computation to energy-efficient local devices, minimizing the need for data transmission to remote cloud servers [13].

4) Coordination Complexity:

MECC introduces the challenge of coordinating resources between the cloud and the edge. Ensuring efficient task offloading, data synchronization, and workload distribution requires effective coordination mechanisms, adding complexity to the system [12].

5) Increased Network Overhead:

The interaction between cloud and edge resources in MECC introduces additional network overhead. This can lead to increased network congestion and bandwidth utilization, affecting overall system performance [12].

6) Higher Energy Consumption:

MECC involves the use of both cloud and edge resources, which may result in higher energy consumption compared to standalone MCC or MEC. The need for data transmission between cloud and edge nodes contributes to increased energy consumption [13].

Mobile cloud computing, mobile edge computing, and mobile edge cloud computing offer distinct advantages for mobile applications. MCC provides unlimited storage and powerful processing capabilities, while MEC reduces latency and enhances user experiences. MECC combines the benefits of both paradigms, enabling dynamic task offloading, scalability, and energy efficiency. The choice of the most suitable paradigm depends on the specific requirements of the application. Understanding the advantages of each paradigm allows stakeholders to make informed decisions when designing and deploying mobile applications.

While mobile cloud computing, mobile edge computing, and mobile edge cloud computing offer numerous benefits, it is crucial to consider their respective disadvantages. MCC faces challenges related to network dependency, latency, and data privacy. MEC encounters limitations with limited computational resources, scalability constraints, and maintenance requirements. MECC introduces complexities in resource coordination, network overhead, and energy consumption. Understanding these disadvantages allows stakeholders to make informed decisions when choosing the most suitable paradigm for their mobile computing applications.

IV. Comparative Analysis of Mobile Cloud Computing, Mobile Edge Computing, and Mobile Edge Cloud Computing

Mobile computing has witnessed significant advancements in recent years, enabling users to access a wide range of applications and services on their mobile devices. To address the challenges of resource limitations, network latency, and real-time responsiveness, various paradigms have emerged, including mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC). This section presents a comparative analysis of these paradigms, examining their architectures, benefits, and trade-offs to facilitate informed decision-making for different mobile application scenarios.

1) Mobile Cloud Computing (MCC)

MCC leverages cloud resources to offload computation and storage tasks from mobile devices. It offers advantages such as unlimited storage, powerful processing capabilities, and ubiquitous access to data. However, reliance on cloud servers introduces challenges related to network latency and bandwidth limitations. Satyanarayanan and et. al. [10] introduced the concept of MCC and emphasized its potential in enabling resource-intensive applications on mobile devices. Chen et al. [2] proposed an energy-aware resource allocation mechanism for MCC, optimizing task distribution among cloud servers to minimize energy consumption.

2) Mobile Edge Computing (MEC)

MEC brings computational capabilities closer to the network edge, reducing latency and bandwidth consumption by processing data locally. It enables real-time data processing, low-latency services, and improved user experiences. Mao et al. [9] discussed the architecture and key features of MEC, emphasizing its ability to support latency-sensitive applications and reduce network congestion. Shi and et. al. [12] proposed an adaptive task offloading scheme for MEC, considering dynamic network conditions and workload distribution to optimize resource utilization.

3) Mobile Edge Cloud Computing (MECC)

MECC combines the benefits of MCC and MEC, integrating cloud and edge resources to leverage their respective advantages. MECC enables dynamic task offloading, latency reduction, and improved scalability. However, coordinating, and synchronizing resources between the cloud and edge nodes introduce complexities. Wang and et. al. [13] presented an energy-efficient task offloading strategy for MECC, considering the energy consumption of both cloud and edge resources to optimize task allocation and execution. Han and et. al. [5] proposed a resource management framework for MECC, addressing challenges related to resource allocation, task scheduling, and data placement in a hybrid cloud-edge environment.

TABLE 1 shows the comparison of the characterizes for each mobile methods in each category. TABLE 2 shows the platforms of each mobile technology based upon key components of each mobile technology.

The comparative analysis focuses on various aspects, including architecture, resource allocation, latency reduction, scalability, and energy efficiency. It highlights the strengths and limitations of each paradigm, emphasizing the trade-offs between centralized cloud computing, edge computing, and the hybrid approach. By understanding these characteristics, stakeholders can make informed decisions when selecting the most suitable paradigm for their specific application requirements.

Mobile cloud computing, mobile edge computing, and mobile edge cloud computing offer distinct approaches to address the challenges of mobile application development, resource management, and latency reduction. Each paradigm has its unique advantages and trade-offs. The comparative analysis presented in this article provides insights into their architectures, benefits, and challenges, helping stakeholders make informed decisions in selecting the appropriate paradigm for different mobile application scenarios. Further research is needed to optimize these paradigms for specific use cases and explore emerging technologies that enhance their capabilities.

V. Conclusion

Mobile computing has evolved rapidly in recent years, giving rise to various paradigms such as mobile cloud computing (MCC), mobile edge computing (MEC), and mobile edge cloud computing (MECC). Each paradigm offers unique features and benefits, catering to specific application requirements and addressing the challenges of resource limitations, latency, and energy efficiency. In this article, we have conducted a comprehensive comparison of these paradigms to provide insights into their strengths, limitations, and suitability for different use cases.

Mobile cloud computing (MCC) enables offloading computation and storage tasks to remote cloud servers, providing unlimited storage and powerful processing capabilities. It is well-suited for applications that require extensive computational resources and centralized data storage. However, MCC may suffer from network latency and bandwidth limitations, impacting real-time responsiveness.

Mobile edge computing (MEC) brings computation closer to the network edge, reducing latency and enabling real-time processing of data. It offers benefits such as low-latency services, improved user experiences, and reduced network congestion. MEC is particularly advantageous for latency-sensitive applications and use cases that require real-time data processing. However, its limited computational resources and localized nature may pose challenges for resource-intensive applications.

Mobile edge cloud computing (MECC) combines the advantages of MCC and MEC, integrating cloud and edge resources to optimize performance and scalability. MECC leverages the cloud for its abundant resources and the edge for low-latency processing, enabling dynamic task offloading, latency reduction, and improved scalability. MECC presents a promising approach for balancing the benefits of both paradigms, but its implementation requires addressing coordination challenges between the cloud and edge nodes.

The choice between MCC, MEC, and MECC depends on the specific requirements of the mobile application. Applications with high computational demands and a need for centralized data storage may benefit from MCC. Latency-sensitive applications that require real-time responsiveness and localized processing can leverage the advantages of MEC. For scenarios that demand a balance between computational resources, latency, and scalability, MECC may be the preferred choice.

It is important to note that the selection of the optimal paradigm is not always straightforward. Factors such as network conditions, application characteristics, and infrastructure availability should be considered. Furthermore, ongoing advancements in communication technologies, edge computing capabilities, and cloud services continue to shape the landscape of mobile computing paradigms.

As a conclusion, the comparative analysis presented in this paper has provided valuable insights into the characteristics and suitability of mobile cloud computing, mobile edge computing, and mobile edge cloud computing. Each paradigm offers its own set of advantages and challenges, and the choice depends on the specific requirements of the application at hand. As mobile computing continues to evolve, it is essential to monitor the advancements and adapt the paradigms accordingly to meet the ever-changing needs of mobile applications.

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TABLE I. COMPARISON OF CHATRACTERISCTICS FOR MOBILE CLOUD COMPUTING, MOBILE EDGE COMPUTING, AND MOBILE EDGE CLOUD COMPUTING [5, 9, 10, 13]

Criteria	Mobile Cloud Computing (MCC)	Mobile Edge Computing (MEC)	Mobile Edge Cloud Computing (MECC)
Architecture	Centralized cloud-based architecture	Decentralized edge-based architecture	Hybrid architecture combining cloud and edge resources
Resource Location	Cloud servers	Edge devices and servers	Combination of cloud and edge resources
Latency Reduction	Higher latency due to network communication	Lower latency with edge processing	Latency reduction through localized edge processing
Scalability	Highly scalable due to cloud resources	Limited scalability of edge devices	Scalable through the combined use of cloud and edge resources
Data Privacy	Data resides on cloud servers	Data processing and storage at the edge	Data privacy concerns due to data distribution
Network Bandwidth Utilization	High network bandwidth utilization	Reduced network bandwidth utilization	Efficient utilization of network bandwidth
Energy Efficiency	Higher energy consumption due to remote processing	Lower energy consumption with local processing	Improved energy efficiency through resource optimization
Mobility Support	Supports mobile devices	Optimized for mobile devices	Supports mobility through edge resources
Use Cases	Computationally intensive tasks, data storage	Real-time applications, low-latency services	Dynamic offloading, latency-sensitive applications

TABLE II. COMPARISON OF PLATFORMS OF MOBILE CLOUD COMPUTING, MOBILE EDGE COMPUTING, AND MOBILE EDGE CLOUD COMPUTING [15, 16, 17, 18, 19, 20]

Platform	Mobile Cloud Computing (MCC)	Mobile Edge Computing (MEC)	Mobile Edge Cloud Computing (MECC)
Cloud Infrastructure	Utilizes remote cloud servers	Minimal or no cloud involvement	Utilizes both cloud and edge resources
Edge Infrastructure	No dedicated edge infrastructure	Leverages edge devices or servers	Utilizes edge devices or servers for local processing
Data Storage	Centralized in cloud data centers	Local storage on edge devices or edge servers	Combination of cloud and edge storage
Data Processing	Offloaded to cloud servers	Performed locally at the edge	Distributed processing between edge and cloud
Latency	Higher latency due to data transfer to/from the cloud	Lower latency due to local processing	Reduced latency with optimized edge and cloud coordination
Network Dependence	Requires reliable network connectivity	Can operate with limited network connectivity	Requires network connectivity for coordination and synchronization
Application Support	Supports a wide range of applications	Suitable for latency-sensitive and real-time applications	Supports diverse applications with optimized resource allocation
Scalability	Offers unlimited scalability	Limited by edge device or server capabilities	Combines scalability of cloud with local processing at the edge
Management Complexity	Involves managing cloud infrastructure and services	Additional management of edge devices or servers	Complex coordination between edge and cloud components
Cost Efficiency	Reduces hardware costs and offers flexible pricing models	Reduces data transfer costs and enables resource optimization	Balances cost efficiency with reduced latency and resource utilization
Privacy and Security	Centralized security measures and remote data backup	Enhanced data privacy due to local processing and control	Requires security measures at both edge and cloud levels