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Comprehensive Survey and Research on Mobile Edge Computing

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ABSTRACT: There has been a massive shift in mobile technology usage over the past few years due to new concepts such as the Internet of Things and 5G communications. Rather than depending on distant large cloud servers, Mobile Edge Computing shifts the computing closer to us, directly at the edge of the network like access points and base stations.

This change enables quicker, more efficient processing on our devices while conserving energy. Scientists and businesses are working diligently to bring into reality through innovative integration of wireless communication and mobile computing. Through efficient resource management, Mobile Edge Computing can provide quicker speeds, improved battery life, and exciting new opportunities.

Looking to the future, developments in fields such as system deployment, cache optimization, and privacy protection will take Mobile Edge Computing from the lab and into our daily lives. Times are exciting as standardization processes and real-world applications of Mobile Edge Computing begin to materialize.

KEYWORDS: Mobile edge computing, fog computing, mobile cloud computing, computation offloading, resource management.

I. INTRODUCTION

Mobile Edge Computing makes us think differently about data interaction by making computational power more accessible to users and devices. The paper introduction explores the changing edge computing environment with specific emphasis on Mobile Edge Computing as a revolutionary technology in the mobile access network. It specifies the basic principle of Mobile Edge Computing, which is to offload computationally intensive tasks from Mobile Users to Edge Servers that are near at hand, thus improving Quality of Service and Quality of Experience for users. Further, the introduction mentions technical challenges encountered during Mobile Edge Computing implementation, including decision-making processes, resource allocation, mobility management, and service migration.

It stresses the need to overcome these challenges for effective offloading of tasks and best utilization of resources in the Mobile edge computing setup. The introduction also mentions some major technical parameters in ES-based service delivery, such as expenditure control, load balancing, ES deployment, and resource allocation policies. It emphasizes the importance of effective resource allocation in base station-based and cloudlet-based Mobile Edge Computing systems to achieve optimal resource utilization, reduce power consumption, and improve user experience. In addition, the introduction briefly mentions the uses of Mobile Edge Computing, including Mobile Edge Internet of Things architecture for effective IoT data processing and video streaming in smart cities with the use of Mobile Edge Computing for improved video delivery and congestion reduction.

Overall, the introduction provides the context for examining the complexities of Mobile Edge Computing, its technical issues, uses, and potential to transform mobile network computing by making cloud resources more locally available and improving system efficiency.

II. OVERVIEW OF MOBILE EDGE COMPUTING

A. Definition

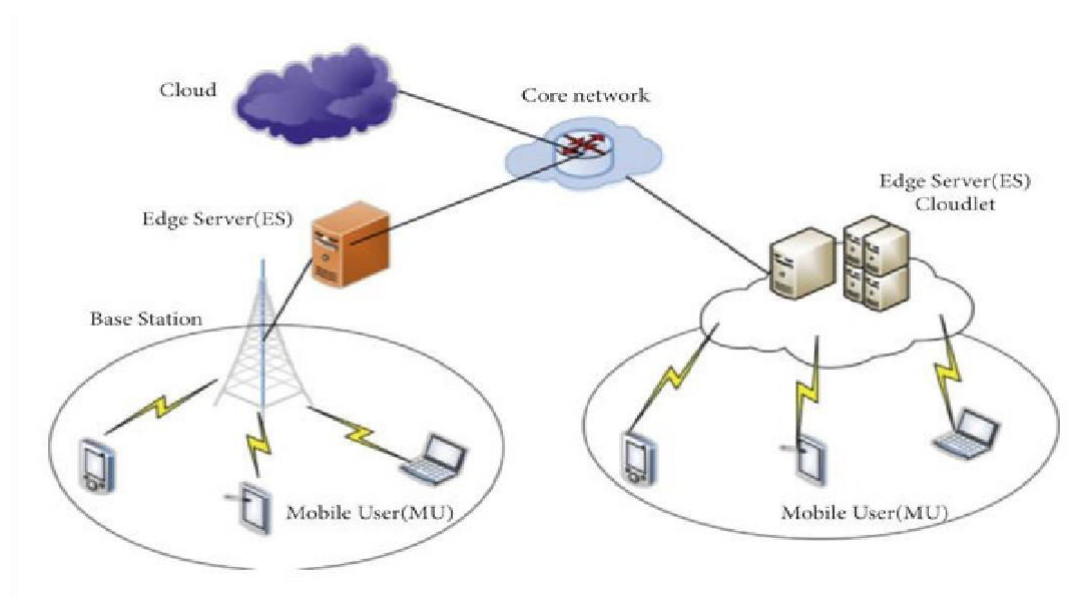
Mobile Edge Computing is defined as a novel network paradigm that provides information technology services and cloud computing services in the mobile access network of Mobile Users. It is situated as a technology that has the capability to offload intensive computing tasks to local Edge Servers, thus mitigating latency and enhancing Quality of Service and Quality of Experience.

B. Service of Mobile Edge Computing

Mobile Edge Computing offers a variety of services and capabilities in the mobile access network, which allows to offload computation and data work to at the edge of the network. With the use of Mobile Edge Computing, Mobile Users can access cloud resources near their own location, eliminating the requirement of transmitting data to remote cloud servers and lowering network delays.

C. Architecture

Mobile Edge Computing is generally positioned in the Radio Access Network and is in close proximity to MUs. The proximity enables Mobile Edge Computing to deliver greater bandwidth with less latency, improving the overall user experience. The European Telecommunications Standards Institute has contributed to standardizing Mobile Edge Computing, highlighting its capability to develop a new ecosystem and value chain for computing tasks.



III. SIMILAR TERMS

D. Mobile Cloud Computing:

Mobile Cloud Computing is a term used to describe an idea where computing tasks are offloaded by mobile devices to cloud facilities. It is the incorporation of cloud resources with mobile networks to expand computing power for mobile users.

E. Fog Computing:

Fog computing is another type of computing paradigm that takes cloud computing to the network edge. It is concerned with spreading computing tasks near the source of the data in order to lower latency and enhance efficiency.

F. Cloudlets

Cloudlets are small-scale cloud data centers on the network edge. They act as go-betweens between mobile devices and the cloud, allowing mobile applications to process data quicker and with lower latency.

IV. MOBILE USERS ORIENTED SERVICE ADOPTION**G. Offloading**

Among the distinguishing features of service adoption at the Mobile Users scale is offloading, with which Mobile Users redirect computation and data tasks to Expert systems residing near the network edges. Computation offloading endeavors to enhance the performance of apps, eliminate delay, and rationalize utilization of resources

Offloading is studied in terms of computation offloading and data offloading. Computation offloading refers to transferring the computational processes from Mobile users to Expert Systems for effective processing. Computation offloading serves to improve the performance of mobile applications and fulfill latency requirements.

Single Mobile Users Offloading Scheme and Multi-Mobile Users Offloading Scheme

The offloading schemes are also classified into single Mobile Users offloading and multi-Mobile Users offloading schemes. These schemes decide how a single Mobile User or multiple Mobile Users offload their tasks to Expert Systems for processing, taking into account application requirements and network conditions

J. Service Adoption Challenges

Mobile Users-oriented service adoption is confronted with issues linked to decision-making, resource provisioning, and mobility management. These must be overcome to guarantee successful offloading of tasks and efficient use of resources within the Mobile Edge Computing environment.

V. EDGE SERVER- ORIENTED SERVICE PROVISION**K. Technical Indicators-**

Expert System-oriented service provision calls for consideration of some technical indicators in an effort to maximize the performance and efficiency of the Mobile Edge Computing system. These indicators encompass factors like expenditure, load balancing, cloudlet placement, resource scheduling, Expert System placement, and Virtual Machine migration.

L. Expenditure

Optimizing the resources and cost of Elastic Search is essential in Elastic Search-based service provisioning. Incentive-compatible auction mechanisms, stochastic control algorithms, and profit-maximizing policies are suggested for maximizing resource allocation and pricing among Mobile Users and Elastic searches.

M. Load Balancing

Load balancing methods are used to improve the allocation of computation tasks among Elastic Searches for the purpose of improving mobile application performance. Load balancing and maximizing mobile application performance are primary goals in Elastic Search-oriented service provision.

N. Elastic Search Placement

To identify the best possible placement of Elastic Search in various cases, including WLAN and WMAN, efficient service delivery requires. Cloudlet placement strategies, server deployment mechanisms, and power-sensitive Elastic Search selection aid in enhanced network performance as well as end-user experience.

O. Resource Allocation

Optimal resource allocation in cloudlet-based Mobile Edge Computing systems and base station-based Mobile Edge Computing systems is essential to maximize the resource utilization and reduce power consumption. Resource allocation algorithms work to maximize computation offloading profit, minimize completion time, and optimize the energy consumed.

VI. APPLICATIONS ON MOBILE EDGE COMPUTING**P. Mobile Edge Internet of Things**

Ansari et al. have suggested a Mobile Edge Internet of Things architecture that makes computing and storage resources more proximate to IoT devices. This architecture supports efficient processing of IoT data near the network edge, minimizing latency and enhancing IoT application performance.

Q. Video Streaming in Smart Cities

Mobile Edge Computing can be used for video streaming services in smart cities, where edge servers handle and provide video content to users in real-time. Through the deployment of services at the network edge, Mobile Edge Computing minimizes congestion and provides timely delivery of video streams to users.

R. Wearable Devices and Cloud Integration

Mobile Edge Computing enables the integration of wearables with cloud services in real-world scenarios. By transferring computation tasks to edge servers, wearables can extend their functionality, save energy, and support smooth user experiences.

S. Flyme Based Mobile Cloud Computing System

A Mobile Cloud Computing system using Unmanned Aerial Vehicles exploits Mobile Edge Computing features to facilitate applications with Unmanned Aerial Vehicles. With edge servers deployed on Unmanned Aerial Vehicles, processing and communication of real-time data can be processed efficiently, and various Unmanned Aerial Vehicles applications can be facilitated.

T. OCR-Like Applications

Mobile Edge Computing can facilitate Optical Character Recognition-like use cases that include text or image processing and analysis in real-time. Through the utilization of edge computing capabilities, Optical Character Recognition use cases can provide low-latency and high-performance, and thus are apt for many use cases.

VII. OPEN ISSUES**U. Service Migration Algorithm**

More research is required to create effective service migration algorithms in Mobile Edge Computing systems. Service migration is important to maximize resource usage, load balancing, and guarantee transparent service continuity in dynamic networks.

V. Security Concerns

Security is a very important concern in Mobile Edge Computing scenarios, and it is necessary to examine security threats, challenges, and mechanisms intrinsic in edge computing paradigms. Researchers are investigating fog-based storage technologies and cybersecurity solutions to counter cyber attacks and protect data in MEC systems.

W. Resource Allocation Challenges

Resource allocation in base station-based Mobile Edge Computing systems must be jointly considered for computation offloading and resource management. Effective resource allocation strategies must be developed to optimize system performance, reduce completion time, and improve user experience in Mobile Edge Computing environments.

X. Multi-Cloudlet Collaboration

Research into multi-cloudlet collaboration techniques is an open research problem in Mobile Edge Computing. Effective collaboration between multiple cloudlets and virtual machines plays a key role in improving resource utilization, increasing scalability, and satisfying the heterogeneity of mobile users' service demands.

Y. Algorithm Optimization

Algorithm design and optimization for cloudlet placement, resource scheduling, and load balancing are continuous challenges in Mobile Edge Computing research. Low-complexity algorithm design for cloudlet placement and scheduling is crucial to handle the dynamic nature of mobile applications and network conditions.

Z. Simulation Tools

Simulation tools designed specifically for Mobile Edge Computing environments are necessary to measure system performance, test algorithms, and validate research. Simulators are being studied by researchers to determine the effects of various parameters on MEC systems and optimize system design.

VIII. TECHNICAL CHALLENGES AND REQUIREMENTS**Network Integration**

Mobile Edge Computing platforms must be able to integrate effortlessly with the current communication networks, including III Generation Partnership Project architectures. The integration should not drastically affect the existing network specifications and operations.

Application Portability

Mobile Edge Computing applications must be portable from one Mobile Edge Computing server to another deployed by different vendors. The process calls for standardized application packaging, deploying, and managing mechanisms to guarantee compatibility and optimization from one platform to another.

Security

Security is an important feature of Mobile Edge Computing systems because of the combination of computing and Information Technology services. Mobile Edge Computing platforms need to confront security issues by providing privacy for the data, preventing unauthorized access, and maintaining countermeasures for logical and physical attacks

Performance

Mobile Edge Computing systems need to provide peak performance without sacrificing network throughput, latency, or packet loss. Proper capacity provisioning is necessary to manage user traffic effectively, particularly for applications with low latency requirements or heavy hardware resource utilization.

Resilience

Mobile Edge Computing platforms need to be resilient and highly available to support the operational needs of network operators. Fault-tolerant features are required to avoid disruptions and maintain continuous service delivery.

Operation

The Mobile Edge Computing system management framework must facilitate virtualization and cloud technologies so that various entities can engage in system management. The framework must be able to handle different deployment scenarios and operational needs

Regulatory and Legal Considerations

Regulatory and legal compliance, including privacy regulations and charging policies, is necessary for the deployment and development of Mobile Edge Computing systems. Data protection and compliance with applicable laws are necessary to ensure trust and compliance

IX. SECURITY AND PRIVACY

Trust and authentication mechanisms need to be set up in Mobile Edge Computing systems to validate the identity of the entities communicating across the network. As a result of the heterogeneity of mobile devices and edge servers in Mobile Edge Computing, traditional trust models developed for Cloud Computing cannot be easily applied. There should be a single trust and authentication mechanism to measure the trustworthiness of edge servers and avoid trust attacks.

Networking Security

Mobile Edge Computing systems are based on communication technologies such as WiFi, LTE, and 5G, each with its own security mechanisms. It is challenging to distribute credentials across various trust domains, and it becomes hard to provide privacy and data integrity in communications. Cryptographic properties can be utilized to share session keys and overcome these challenges.

Privacy Enhancement

Mobile Edge Computing provides greater privacy and security than the conventional Cloud Computing by using proximate edge servers that are more immune to attacks. Cloudlets owned privately can counter data leakage issues, particularly for sensitive applications needing secure data exchange between end-users and servers.

Data Encryption

Encrypting data in transit and at rest is important to secure sensitive data against unauthorized access. Robust encryption algorithms and good key management practices must be used to maintain data confidentiality in Mobile Edge Computing environments.

Access Control

Enabling robust access control ensures that authorized users and devices alone can access Mobile Edge Computing resources. Role-based access control, authentication protocols, and secure Application Programming Interfaces enable enforcements of access policies and avoid unauthorized access

Security Monitoring

Regular monitoring of Mobile Edge Computing systems for security vulnerabilities, anomalies, and unauthorized activities is crucial. Intrusion detection systems, log monitoring, and security audits can assist in detecting and responding to security incidents in a timely manner

Complains and Regulations

Compliance with data protection legislation, industry best practices, and privacy regulations is essential for Mobile Edge Computing deployments. Adherence to regulations like GDPR, HIPAA, or industry-specific standards makes data handling processes in Mobile Edge Computing systems legal and ethical

Table 1: Edge computing vs Cloud computing

Edge Computing	Cloud Computing
Edge computing is a distributed computing approach with computational resources and data storage, available close to the source of data, so that processing takes place at the edge of a network and near data-generating devices.	Cloud computing consists of providing computing services over the internet, specifically where data analysis, and data processing take place at centralized data centers.
Processing takes place near the "edge" or data source, usually in the form of common devices such as a smartphone, IoT devices, or localized servers. Processing data where it is generated, often referred to as "local" processing offers the benefit of improving latency and limiting bandwidth usage.	Processing takes place on remote servers maintained by cloud service providers. Users access computing resources and store their data via the internet.
Low latency is significant as it enables data to be processed locally. This equates to the ability to process data more rapidly, therefore eliminating the lag time passing the data to a centralized processing location. Real-time or near-real-time processing applications are significant.	While cloud services have made considerable strides in improving latency, and most offer good speeds, there is still time involved for transmitting the data to and from data centers, which may not be suitable for applications which are latency sensitive.

Limited scalability due to the constraints of edge devices. Each device has its processing capacity, and scaling may require adding more physical hardware.	Cloud computing offers customers an extremely scalable service, as cloud service providers can allocate resources dynamically, based on demand. Customers can complain as much or as little computational computing resources as they require such as computing power, storage, bandwidth, etc.
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.	Cloud computing provide virtually unlimited computing resources and storage capacity; to far exceed the limit placed upon edge devices. As mentioned, customers can access computing resources on demand as needed, and only pay for the resources used.
In addition, data processing and storage occurs locally thus supporting security and privacy initiatives. Security and privacy are facilitated by processing and storing sensitive information relative to its location while controlling the level of exposure to security vulnerabilities when sensitive data is passed across the network.	Security is applied at the data center level, and in most cases security is substantial meaning there is a combination of encryption, firewalls, and access controls. But regardless of access, due to data privacy/compliance which may arise while data is retained 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 addresses the security issues faced in edge paradigms such as fog computing, mobile edge computing, and mobile cloud computing.

It defines core problems and discusses some of the threats being aimed at these paradigms, including available defense mechanisms. In addition, the conclusion enters into Mobile Edge Computing as a means of solving latency problems for applications with delays accessing resources in the cloud.

It introduces various definitions of Mobile Edge Computing, its motivations based on real-world scenarios, and the opportunities it offers to readers and service providers. Additionally, the conclusion states research challenges in deploying Mobile Edge Computing, offering insights for future advancements in the area of edge computing. It stresses the need to understand and counter security threats while harnessing the advantages of Mobile Edge Computing for improving application performance and user experience.

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