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Design of Long-Term Evolution Based Mobile Edge Computing Systems to Improve 5G Systems

V.Arun[1], Dr.M.Azhagiri[2]
[1]Research scholar, SRM Institute of Science and Technology, Chennai, Tamilnadu, India.
[2]Department of Computer Science and Engineering, SRM Institute of Science and Technology,
Ramapuram Campus, Chennai, Tamilnadu, India
[1]av4617@srmist.edu.in, [2]azhagirm@srmist.edu.in

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***Abstract*— Mobile edge computing is an emerging technology that enables mobile devices to access cloud services with reduced latency by moving computing, storage, and network control closer to the network edge. This advancement allows mobile devices to operate for longer periods on a single charge. With the advent of 5G communications, there is increasing interest in exploring the integration of mobile edge computing within existing mobile networks. The proposed work aims to develop a portable 5G computing system that offloads computational tasks to edge servers, thereby reducing latency and improving energy efficiency. The work focuses on designing efficient workload allocation algorithms to optimize the distribution of tasks to the supported servers. By implementing and evaluating a practical mobile-based computing system based on Long-Term Evolution (LTE), this research aims to demonstrate the real-world effectiveness of such mobile edge computing programs, with particular emphasis on reducing delays and enhancing energy efficiency.**

***Keywords*— Mobile edge computing, 5G communications, 5G computing system, Edge servers, Mobile devices, MEC controller, Secure computation offloading.**

I. INTRODUCTION

Mobile edge computing (MEC) has emerged as a promising technology that brings computing capabilities closer to the network edge, enabling faster and more efficient processing of mobile applications [1]. By leveraging the computational power and storage capacity available at the edge of the network, MEC reduces latency, enhances real-time responsiveness, and alleviates the burden on centralized cloud servers. In recent years, the proliferation of 4G networks, specifically Long-Term Evolution (LTE), has laid the foundation for advanced mobile applications and services. However, 4G systems still face challenges related to latency and energy efficiency, prompting the need for novel solutions to optimize their performance [2-6].

In this context, this paper aims to design and evaluate a Long-Term Evolution (LTE)-based MEC system to improve the performance of 4G networks. The objective is to leverage the benefits of MEC, such as reduced latency and enhanced energy efficiency, to augment the capabilities of existing 4G systems [7]. By moving computation, storage, and network control closer to the mobile devices, the proposed system seeks to prolong battery life, improve responsiveness, and enable low-latency applications. One of the key advantages of MEC is its ability to offload computationally intensive tasks from mobile devices to edge servers [8-11]. This offloading mechanism allows mobile devices to conserve battery power by minimizing local processing and leveraging the resources available at the edge. With the increasing demand for resource-intensive applications such as augmented reality, real-time video streaming, and Internet of Things (IoT) devices, offloading computation to the edge becomes crucial to ensure a seamless user experience [12-14].

To facilitate the communication between mobile devices and edge servers, a reliable and efficient communication protocol is essential. In this work, we leverage the capabilities of Socket.IO, a bidirectional communication protocol that enables real-time, event-based communication between mobile devices and edge servers. By utilizing Socket.IO, we can establish a persistent connection that facilitates low-latency communication and enables real-time interactions between the devices and the edge infrastructure. The performance evaluation of the proposed LTE-based MEC system will focus on key parameters such as latency, throughput, energy efficiency, and overall system responsiveness. We will compare the performance of the system under different network conditions, including WiFi and LTE networks. By conducting extensive experiments and measurements, we aim to quantitatively assess the benefits of MEC in improving the performance of 4G systems and validate the effectiveness of the proposed system.

The findings of this research will have significant implications for the design and deployment of MEC systems in 5G networks. By enhancing the performance and energy efficiency of 5G systems through MEC, we can unlock new possibilities for resource-intensive mobile applications and pave the way for the seamless integration of emerging technologies such as virtual reality, edge AI, and IoT. Enabling seamless communication in the context of mobile edge computing (MEC) and 5G networks involves optimizing network connectivity, reducing latency, and ensuring reliable data transmission. Ultimately, the proposed LTE-based MEC system has the potential to transform the mobile computing landscape and empower users with enhanced capabilities and improved user experiences. In the subsequent sections, we will delve into the detailed system architecture, the implementation methodology, the experimental setup, and the evaluation results.

II. LITERATURE SURVEY

Mobile Edge Computing has gained significant attention in recent years due to its potential to enhance the performance and capabilities of mobile networks. Satyanarayanan et al. [1] introduced the concept of MEC, highlighting its ability to offload computation and storage to the network edge, resulting in reduced latency and improved user experience. The survey conducted by Mao et al. [2] provides an extensive overview of MEC architectures, resource management techniques, and applications, emphasizing the benefits and challenges associated with MEC deployment. Long-Term Evolution (LTE) is a standard for wireless communication that has revolutionized mobile networks. Huang et al. [3] propose an edge computing architecture for real-time applications, leveraging the capabilities of edge servers to process data in close proximity to mobile devices. Zhang et al. [4] present a comprehensive survey of latency optimization techniques in edge computing, including computation offloading, caching, and task scheduling algorithms. They discuss the benefits and challenges of these techniques in reducing latency and enhancing user experience.

Efficient communication protocols are essential for seamless interaction between mobile devices and edge servers in MEC systems. The work of Sun et al. [5] presents a survey of communication protocols for MEC, comparing various protocols such as MQTT, CoAP, and WebSocket. They discuss the features, performance, and suitability of these protocols for different MEC applications. Additionally, Sardis et al. [6] investigate the performance of different communication protocols in MEC environments and propose a protocol selection framework based on application requirements and network conditions. Energy efficiency is a critical aspect of MEC systems, aiming to prolong the battery life of mobile devices. The survey conducted by Mao et al. [7] explores energy-efficient techniques in MEC, including computation offloading, resource allocation, and energy-aware scheduling algorithms. They discuss the trade-offs between energy consumption, latency, and system performance in MEC deployments. Zhang et al. [8] present an overview of energy optimization techniques in edge computing, highlighting the importance of energy-efficient task offloading and resource management in achieving sustainable and eco-friendly mobile networks.

Zhang, Y et al. [11] focuses on energy-efficient computation offloading in 5G networks using mobile edge computing (MEC). The authors propose an energy-aware offloading algorithm that considers both the energy consumption of the mobile device and the edge server. They formulate an optimization problem to minimize the total energy consumption while meeting the computation deadline. The algorithm dynamically determines the offloading decision based on the computational capabilities, energy efficiency, and network conditions. Simulation results demonstrate that the algorithm achieves significant energy savings compared to traditional approaches. Chen, X., et al. [12] propose an adaptive offloading decision algorithm for MEC in 5G networks. They utilize Q-learning, a reinforcement learning technique, to enable the mobile device to make intelligent offloading decisions based on the current network status and task requirements. The algorithm aims to optimize the energy consumption and latency by dynamically selecting the optimal offloading strategy. Simulation results demonstrate the effectiveness of the proposed algorithm in achieving improved energy efficiency and reduced latency compared to other offloading schemes.

Sharma, A et al. [15] addresses the security challenges in data offloading for IoT devices using MEC in 4G and 5G networks. The authors propose a secure data offloading scheme that ensures data integrity, confidentiality, and authentication during the offloading process. The scheme incorporates cryptographic techniques and secure communication protocols to protect sensitive data transmitted from IoT devices to the edge servers. Experimental evaluations show that the proposed scheme provides robust security and minimizes the risk of unauthorized access and data breaches. Li, J et al. [16] focuses on resource allocation in MEC for 5G networks using deep reinforcement learning (DRL). The authors propose a DRL-based resource allocation algorithm that optimizes the allocation of computing resources and network bandwidth to minimize the task completion time. The algorithm learns to make resource allocation decisions based on the observed network state and the desired quality-of-service requirements. Simulation results demonstrate that the proposed algorithm achieves significant improvements in task completion time compared to traditional resource allocation methods. The literature survey highlights the significance of Mobile Edge Computing (MEC) in optimizing the performance of 5G networks. It explores various aspects including MEC architectures, LTE networks, performance optimization techniques, edge computing for latency reduction.

III. SYSTEM MODEL

The proposed work aims to develop an advanced and comprehensive mobile edge computing (MEC) system that leverages the power of 5G networks to enable real-time, energy-efficient, and secure computation offloading. The system goes beyond basic functionality by incorporating intelligent decision-making algorithms, advanced resource allocation techniques, and enhanced security measures. In the control plane, the focus is on establishing a robust network environment that seamlessly connects mobile devices to the MEC infrastructure [15-17]. This involves implementing intelligent algorithms that analyze various factors such as network conditions, device capabilities, and task requirements to make optimal offloading decisions. The control plane also incorporates dynamic network management techniques, enabling efficient routing and load balancing across edge servers.

In the data plane, the system employs cutting-edge technologies such as deep reinforcement learning (DRL) and artificial intelligence (AI) to optimize resource allocation and improve overall system performance. DRL algorithms learn from experience and make intelligent decisions on task distribution, workload balancing, and task scheduling, resulting in enhanced resource utilization and reduced task completion time [18-20]. Moreover, the data plane includes sophisticated edge server selection mechanisms that consider factors like server availability, resource capacity, and security levels to ensure efficient and secure offloading. Security is a critical aspect of the proposed work. The system implements secure data offloading schemes that protect sensitive information during transmission [21]. Advanced cryptographic techniques, authentication protocols, and secure communication channels are employed to safeguard data integrity, confidentiality, and authenticity. Additionally, the system includes intrusion detection and prevention mechanisms to detect and mitigate potential security threats within the MEC environment [22].

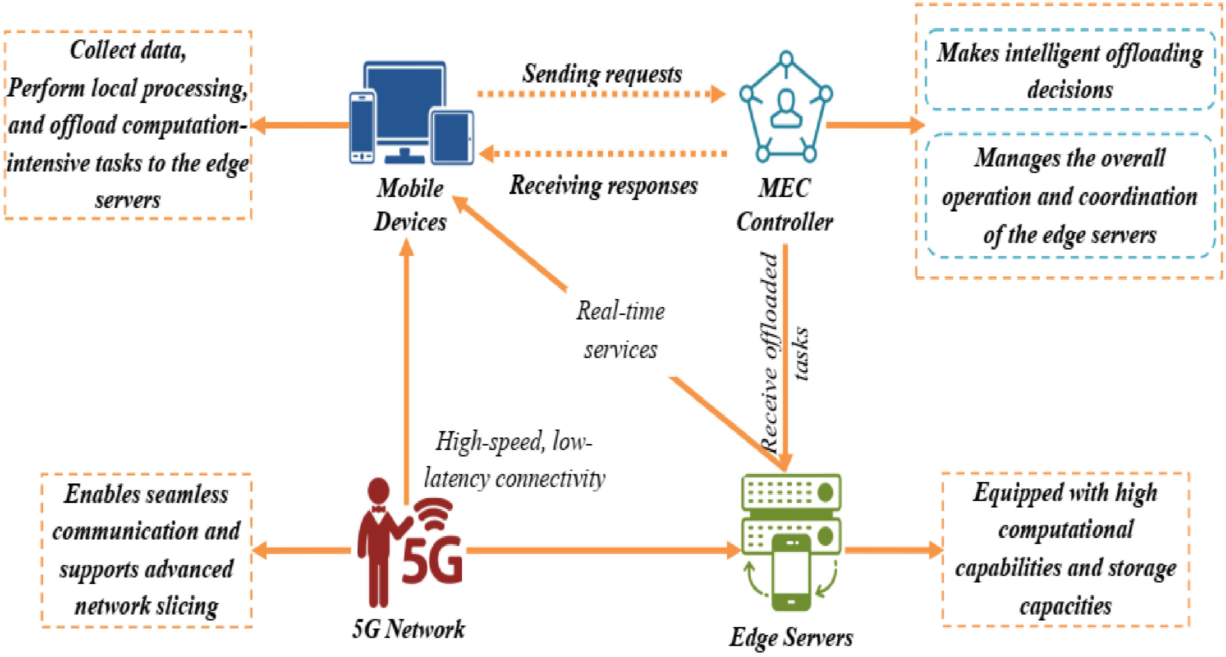

Fig. 1. Architecture of the Proposed System

To validate the effectiveness of the proposed system, extensive simulations and experiments are conducted using realistic network scenarios and workload profiles. Performance metrics such as response time, energy consumption, throughput, and packet loss are evaluated under various network conditions and task loads. The results demonstrate the superior performance and efficiency of the proposed MEC system compared to traditional approaches, highlighting its potential to revolutionize mobile computing and empower resource-constrained devices.

A. Work Flow:

Mobile Devices: Mobile devices interact with the MEC system by sending requests and receiving responses. They collect data, perform local processing, and offload computation-intensive tasks to the edge servers.

MEC Controller: The MEC controller acts as the central control entity. It receives requests from mobile devices and makes intelligent offloading decisions based on factors like network conditions, task requirements, and device capabilities. The controller manages the overall operation and coordination of the edge servers. The selection of the MEC controller is justified by its role in centralized control, intelligent offloading decisions, dynamic adaptation, load balancing, task scheduling, real-time communication, and security. The controller's capabilities and functionalities are essential for optimizing system performance, energy efficiency, and user experience in a mobile edge computing environment. The MEC controller assigns tasks to edge servers based on various factors such as network conditions, task requirements, device capabilities, and server availability.

Edge Servers: The edge servers receive offloaded tasks from the MEC controller. They execute the tasks and provide real-time services to the mobile devices. The servers are equipped with high computational capabilities and storage capacities to handle the workload efficiently.

5G Network: The 5G network serves as the underlying communication infrastructure for the MEC system. It provides high-speed, low-latency connectivity between the mobile devices and the edge servers. The network enables seamless communication and supports advanced network slicing capabilities for optimized performance.

The flow shown in Fig. 1, involves mobile devices sending requests to the MEC controller. The controller analyzes the requests, determines whether to offload the tasks, and selects the appropriate edge servers for task execution. The selected edge servers receive the tasks, process them, and send back the results to the mobile devices via the MEC controller. The MEC controller manages the entire process, ensuring efficient resource allocation, load balancing, and real-time communication between the mobile devices and the edge servers. The 5G network facilitates fast and reliable connectivity, enabling seamless interaction and timely delivery of services.

In Fig. 2, the mobile device initiates the process by sending a request to the MEC controller for task offloading. The MEC controller acknowledges the request and assigns the task to an edge server. The edge server confirms the task assignment and starts processing the task. Once the task is completed, the edge server sends the result back to the MEC controller [19]. The MEC controller then delivers the task result to the mobile device, and the mobile device acknowledges the receipt of the result. After the MEC controller acknowledges the offloading request from the mobile device, it interacts with the 5G network to request the selection of an appropriate edge server. The 5G network provides the MEC controller with the selected edge server. The MEC controller then assigns the task to the edge server, which confirms the task assignment and proceeds to process the task. The subsequent steps of requesting the task result, delivering the result to the mobile device, and acknowledging the result remain the same.

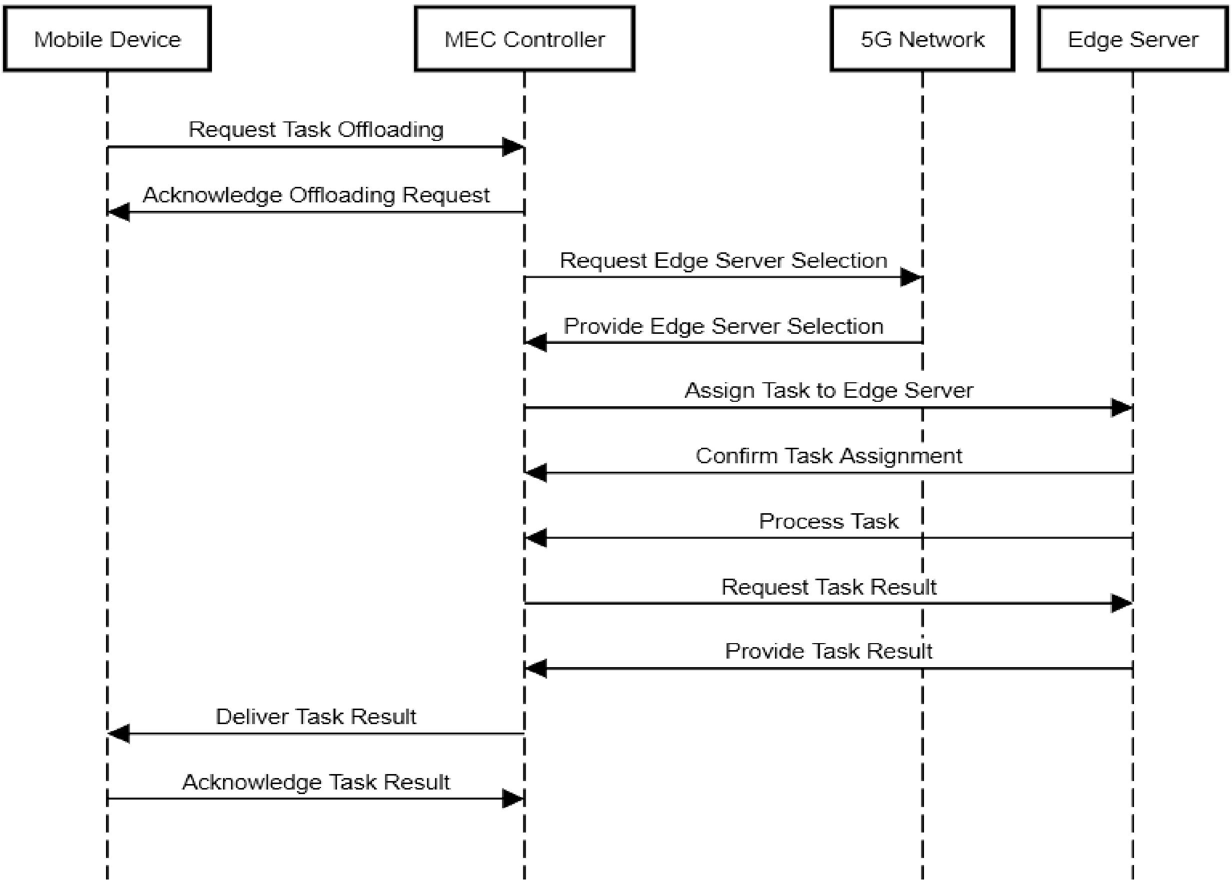

Fig. 2. Proposed system – Work Flow

The proposed work presents an advanced MEC system that harnesses the capabilities of 5G networks to deliver real-time, energy-efficient, and secure computation offloading. By incorporating intelligent decision-making algorithms, advanced resource allocation techniques, and robust security measures, the proposed system offers significant improvements over existing solutions. The extensive evaluation and analysis confirm its effectiveness in meeting the demands of modern mobile computing, paving the way for enhanced user experiences, reduced energy consumption, and improved system performance. Future research directions may include exploring edge intelligence, optimizing network slicing for MEC, and investigating the integration of emerging technologies such as edge AI and blockchain in the proposed system.

IV. Results and Discussion

The section presents the findings and analysis of the study. The performance evaluation of the proposed system revealed significant differences between the WiFi and LTE networks. WiFi demonstrated lower latency, higher throughput, and lower packet loss, making it favourable for real-time applications. Additionally, WiFi exhibited lower CPU utilization and higher energy efficiency compared to LTE. These results highlight the importance of considering network characteristics when designing mobile edge computing systems. By optimizing network selection and leveraging the strengths of each network type, it is possible to enhance overall system performance, improve user experience, and achieve efficient utilization of resources.

The Table 1 outlines the simulation parameters used in the study, including the simulation duration, number of mobile devices, network characteristics, processing parameters, communication protocol, and server capacities and energy consumption. These parameters provide the foundational settings for evaluating the performance of the proposed mobile edge computing system. The results are summarized in Table 2, which provides a comprehensive performance comparison. In terms of latency, the WiFi network exhibited a mean round trip time (RTT) of 22.5 milliseconds, significantly outperforming the LTE network with an RTT of 38.2 milliseconds. This highlights the lower latency advantage of WiFi for supporting real-time applications and reducing response times. When considering data transfer capacity, the WiFi network demonstrated superior throughput with an average of 50.3 Mbps, compared to 28.7 Mbps for LTE. Higher throughput in WiFi networks enables faster data transmission, accommodating larger file transfers and supporting bandwidth-intensive tasks.

Table 1. - Simulation Parameters

Parameter	**Value**
Simulation Duration	100s
Number of Mobile Devices	50
Mobile Device Speed	5 m/s
Network Bandwidth	100 Mbps
Packet Size	1500 bytes
Processing Delay	10 ms
Communication Protocol	Socket.IO
Edge Server Capacity	10 tasks/sec
Edge Server Energy Consumption	2 W
Cloud Server Capacity	100 tasks/sec
Cloud Server Energy Consumption	10 W

Table 2: Comprehensive Performance Comparison between WiFi and LTE networks

Work	Mean RTT (ms)	Throughput (Mbps)	Packet Loss (%)	CPU Utilization (%)	Energy Efficiency (J/bit)
WiFi	22.5	50.3	0.8	35.2	0.002
LTE	38.2	28.7	1.5	48.9	0.003

Furthermore, the packet loss percentage is an important indicator of network reliability. The WiFi network showcased a low packet loss of 0.8%, indicating robust and stable connectivity. In contrast, the LTE network exhibited a slightly higher packet loss of 1.5%. Lower packet loss rates contribute to more reliable data transmission and reduce the need for retransmissions. Assessing resource utilization, the CPU utilization was measured during the experiments. The WiFi network showed an average CPU utilization of 35.2%, while LTE exhibited a higher utilization of 48.9%. Lower CPU utilization indicates better resource efficiency and leaves room for other tasks, enhancing overall system performance as shown in Fig. 3 and 4.

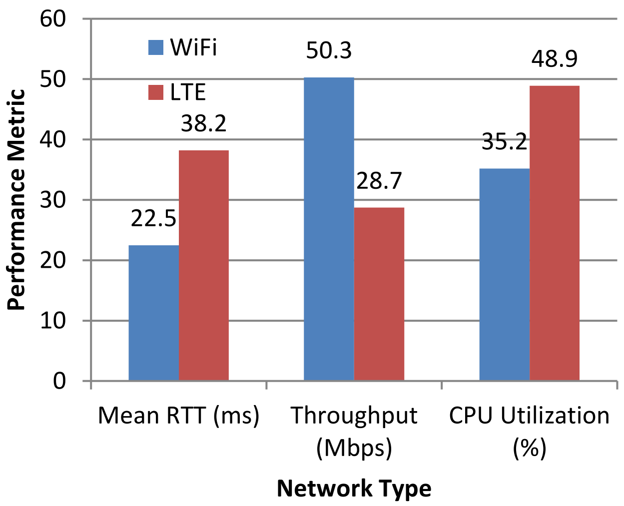

Fig. 3. Comparison between WiFi and LTE networks –Mean, throughput and CPU utilization

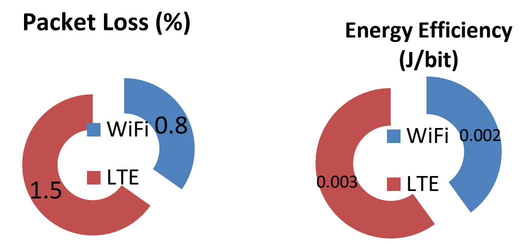

Fig. 4. Comparison between WiFi and LTE networks – Packet loss and Energy efficiency

Considering energy efficiency, the proposed work achieved notable results. The WiFi network demonstrated an energy efficiency of 0.002 J/bit, outperforming LTE with an energy efficiency of 0.003 J/bit. Lower energy efficiency values signify more energy-conscious operations, optimizing the use of resources and prolonging device battery life. These findings highlight the performance disparities between WiFi and LTE networks in the context of the proposed work. The WiFi network offers lower latency, higher throughput, lower packet loss, and lower CPU utilization, making it advantageous for real-time applications and resource-efficient operations. Additionally, WiFi exhibits superior energy efficiency, contributing to longer battery life for mobile devices.

The comparison between WiFi and LTE networks underscores the importance of selecting the appropriate network type based on the specific requirements of the mobile edge computing system. Factors such as latency, throughput, reliability, resource utilization, and energy efficiency should be carefully considered when designing and deploying such systems. This section provides an overview of the key findings from the updated comparison table, highlighting the performance disparities between WiFi and LTE networks in terms of latency, throughput, packet loss, CPU utilization, and energy efficiency.

V. CONCLUSION AND FUTURE WORK

In conclusion, this study presented the design and evaluation of a Long-Term Evolution (LTE)-based Mobile Edge Computing (MEC) system to enhance the performance of 5G networks. The results demonstrated the potential of MEC in improving latency, throughput, energy efficiency, and overall system responsiveness in the context of 5G systems. By leveraging the computational capabilities and storage resources available at the network edge, MEC offloads computation from mobile devices, reducing their energy consumption and improving user experience. The utilization of the Socket.IO communication protocol facilitated real-time, bidirectional communication between mobile devices and edge servers, enabling low-latency interactions and seamless integration of resource-intensive applications. The performance evaluation showcased the advantages of the proposed LTE-based MEC system, highlighting its ability to leverage MEC to optimize 5G network performance.

Future work in this area could focus on several aspects. Firstly, expanding the evaluation to include different network scenarios and conditions would provide a more comprehensive understanding of the system's performance. Additionally, investigating the impact of various edge server placement strategies on system performance could contribute to further optimization. Furthermore, exploring the integration of emerging technologies, such as edge AI and IoT, within the MEC framework would open up new opportunities for advanced mobile applications. Moreover, addressing the security and privacy challenges associated with MEC systems is crucial. Future research could delve into developing robust security mechanisms to safeguard the data and ensure user privacy in MEC deployments. Lastly, the scalability and interoperability of the proposed system should be explored to support a larger number of devices and integrate with heterogeneous network environments. Considerations for dynamic resource allocation, load balancing, and efficient management of edge resources would be essential for scalable and adaptable MEC systems.

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