An Analysis of Handover Techniques, Management, and Challenges in Edge Computing at Multiple Access Points

Saket Nandan: PG Scholar, School of CS and IT, Jain (Deemed to be University), Bangalore
Prakash Sirvi: PG Scholar, School of CS and IT, Jain (Deemed to be University), Bangalore
Ranganath R.: PG Scholar, School of CS and IT, Jain (Deemed to be University), Bangalore
Dr. Gobi Natesan: Assistant Professor -School of CS and IT, Jain (Deemed to be University), Bangalore

ABSTRACT

Edge Computing at Multiple Access Points compute (MEC) is implemented and operated at the network edge to provide end user devices with low latency compute and storage services. A handoff technique that ensures the uninterrupted migration of device and application state data between MEC nodes is a fundamental technology, while device mobility support remains a fundamental requirement for MEC. To ensure a smooth transition between MEC nodes, the handover strategy combines a handover technique with a MEC node selection technique. Algorithms, queueing, and other factors have been the subject of research on MEC handover techniques. The complicated process of migrating the MEC device and application context requires the allocation of resources at the target Edge computing node. This may include deploying application instances and in certain cases, enabling the receiving of virtual machines (VMs) or containers from the source MEC node. In addition to reviewing MEC handover strategies, this paper describes the MEC architectural framework and suggests handoff methods and algorithms derived from existing literature. To offer direction for further research, MEC handover difficulties and knowledge gaps are examined.

INDEX TERMS

Application mobility, edge networking, cloud technology, state transfer, Edge Computing at Multiple Access Points, seamless transition, and handoff mechanisms.

I. INTRODUCTION

Multi-Access Edge Computing (MEC), once referred to as mobile edge computing, is a concept defined by the European Telecommunications Standards Institute (ETSI). In order to reflect non-cellular operators' increasing interest in offering applications and services located at the network's edge, ETSI redefined it. In addition to the capabilities of the mobile edge cloud, MEC delivers minimal delay in processing and storage capabilities for consumers and connected IoT systems. Providing cloud computing services to end users at the access layer of the radio network (RAN) is a fundamental aspect of MEC deployments [1], [2], [3], [4]. MEC represents a sophisticated methodology that extends cloud computing capabilities to the network's edge point. MEC enables devices to use the RAN or other wireless or satellite networks to deploy and allocate services and applications that act as a cloud enhancement infrastructure or server hubs as they move across the network. MEC integrates 5G-mobile networks with distributed computing to greatly enhance service and app efficiency, allowing operators to add edge computing capabilities directly to Base Stations (BS). MEC seeks to enhance network's performance, particularly through the transit and central networks, while improving user experience and optimizing resource utilization [5], [6]. The figure 1., highlights the rising market demand for MEC solutions to support a variety of sectors, including smart homes, healthcare, education, and numerous other applications.

The MEC framework allows dynamic allocation of resources, such as processing, data storage, and communication to efficiently support a wide range of services and applications.

By leveraging edge intelligence, MEC reduces the dependency on centralized cloud data centers, enabling faster response times. This not only benefits latency-sensitive applications but also enhances overall network resilience. Additionally, MEC contributes to energy efficiency by reducing the need for long-haul data transmissions. With ongoing advancements in edge AI and federated learning, MEC continues to evolve, paving the way for smarter and more adaptive network infrastructures.

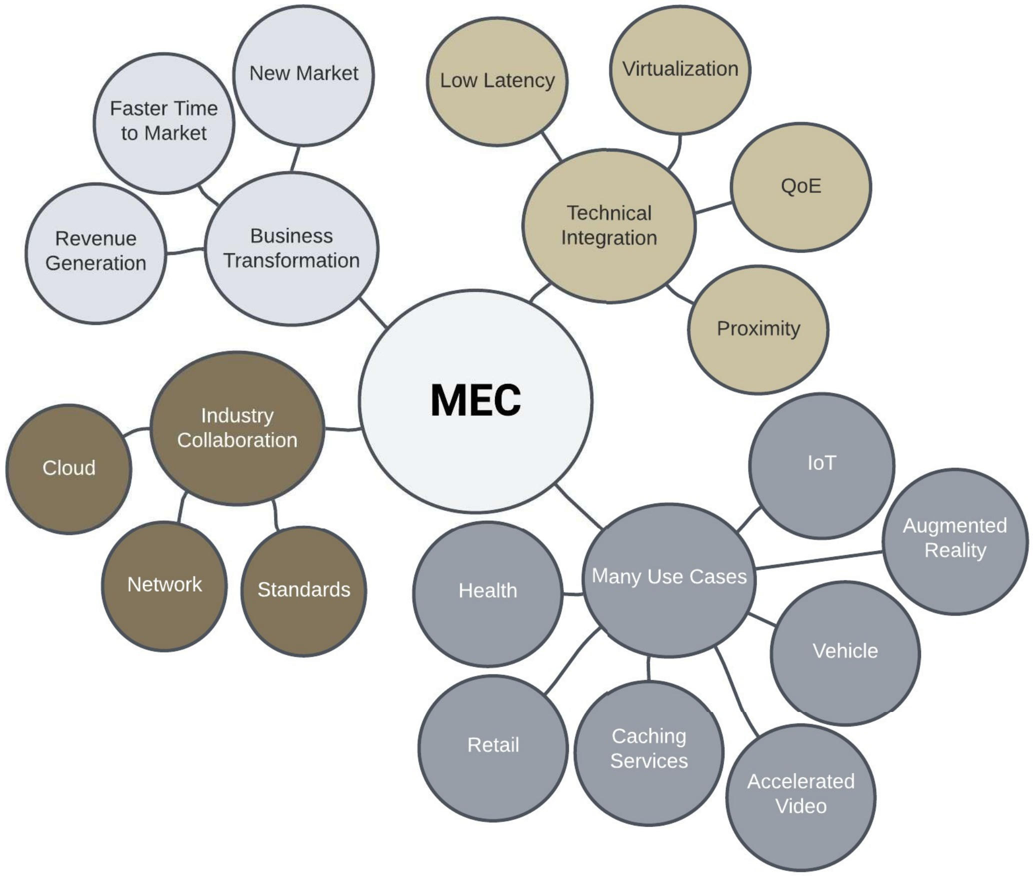

FIGURE 1: Various applications and use cases of MEC.[7]

Interaction with cloud services, apps, and facilities is supported by the functionality offered. Frequently used services and applications in Multi-Access Edge Computing encompass network oversight, content delivery at the edge, workload delegation, ecological observation, defense reconnaissance, distance education, mobile gaming experiences, self-driving vehicles, on-the-go medical services, video analysis at the edge, along with numerous others [1], [8]. Content distribution at the network's edge is a key application that enables cloud services to be deployed on MEC nodes, alleviating congestion across both transit and central network. Motivators for MEC include lowering network costs and traffic latency, optimizing network performance, and enabling online content caching at the edge of network to enhance user experience. Augmentation, or providing Application Service Provider (ASPs) with information that allows them to modify their service plans in real-time, is another use case for MEC. Underlying technology with particular approaches to control resource usage and enhance networking make up MEC services and applications. By shifting devices to nearby MEC node and transferring services and applications, MEC facilitates mobility and low latency while maintaining session continuity [9]. This procedure is known as a handover.

It involves managing sessions of individuals, information, or software applications at one base station and smoothly transitioning them to another in wireless communication. In the context of MEC, handover facilitates the transfer of a connected device to a target MEC node while also transferring device's access state information for services and apps [10]. The goal of handover is to guarantee that devices can move within a network without experiencing session interruptions and that MEC nodes can offer them services and applications. The handover procedure in MEC bears a striking resemblance to that of other wireless access technologies, such as mobile cellular networks, where end user radio links continue to function while switching between radio terminals [11]. When an alternative is available and the Received Signal Strength (RSS) has deteriorated, since it is close to the cell border, the handover process begins. In mobile cellular networks, there are two types of handovers: a Hard Handover (HHO) and a Soft Handover (SHO) [12]. There are benefits and drawbacks to each sort of handover. For example, the choice to initiate a handover is dependent on network & radio's strength measurement factors, like the physical gap between the base station and the mobile device, the distance from the base station to the Received-Signal-Strength (RSS), and

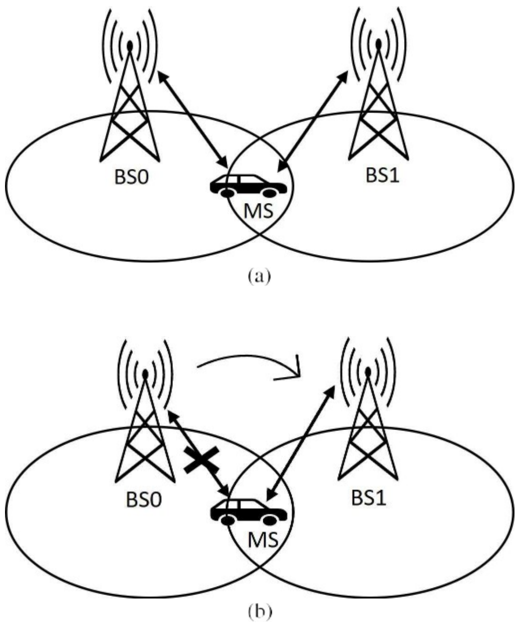

FIGURE 2: Types of mobile system handovers: (i) Soft Handoff (SHO) and (ii) Hard Handoff (HHO).

bit error rate (BER). When two BSs are linked to a single mobile device at the same time, the SHO is best started. Unlike SHO, HHO is started when the mobile device is forced to look for a new connection when the link between the base station and the mobile-device disconnects. Unlike Soft Handover (SHO), Hard Handover (HHO) can lead to higher packet loss and a deterioration in Quality-of-Service (QoS). Fig. 2 shows the two sorts of handovers. Hard Handoff (HHO) occurs once the Mobile Station (MS) severs its connection with the previous base station (BS), as shown in Fig. 2a, whereas SHO permits the completion of the MS's service handover prior to the MS's actual disconnect from the old BS.

In order to facilitate the migration of application and service state data between MEC nodes, this study examines relevant tactics and management approaches. The use cases for MEC deployment in heterogeneous network environments are expanding and drawing attention from academia and business. There is a standard method for MEC nodes to use when implementing linked device handover.

By offering a thorough analysis of the literature on handover techniques for MEC, this research contributes. The difficulties in attaining an ideal handover plan are noted, and an outline of MEC and related technologies is given. The main advancements presented in this article are outlined below:

- Talk about the improved architectures, application cases, and MEC handover techniques.
- Grouping handover techniques that have been successfully applied in various studies according to the improvement method for completing the handover.

TABLE 1. A collection of acronyms that are frequently used in this work.

Acronym	Definition
3GPP	3rd Generation Partnership Project
5G	Fifth Generation
ADMM	Alternating Directions Method of Multipliers
AP	Access Point
API	Application Programming Interface
APPs	Mobile Edge Applications
AQM	Active Queue Algorithm
ASPs	Application Service Provider
BER	Bit Error Rate
BS	Base Stations
ETSI	European Telecommunications Standards Institute
E2E	End to End
HHO	Hard Handover
IoT	Internet of Things
IP	Internet Protocol
MEC	Multi-Access Edge Computing
MEH	Mobile Edge Host
MEO	MEC Orchestrator
MEP	MEC Platform
MNs	Mobile Networks
MS	Mobile Station
M2M	Machine-to-Machine
NFV	Network Function Virtualization
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RNIS	Radio Network Information Service
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
RTT	Round-Trip Time
SDN	Software Defined Networking
SHO	Soft Handover
SNR	Signal to Noise Ratio
S1	Signalling Application Protocol
UE	User Equipment
VANET	Vehicular Ad-Hoc Network
VHDL	Very High-Speed Integrated Circuit Hardware Description Language
VI	Virtualization Infrastructure
VIM	Virtualization Infrastructure Manager
VMs	Virtual Machines
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything

- Handover methods are classified according to the MEC and network parameters that influence the decision-making process for handovers.
- Examine the obstacles related to MEC handover, highlighting the absence of a uniform protocol that accommodates the variety of networks and devices.

This is how the remainder of paper is structured. The fundamentals of MEC and associated work on MEC handover and seamless handover strategies are presented in Section II. The state relocation strategy, MEC applications, use cases, and ETSI Multi-Access Edge Computing reference model and framework are presented in Section III. The framework handover interface and MEC's handover management techniques are examined in Section IV.

FIGURE 3: Edge Computing At Multiple Access Points (MEC) [1].

II. Overview of MEC

Microsoft began looking at MEC in 2009, and in Dec. 2014, European Telecommunications Standards Institute (ETSI) started their own inquiry. Applications and capabilities for MEC are constantly being developed. MEC was proposed as a viable Mobile Network (MN) communication technology aimed at optimizing Quality-of-Service (QoS) and Quality-of-Experience (QoE) for end users.

According to Cisco [13], by 2023, there will be about three times as many devices linked to IP networks as there are people, and more than 40% of the 14.7 million device-to-device (D2D) connections will be driven by IoT devices, such as home appliances. Additionally, according to Cisco, the typical 4G mobile connection will be 13 times slower than the 5G transmission speed. By the end of 2023, mobile cellular communications must be able to handle the enormous increase in data consumption and processing power needed by approximately 13.1 million devices.

A network model connecting end users, including automobiles, live traffic tracking, intelligent sensors, connected homes, and other applications, is depicted in the given MEC network (Figure 3) example. As the example illustrates, devices send data and task directly to the MEC servers, which provide restricted processing and storage resources in comparison to the cloud. MEC is regarded as the greatest substitute for remote cloud services since data is processed and stored at available processing and storage capacities.

In the context of this network, MEC is required to decide the appropriate timing for relocating services, as mobility of devices demands uninterrupted connectivity. Along the path device is moving, applications move the active session from the current MEC server to a nearby MEC servers. During handover procedure, the application sessions operate concurrently on two servers. For handover process to be completed without connection disruption or quality degradation, any active session that is being relocated must first share relevant session details with target MEC server.

In an effort to improve management and orchestration of Mobile Edge Hosts (MEH), new MEC architectures have been developed that integrate cloud-based virtualization methods, like containers, integrated with Software Defined Networking (SDN). When mobile users travel between multiple MEHs, the envisaged design allows End-to-End (E2E) mobility, which is crucial for ensuring service continuity and reliability. [14] Shah et al. present an SDN-enhanced edge computing architecture in which, this approach combines the SDN framework with an edge computing ecosystem. The idea facilitates interactions between operators for QoS control and E2E mobility. The core features of SDN—scalability, availability, interoperability and extensibility and robustness—are highly beneficial for servers of MEC [15]. Shah et al. [16] conducted a separate study that advocates for the adoption of a decentralized control plane structure over a centralized one for MEC-based vehicle networks to enhance handover management, network performance, and mobility optimization.

A variety of considerations have been taken into consideration in proposals examining MEC handover. From the deployment of network orchestrators with MEC servers to the techniques used for decision-making to guarantee that the continuous operation of applications and services. [17] Fondo-Ferreiro et al. conducted experimental research on migrating stateful applications across MEC servers, as discussed in their respective studies. The study shows how moving a video processing program can aid drivers in remembering the most recent traffic signs. To analyze handover performance for video content delivery services in MEC, Simu5G— a network simulation tool at the system level integrated with the OpenNESS—was evaluated.

To enhance the network's long-term throughput while addressing ongoing challenges related to service reliability and energy limitations in edge computing networks, Liao et al. introduced a learning-driven channel selection framework. The Round-Trip Time (RTT) for the connection between vehicles and infrastructure (V2I) involving a vehicle operating a selected application was taken into consideration in the proposed optimal handover approach. A framework for smooth service migration in autonomous driving within MEC environments was proposed by Doan et al. [18], [19] They employed the FAST handover algorithm, which leverages SDN to forward states between source and destination instances, creating a programmable system to minimize migration costs. Comparable concepts were also explored by Gember-Jacobson et al.

III. STRUCTURE, FRAMEWORK, AND USE CASES OF MEC

ETSI has made efforts to standardize MEC [20], and the latest reference architecture for MEC, shown in Fig. 4, consists of entities categorized into the MEC

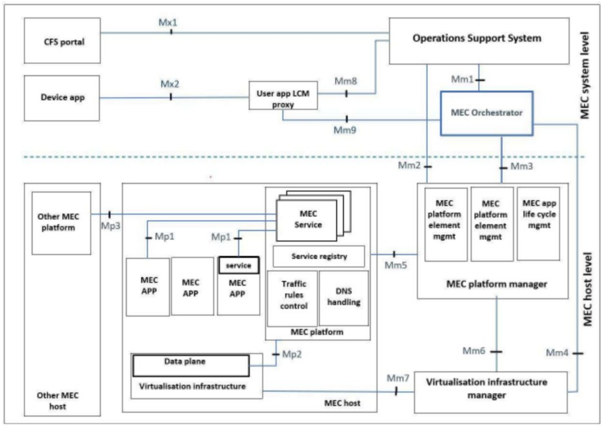

FIGURE 4: ETSI's MEC reference architecture

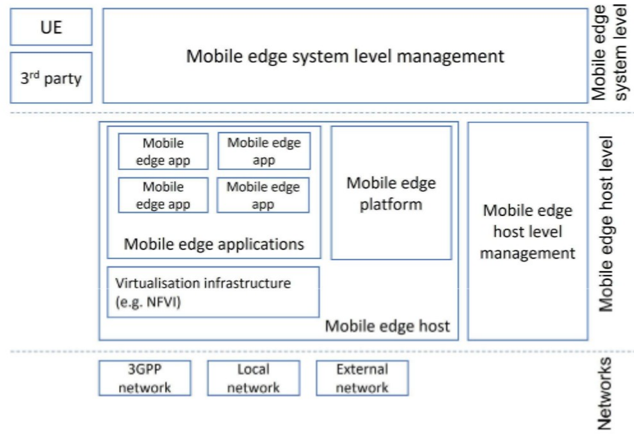

FIGURE 5: Reference Framework for ETSI MEC[31].

service host level and the Edge Service Management Layer, excluding the network level [20].

- **The level of MEC management.** the organizations needed to operate and support MEC services within a network operated by an operator. The MEC Coordinator (MEO), functioning as a management system, plays a key role in selecting appropriate MEC hosts and applications according to their specific needs, as well as managing policy compliance to safeguard the integrity and authenticity of hosts and the applications in operation [21].
- **MEC host layer.** An environment that provides network resources, storage, computing, and interfaces to host virtualized applications and services is known as a Virtualization Infrastructure (VI). Beyond delivering virtualized infrastructure (VI) for essential resources like storage, processing, and network connectivity to facilitate Mobile Edge Applications (APPs), the host level also handles the core system operations. The following entities make up host level:
  1) **The MEC Platform.** comprises the VI and additional features necessary for hosting services and applications, manages the start and stop of applications and services as necessary, and offers a forwarding plane interface.
  2) **Infrastructure Manager for Virtualization (VIM)** provides network infrastructure, computing power, and storage for apps and services. It facilitates VM handoff by communicating with external cloud management. Performance metrics and issue reports sent to the MEC management layer aid in troubleshooting and resolving MEC framework challenges.
  3) **Applications and interfaces.** Applications, services, and other features, such as interfaces, are hosted on the VI. Applications and services are started, configured, and verified on the VI in accordance with the MEC management instructions.

Fig. 5's MEC reference framework outlines the organizations involved in hosting services and applications on virtualized infrastructure (VI). The MEC framework consists of three levels: host, management, and networking. The networking layer ensures connectivity between the RAN, core networks, and cloud. The host level includes the MEP, VI, and auxiliary features. The ETSI architecture enables seamless communication between edge services and connected devices, supporting MEC in 5G deployment and the transition from 4G to 5G.

A. MEC SERVICES AND APPLICATIONS

MEC servers can host a variety of applications, from gaming and multimedia to machine-type communication services like IoT and Vehicle to Everything (V2X). By connecting to MEC servers, millions of mobile devices can take advantage of storage and edge computing, this gives MEC a distinct edge over cloud computing by providing extremely low latency (close to 1ms) and facilitating local data aggregation and analysis. Application can operate in containerized environments, virtualized setups, or virtual machines (VMs).

By placing several MEC servers in various geographic areas, MEC guarantees access with minimal latency at the network edge, combined with distributed strategies. Network administration may become more difficult, though, if MEC servers are dispersed across numerous locations with varying computer capacities. SDN enables advanced real-time decision making, allowing seamless and transparent network control while streamlining management of network.

The research examines the SDN's role in MEC handover management, comparing distributed and centralized control planes. In large-scale dynamic networks, distributed control proved more effective, enhancing mobility management. MEC enables edge devices (e.g., laptops, smartphones, smartwatches) to offload demanding activities to a MEC server or

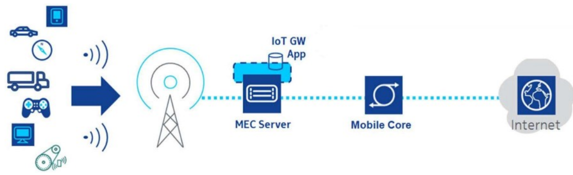

FIGURE 6: MEC acting as an entry point to IoT services.

groups of MECs. Various task offloading methods, such as 'JCORAMS','COBSCN', 'ILP', 'MPOD', 'CaPC', 'COD', 'ELT-ENO', and 'COA-GT', used for efficient processing.

When employing real time radio and data about the network, cloud service subscribers can take advantage of MEC's contextualized and tailored experience. The 3GPP organization's specifications established the ETSI MEC, which is currently becoming an essential part of contemporary networks. MEC was put into place, alongside 4G network during early stages of the development of technologies that would ultimately evolve into 5G. The progress of MEC for 5G networks has been improved by the learning results founded by integrating MEC with 4G networks. The combination of MEC, SDN technology, and NFV are considered essential enablers for the success of 5G network services.

Consequently, MEC shows great potential as an MEP for 5G network services and target configurations. It achieves the data processing, job offloading as well as aggregation at the network edge necessary for future MNs, in addition to facilitating ultra-low latency [22].

The MEC architecture solves latency and bandwidth issues for Internet of Things (IoT) as well as additional applications like augmented reality, location services, video analytics, and data caching. MEC was recognized by ETSI as a crucial facilitator for the live operations needed for IoT applications and the services. The distributed control plane architecture of MEC can serve IoT systems with critical demands scenarios that needs a latency-1ms and the high dependability of 99.99% while also facilitating IoT device mobility.

Resource-constrained IoT devices can leverage MEC's enhanced computing and data storage capabilities to achieve the desired outcomes. As shown in Figure 6, MEC servers can support IoT applications by serving as gateways or quick response aggregation points that can evaluate and combine IoT services traffic prior to its transmission to the core network [23]. Handover is an essential process at the edge that guarantee uninterrupted service and accomplish decreased latency.

B. STATE CHANGES IN MEC

Triggering application initiation and termination as well as relocation when necessary are among the MEO's primary responsibilities. As explained in, MEO chooses the selected MEC host(s) according to the latency as well as the services and resources that are available to start applications within the MEC framework. Therefore, controlling the movement of devices during a real time session should be taken into consideration when designing the orchestration framework. In applications that are sensitive to delays, timing is crucial. To transfer jobs between the edge nodes, a running session can be moved live to a different server without causing any disruptions or disconnecting users. One of the solutions utilized by cloud services is the Docker Transition Service, a container-based platform that oversees containers, replacing the use of traditional virtual machines.

The MEO, as the MEC system manager, oversees the relocation of applications or states within the system. Ensuring service continuity during relocation involves validating the network link between the two MEC hosts while ensuring the MEC application instance remains intact after the transition is complete. The MEO, overseeing the MEC framework, handles the relocation of applications or states within the system. Service continuity must be guaranteed before moving an application or a state. This is accomplished by making sure that the two MEC hosts are connected to the network while ensuring the MEC App object operating once the migration is complete [24].

Connectivity depends on the proximity between the UE and its designated MEC host, as well as the level of network congestion. As a result, even when the MNs' locations shift, MEC apps can still provide UE. When the UE is in motion and connects to another MEC host better suited for application and service performance, the decision to relocate is generally made to meet latency and resource accessibility needs. The procedure is determined by the architecture of the application because there is presently no standardized mechanism for the interaction from source to target MEC hosts to transfer application state from one object to another.

When the MEC system receives a service for providing radio network information (RNIS) message, application relocation in MEC begins. Because of user mobility, the serving cell is changing. The purpose of the application relocation is to make sure the MEC app object has earlier been migrated and becomes functional when the end user's state shifts to an alternate cell. Every time a newly MEC application is launched, MEC establishes an application context to preserve data structures. Application relocation is started for many reasons, according to ETSI. One scenario where the MEC application is moved because of a lack of resources in the virtualized environment [24] is to address a resource limitation, as seen in Fig. 7. The alternative scenario includes user relocation, as shown in Figure 8. In which handovers occur vertically or horizontally as a result of switching between access technologies or changing connectivity technology (such as Wi-Fi to 5G) [24].

The web session object is a common illustration of a state session; according to Microsoft, the session object can hold user preferences and other parameters.

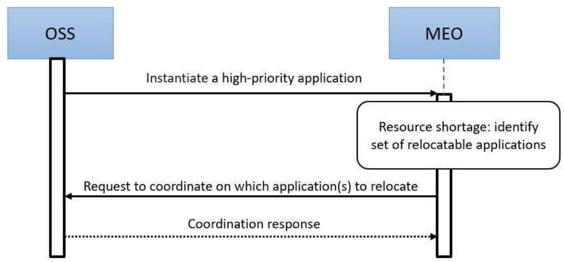

FIGURE 7. Due to a lack of resources, the application was moved..

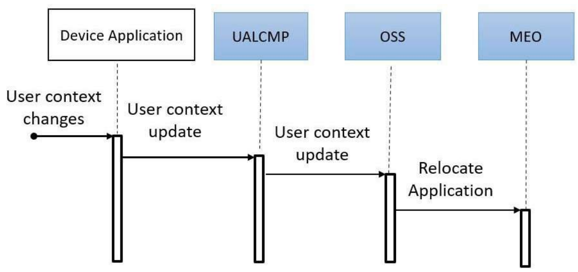

FIGURE 8. Managing the mobility of users.

When a user navigates across pages within a specific application, for example, user information is retained in the session object until the session concludes or reaches its expiration limit. This preserves details regarding a particular "user session on the destination device. One example of this is a web browser session, which preserves the session's state in browser that allow cookies [25]. Similar to this, in order to effectively serve the UE, the session status of the MEC application is moved between MEC servers.

A key challenge in MEC state migration is minimizing the total cost of state transfer, given the constraints of available resources. Doan et al. highlight that reducing latency to minimize service disruption and meeting four critical MEC demands— high reliability, adaptability, minimal latency, and versatility—are significant hurdles in managing MEC state. They introduced a framework for smooth, real-time service migration in autonomous driving systems to assess MEC's impact on smooth migration. By contrasting a central cloud setup with an MEC environment, their study showed that MEC can efficiently tackle and solve latency challenges during real-time service transfer.

The MEC handover management procedure is in stark contrast to the state relocation strategy. While the handover generally explains the smooth transition of the entire connection session, the state relocation largely covers the tactics used to transition to the state of computation. The general state relocation strategy is described in Fig. 9. The service successfully moves from the original MEH to the destination MEH, as shown in the illustration by the events A and B. Service migration is triggered by one of three elements: the Mobile Edge Orchestrator (MEO), the MEC application on the User Equipment (UE), or the Radio Network Information System (RNIS) at the source or destination Mobile Edge Host (MEH).

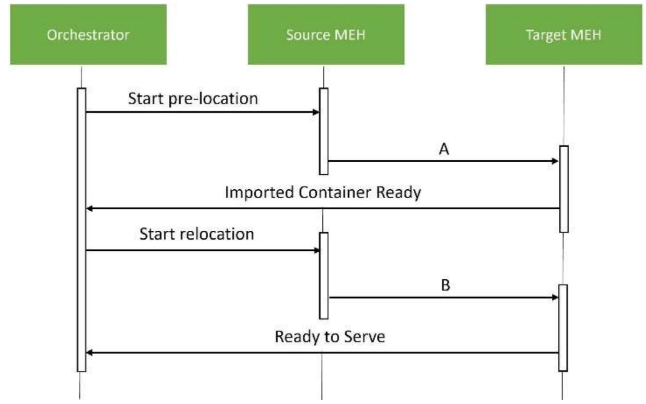

FIGURE 9. State relocation strategy.

IV. CONTROL OF MEC HANDOVER

In a wireless network, a series of preset operations is used to accomplish a smooth handover. The linked MEC server collects information from neighboring servers during the network discovery phase before the transition, aiming to determine the most appropriate server that aligns with the UE, QoS, QoE. The end user's QoE may be significantly impacted by the handover procedure. To improve the network's overall efficiency, MEC must preserve QoE. A service's total performance is assessed on its Quality-of-Service (QoS). QoE in edge computing is the end-user's qualitative evaluation of a particular service [26]. To put it another way, identifying a server capable of functioning as the UE's new host when it traverses across a network while still meeting QoE and QoS standards and ensuring uninterrupted service. After determining that the UE needs to be relocated to the chosen destination MEC server, the transition process, referred to as the beginning phase, starts.

Determining the circumstances that cause handoff to start is crucial to improving handover. Handover in wireless communication networks is categorized according to protocol levels, UE, and access technology. There are two categories of technology handover. Within a homogenous system, a lateral handoff, also called as an intra-network handoff technology, involves the transfer among similar network technologies, such as transitioning between 4G networks. On the other hand, a vertical handover, sometimes called an inter- network handover technology, entails a switch between various network technologies, such as 3G-to-4G, and involves coordination between the second layer (Data Link) and the third layer (Network) to ensure the handover process is completed successfully. A protocol layer handover refers to the specific type of handover associated with the particular layer involved in the process, whether it occurs at the network layer, data link layer, or through cross-layer interactions. The network technology classification, primarily divided into HHO and SHO categories, is the most widely used handover classification. Aside from previously mentioned network metrics and needs to take into account when making handover choice, the start of the handover procedure varies for each kind.

MEC servers facilitate smooth application handover driven by end-user mobility, ensuring that QoE and MEC services are not compromised. A method for load awareness in MEC integrated SDN is shown in Fig. 10 to enable smooth application shift between MEC servers. A MEC environment supported by SDN boosts the functionality of MEC servers and enhances the performance of the edge network. The network layer of MEC servers may function as a component of the SDN-powered MEC framework, which establishes a framework that disconnects the data-plane from the forwarding-plane in network equipment. The configurable nature of SDN allows MEC to abstract the complexities of various edge networks from end users, streamlining network architecture and regulatory implementation. The ability of terminal devices to switch (APs) is improved by implementing an SDN-based MEC environment [27].

Enhancing QoE is one of MEC's driving forces. Managing the handover process during device mobility is a significant challenge in MEC use cases. The technique employed by edge servers prior to, during, and following the handover procedure is known as handover control. The ideal handover performance of a system is assessed using particular metrics. However, depending on the system's use cases, different systems may have different definitions of optimality.

For example, with 5G systems, besides delivering services and apps., offering extremely low latency, exceptionally high reliability, availability, and fast data speeds, one of the key challenges in developing unique services is managing the transition of applications. A handover between APs or cloud servers takes place in an IoT heterogeneous environment. Because mobility and continuity have a significant effect on MEC services including distribution of resources, offloading of computations and orchestration of services, they are demands in the MEC environment.

Common measures used to assess network performance, such as latency, RTT, SNR, network coverage, and power consumption in certain situations, can be used to assess handover performance [8]. Another key metric used in handover strategies is service interruption time, defined as the duration between the suspension and resumption of transmission as established by the indicator measuring the received signal strength (RSSI) along with the handoff process's conclusion. There is continuous research to enhance handover methods and tactics to better enable service continuity and mobility. Selected handover techniques and algorithms to enhance network performance are listed in Table 2, which also categorizes the techniques based on the efficacy of the tactics used using standard network metrics, such as delay, RSS, mobility and packet loss.

Through a technique that considers two factors—the timing and the selection of the MEC server—to determine the transition decision between edge computing nodes, several experiments were carried out to determine the most effective transition process. Eijnden [8] split the MEC transition process into two components: radio transition and the transfer of the MEC server application state, also referred to as data transfer. The study found a way to reassess the optimality of each handover operation that is performed. The goal of this method is to identify the best handover plan in real time.

To support MEC, ETSI established an RNIS that provides authorized applications with the latest radio network condition information. An optimization model was suggested to handle mobility processes using RNIS from an AP through the Signaling Application Protocol (S1). The research highlighted the role of MEC applications, MEP, and RNIS in exchanging information to improve service accomplishment. To verify the behavior of the origin and destination nodes in the network, data, including transition statuses, is shared. The model is employed to enhance the mobility needs essential for maintaining uninterrupted service. RNIS provides notifications for handover procedures, covering initiation, finalization, setup, termination, and failure.

To identify the optimal time to make the handover decision and the best destination MEC server, MEC servers need to employ two methodologies. The efficiency of the present and possible target MEC servers is reassessed at each handover methods. In handle the handover without figuring out the best MEC handover technique, the author offered a number of recommendations. Another suggestion introduces a structure that divides the MEC framework into three levels: the foundational level, the application level, and the instance level. These levels encompass the guest operating system and kernel, the idle version of the application, data specific to the application, and the operational state of the application.

There would be no need to send the base layer during a handover event because each MEC server retains a duplicate of it. Applications are launched at the application layer, and all MEC-compatible apps are pre-installed. During a transition, the instance is consistently migrated. Regardless of the application's status, hosted applications and services are transferable, and instance data is transmitted to the target MEC server after pausing the application instance but prior to the application being initiated by the destination server's application layer. This strategy might minimize the amount of data sent, which could enhance handover performance for some applications.

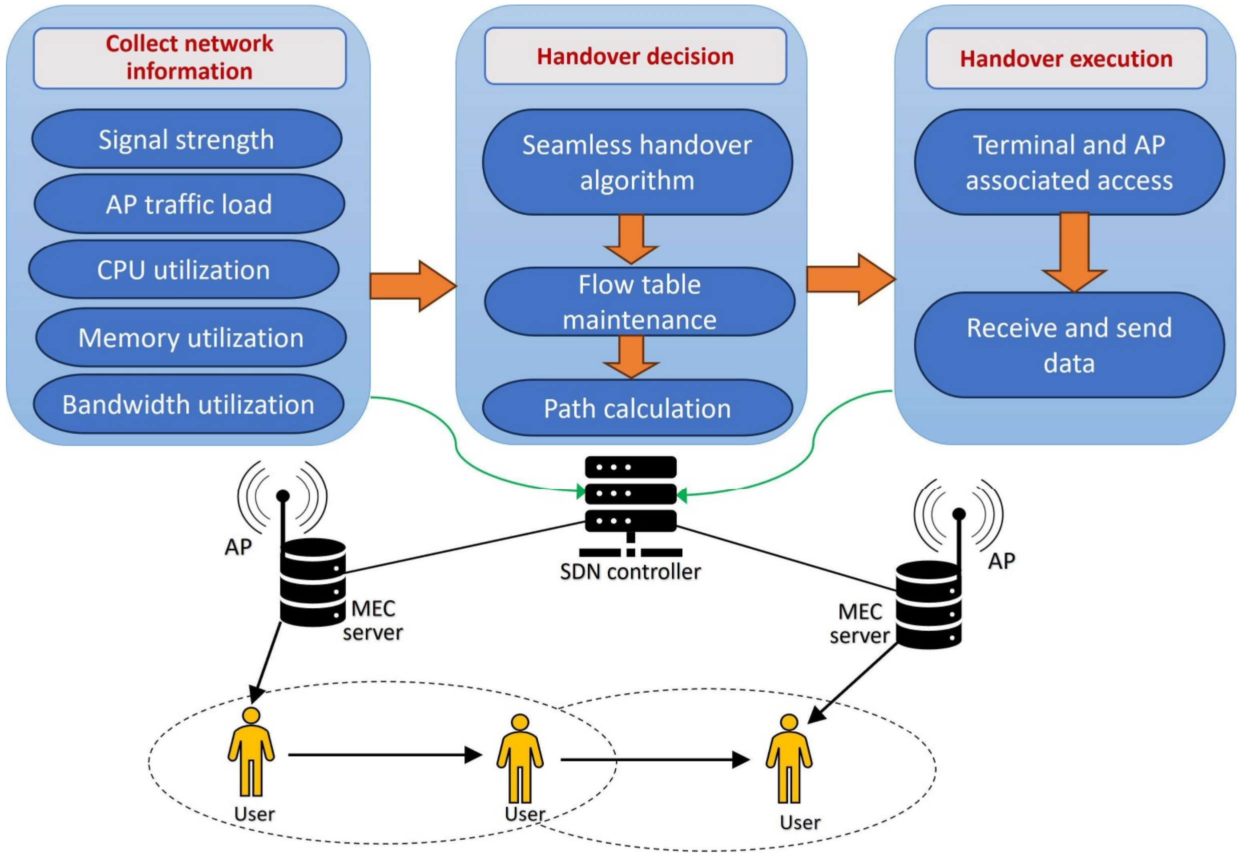

FIGURE 10. Efficient handling of handover in an SDN-based MEC environment

One method that is suggested for managing the handover in MEC in vehicular mobility is SDN. By sharing network state information among distributed controllers across different domains, the suggested architecture break down extensive networks into domains controlled by SDN to manage requests for service relocation and vehicle transfer operations. According to a number of experimental studies conducted, when resource saturation arises in a MEC server, the physical distance-metric approach advises initiating handover. The study outlines a powerful approach utilizing latency-based hysteresis, a strategic decision-making process designed to aggressively identify a backup MEC server with a minimum of 15% greater resources than the existing server, to achieve an ideal handover while drastically cutting down on RTT time.

V. DIFFICULTIES WITH HANDOVER IN MEC

Because of elements such as interference, movement, data loss, memory limitations, traffic patterns, channel capacity, and several other factors, handover failure is a fundamental issue in wireless networks. MEC-deployed networks are still regarded as more sophisticated and intricate than centralized cloud-based networks. However, for a variety of reasons, including application kinds, system needs, or the general compatibility of installed MEC servers, regulating handover may differ in MEC systems.

By guaranteeing low latency connection, enhanced flexibility, agility, and virtualization utilization, MEC can offer end users a superior quality of experience (QoE). Table 3 presents a comparison of specific MEC handover difficulties, their effects on the network, and some recommendations for remedies. They fall into the following categories: EC servers.

A. MOBILITY, MIGRATION, AND COHERENCE

During edge server changeover, mobility might lead to service interruption. When the link between the User Equipment (UE) and the MEC server is impacted by lower bandwidth, higher latency or fluctuations in delay, and other variables, the application service quality may suffer. Discrepancy in network traffic burden distribution and, in certain situations, a reduction in Quality-of-Service (QoS) might result from the network's condition during handover.

Synchronization between the origin and target servers is essential to reduce the duration required for the transfer procedure; this process necessitates exchanging information prior to maximize the transfer procedure and prevent service disruption during the transition. [28] Yaqoob and Shah addressed this problem to highlight the significance of a data aggregation management service for mobility in order to seamlessly integrate IoT services.

TABLE 2. Comparing different methods to handover strategies.

Scheme	Ref.	Strategy	Contribution	Results	Performance Evaluation Metrics			
					Delay	RSS	Packet Loss	Mobility Management
Load awareness and buffering	[54]	Seamless handover based on load awareness	-Using wireless AP perception - Algorithms to select APs with highest weight	- Reduced frequent handover, network load, delay, cost and consumption - Improved throughput and network imbalance	✓	-	✓	✓
	[60]	Two Network-based handover mechanisms	- Pre-handover and buffer scheme - SDN-based defined solution	Reduced packet loss and handover latency	✓	✓	-	-
Threshold	[8]	Delay-hysteresis strategy	- 4-Triggers used to evaluate handover based on delay and distance - Handover whenever alternative with 15% better is available	Significant less RTT percentage	✓	-	-	-
	[11]	Threshold handover scheme	Calculates three threshold levels of RSS	64% better handover quality from the traditional handover	-	✓	✓	-
Location optimization	[56]	Gateways location optimization algorithm and Active Queue Algorithm (AQM) algorithm	- Selecting gateways based on importance and given targets - Keeping buffers short enough	Both algorithms minimize E2E latency	✓	-	-	-
	[57], [61]	Deploying RNIS in mobile edge networks	Up to-date handover notification for mapping RNIS Application Programming Interface (API) onto S1 application protocol	- A usable model in based on up-to-date radio information - Used to optimize mobility and service continuity	-	✓	-	✓
Searching Algorithms	[59]	MEC server searching algorithm	Utilizing cooperative MEC search strategy to support mobility for V2I and Vehicle-to-Vehicle (V2V)	Minimal latency with high bandwidth	✓	✓	-	✓
QoS	[14]	Handover decision making approach	- Collecting handover information using Very High-Speed Integrated Circuit Hardware Description (VHDL) language to facilitate handover decision making	- Maintains QoS parameters when handover - Applicable to other MNs - Selecting optimal path for handover	-	-	-	✓
	[59]	Vehicle-level caching technique	- Utilizing V2V instantaneous communication - Compare latency at the core cloud and the network edge	Better QoS and high service availability	✓	-	-	-
	[62]	MEC handover authentication scheme	- Supports MEC handover authentication - Supports inter-domain and intra-domain handover	- Robust security protections - Congestion avoidance - Reduced computational and communication overhead	✓	-	✓	-
Framework or architecture	[23]	New distributed control plane architecture	- Leverages multiple SDNs controllers - Collect network-wide information in real time	Effective mobility in dynamic and large MEC environment	-	-	-	✓
Timing and scheduling	[44]	Seamless handover timing scheme	- Pre-migration computations when handover is expected - Handles consecutive handovers in a short time	- Latency reduction - Recovers missing jobs during handover	✓	-	✓	-
	[63]	- Service scheduling approach - Inter-cell handover mechanism	- Controlling traffic forwarding - Service scheduling to control traffic and execute tasks	- Enhanced MEC mobility management - Reduced latency cost, and congestion	✓	-	✓	✓
Forwarding and switching	[15]	Four soft-handover solutions	- Switching enhancement of edge gateways by adding 1-byte to sequence field - Using overlaps links to connect AP's	- Ensured lossless and in-sequence delivery of data - Seamless SHO - Applicable to other network systems	✓	-	✓	✓
	[25]	MEC-SDN redirection approach	- Relies on SDN to redirect traffic	- Reduced latency and throughput impairments - Compatible with large populations	✓	-	-	✓
	[45]	Application-driven handover (ADHO) strategy	Open radio resources for 3rd party applications to apply handover policy	Using and optimizing the limited radio resources management efficiently	-	-	-	✓

Checkmark (✓): Used to indicate that the strategy has contributed to enhancing a parameter. Hyphen (-): Used to indicate that there is no change in the parameter.

MEC servers must effectively accomplish mobility management tasks, which involves setting up a BS channel in the event that MEC server is combined with the BS, initiating the handover process, and disconnecting from the previously linked BS. The handover functionality may benefit from the influence of traffic flow and mobility prediction. QoE and High mobility pose significant challenges for the VANETs (Vehicle Ad-Hoc Networks), which needs handoff techniques with advanced methods to manage UE (User Equipment) overlap at crossroads, according to seamless handover experiments [29].

To manage this process, the Figure 11 demonstrates how, when Player 1 moves between connected MEC servers, the ongoing task is transferred to the designated MEC host, which comes with a new access point (AP). This transfer, which is brought on by UE mobility, only moves MEC servers that are currently in use, preserving end user quality of experience without requiring assistance from the centralized data center. Typically, the task migration is managed within the network.

B. SERVICE QUALITY AND SECURITY

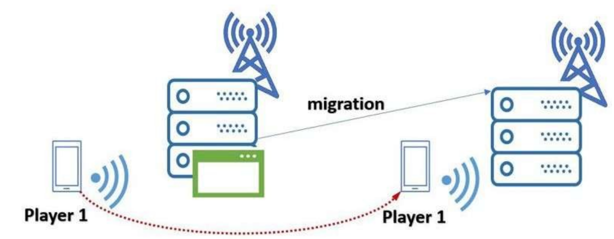

FIGURE 11. Offloading and migration of tasks.

Reliability, QoS, and security are all necessary for a smooth transfer; managing the three needs is a significant issue for handover management process. Monir et al. conducted an experiment to find how the duration of the handover process impacted application QoS. To ascertain the optimal quality after a comprehensive handover process, three RSS threshold levels were evaluated utilizing servers of MEC. To improve results when the handover is carried out, the study suggested using more metrics in the algorithm schemes and handover analysis. To achieve continuous QoS and minimize latency in various applications and scenarios, the advancement of various networking technologies and solutions demands increased network resources and computational power.

Besides the need for a handoff mechanism that supports varied mobile endpoints, another research explored the necessity for advanced pathfinding algorithms that facilitate MEC handoff while ensuring consistent service quality. One issue that has been noticed is data security during handover.

C. CONSUMPTION OF ENERGY

The authors found that the MEC server's high energy consumption during job completion and task management operations, such as commissioning and decommissioning, continues to be a problem. IoT applications continue to face issues with limited energy and computational capacity, and this inefficiency is reflected in MEC-enabled IoT environments. To improve energy efficient task offloading for user equipment (UE), [30] Zhou et al. presented an energy efficiency algorithm for automotive systems user equipment (UE), including phones and Internet of Things devices(IoTs). In contrast to the popular centralized method, a simpler distributed option leveraging the ADMM approach with consensus for optimization was put out, offering greater scalability, lower signaling cost, and greater flexibility.

D. SCALABILITY AND HETEROGENEITY

System scalability refers to the capacity to guarantee service continuity, irrespective of the number of edge-network devices functioning. To avoid service interruptions, every edge device must simultaneously connect to edge apps. During the handover, migration of services must be

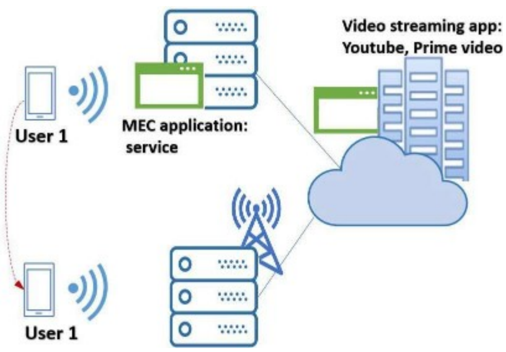

FIGURE 12. Migration of services in MEC.

accomplished without compromising end user quality of experience. For example [Fig 12], if an end user switches between BSs, the complete service and all of its resources will move to the new BS's associated MEC host. ASPs typically use this to enhance network performance and availability by reducing latency or efficiently handling network assets by distributing the load across MEC servers.

For a smooth transition across diverse MEC hosts, the ASP opts to migrate either all or a portion of the resources. Regardless of the number of active subscribers, MEP and other deployment platforms for applications leveraging diverse access technologies, including Wi-Max, Wi-Fi, 3G, 4G, 5G and others, should be able to operate continuously and seamlessly transition among MEC servers or edge points. A Follow-me fog structure was suggested by one study to guarantee continuous services throughout the handover procedure. In addition to managing resource allocation, 5G employs a MEC-based environment and has certain handover issues related to service transfer. One of 5G's enduring characteristics is the requirement for new interference and handover strategies to guarantee service continuity because it allows varied interface frameworks [31].

E. NO STANDARD HANDOVER PROTOCOL IS IN PLACE

Earlier studies have addressed and fixed challenges associated with transfer and state migration of application sessions across MEC servers. Many approaches can effectively and economically handle application migrations between edge clouds. Despite this, no protocol has been found in any prior research to oversee the transfer process between MEC servers capable of accommodating a large number of end users or edge network-connected devices [32]. Therefore, as a research gap, we propose to develop a model for a transfer protocol that handles the migration of sessions procedure among one or more interconnected edge servers. As MEC is an cutting-edge innovation that is still in the testing phase and implementation stages, ETSI strongly insisted on critical necessity for a unified framework to govern the MEC handoff-processes[33].

TABLE 3. A comparison of typical MEC handover issues.

Ref.	Challenges	Description	Impact	Solution
[8], [11], [54], [60], [66]	Mobility and synchronization	Maintaining QoS during mobility to avoid any service disconnection during handover between edge servers, managing dynamic network conditions and UE mobility pattern	Affecting QoS, network load imbalances	Synchronization mechanisms and improved algorithms to overcome the UE overlapping at a crossroad
[65], [67]–[70]	Mobility and migration	High mobility, services migration and synchronization during handover between source and destination servers to minimize the handover time, maintain continuity, involving state transfer, session persistence, and real time data synchronization	Service degradation, network load imbalance	Efficient IoT data management
[11], [14]	Security and QoS	Challenges associated with ensuring reliability, QoS and security during the handover, addressing vulnerabilities during handover transitions, ensuring data integrity and privacy, and adapting QoS dynamically based on varying network conditions and security requirements.	Influences application QoS, requires new routing algorithms	Dynamic Qos adaption mechanisms to ensure uninterrupted Qos
[41], [72]	Security and QoS	Encompassing the reliability, QoS and MEC security aspects as QoS is highly affected by handover timing	Influences application QoS, requires new routing algorithms	Handover protocols to handle heterogeneous mobile terminals, data security measures
[41], [44], [75]	Heterogeneity and Scalability	Challenges arising from ensuring uninterrupted services and managing resource allocation complexity, scalability of MEC systems and managing heterogeneity of edge devices, including challenges of interoperability, and resource management in diverse environments	Service interruption, resource allocation complexity	The use of frameworks like the Follow-me fog framework that ensures uninterrupted services during handover
[4], [65], [76], [77]	Heterogeneity and Scalability	MEC systems scalability and edge devices heterogeneity, and maintaining service quality across scales during handover without affecting the end user QoE	Service interruption, resource allocation complexity	Strategies for handling interference in heterogeneous environments
[54], [64]	Energy Consumption	High energy consumption of MEC servers during task management, Critical need for energy-efficient operations in MEC servers, especially for intense computation and data processing tasks; importance of optimizing energy usage	High energy inefficiency and environmental sustainability concerns	Energy-efficient algorithms
[73]	Energy Consumption	The imperative for efficient energy management, and imperative for efficient energy management by focusing on computational efficiency and reduced energy usage under high-load conditions	Computing capacity limitations	Less-complex distributed solutions based on ADMM

VI. CONCLUSION

The constraints of enabling new applications that need ultra-low latency and the growing demand for task offloading by UE—specifically, IoT devices and vehicular networking—are addressed by MEC deployments. Enhancements in QoS and QoE are important drivers of MEC development and continuous study. One of MEC's main requirements is a successful handover that is dependable, effective, and guarantees service continuity. In addition to outlining current research and suggestions for handover strategies that offer improved mobility and state relocation, this study covered the ETSI-MEC standard architecture and framework. Research gaps and challenges have been discovered, especially with regard to handover. In addition to presenting MEC handover management solutions that have recently been suggested in the literature, this thorough review has revealed state relocation approaches.

MEC is a key enabler for the development of 5G and IoT applications, according to ETSI. A strong handover management system is necessary for the deployment of MEC in a mobile and Internet of Things setting. Finding a reliable handover protocol and improving handover management while using less energy are the tasks that still need to be completed.

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