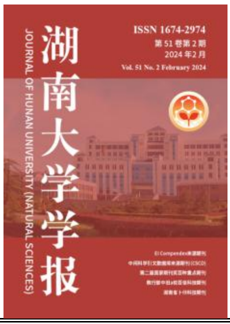

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Mobile Edge Computing in Smart Healthcare: A Comprehensive Review, Challenges and Future Directions

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Abstract: Mobile Edge Computing (MEC) is a distributed computing paradigm that brings computational resources closer to the edge of the network, enabling faster processing and low-latency interactions for applications and services. This computing paradigm is crucial for many applications, including intelligent healthcare systems, where it allows for the rapid analysis of healthcare data at the edge, supporting prompt and effective health-related services, remote patient monitoring, and personalized medicine. In this paper, we aim to comprehensively review MEC applications in the context of smart healthcare systems. The primary focus is on the integration of MEC technology as a pivotal solution to address the growing demand for efficient and real-time healthcare services. To highlight the purpose and novelty of this research, we delve into the current status of MEC in healthcare, examining both the significant challenges and opportunities in this domain. Challenges, including latency, security, and scalability, are discussed, providing insights into the complexities of implementing MEC in healthcare. Notably, our paper contributes by providing research directions to address these challenges, thereby unlocking the full potential of MEC, hence offering a roadmap for future advancements for smart healthcare systems.

Keywords: mobile edge computing, smart healthcare, network.

智能医疗中的移动边缘计算：全面回顾、挑战和未来方向

摘要：移动边缘计算 (MEC) 是一种分布式计算范例，它使计算资源更接近网络边缘，从而实现应用程序和服务的更快处理和低延迟交互。这种计算范式对于许多应用至关重要，包括智能医疗系统，它允许在边缘即时分析医疗数据，支持及时有效的健康相关服务、远程患者监测和个性化医疗。在本文中，我们的目标是全面回顾智能医疗系统背景下的 MEC 应用。主要重点是将 MEC 技术集成作为关键解决方案，以满足对高效实时医疗保健服务日益增长的需求。为了突出这项研究的目的和新颖性，我们深入研究了 MEC 在医疗保健领域的现状，研究了该领域的重大挑战和机遇。讨论了延迟、安全性和可扩展性等挑战，深入了解在医疗保健领域实施 MEC 的复杂性。重要的是，我们的论文提出了解决这些挑战并释放 MEC 全部

潜力的研究方向，为 MEC 和智能医疗系统交叉点的未来发展提供了路线图。

关键词：移动边缘计算、智能医疗、网络。

1. Introduction

The convergence of Mobile Edge Computing (MEC) and smart healthcare systems opens a new era of healthcare technology, enhanced efficiency, and real-time responsiveness [1]. In the face of escalating demands for instantaneous healthcare services, the integration of MEC emerges as a pivotal solution, leveraging the proximity of computational resources to the point of data generation [2]. Fig. 1 illustrates the architecture for MEC-based healthcare system which intricately integrates edge computing capabilities to optimize health monitoring, showcasing the deployment of MEC in transforming and enhancing various healthcare applications. The architecture highlights the proximity of computational resources to the point of data generation, emphasizing the system's efficiency and responsiveness in healthcare delivery.

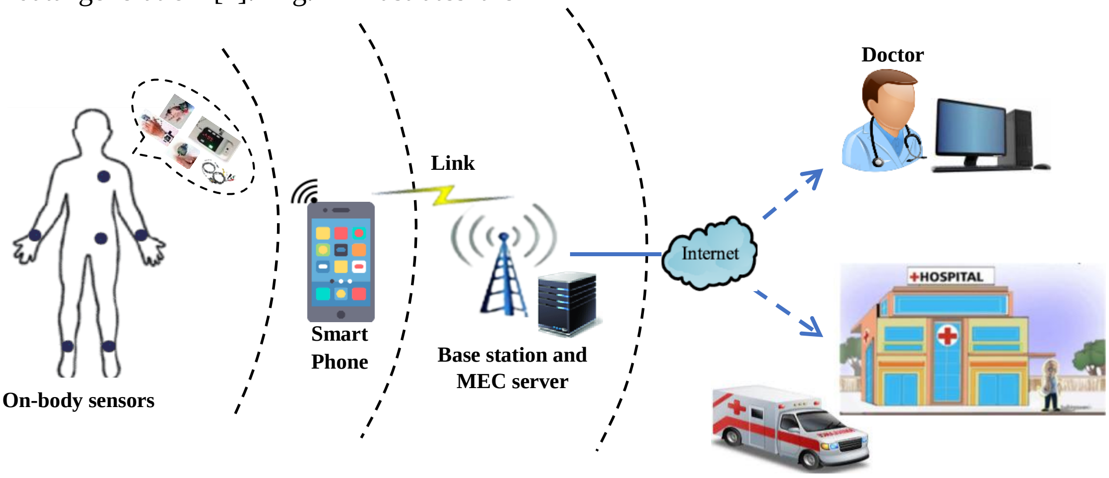

Fig. 1 Architecture for the MEC-based healthcare system (The authors)

This paper embarks on a comprehensive exploration of MEC in smart healthcare systems, with the aim of revealing the current landscape, challenges, and future research directions in this intersection. The fusion of mobile edge technologies with healthcare systems holds the potential to revolutionize patient care, diagnostics, and overall healthcare delivery.

As we delve into the details of MEC applications in healthcare, we embark on a journey through existing literature, examining successful implementations and shedding light on areas requiring further attention. The seamless integration of MEC technologies into healthcare stems not only promises to enhance the efficiency of healthcare services but also opens new possibilities for personalized medicine, remote patient monitoring, and timely responsiveness. Challenges in the deployment of MEC, such as latency, security, and scalability etc., are dissected to underscore the complexities inherent in this transformative endeavor. While these challenges are formidable, they present opportunities for innovation and collaboration across disciplines. The ability to process and analyze healthcare data at the edge introduces a paradigm shift, necessitating the development of resilient and secure architectures.

In navigating these challenges, the paper proposes research directions that aim not only to address current impediments but also to chart a course for future innovations. The objective is not only to understand the existing landscape but also to contribute to the evolving narrative of MEC in smart healthcare systems. By considering the potential impact of MEC on healthcare accessibility, quality, and patient outcomes, we lay the groundwork for a more robust and responsive healthcare ecosystem.

Combining insights from literature, critical analyses of challenges, and forward-thinking research directions, this paper aims to guide researchers, practitioners, and policymakers through the intricate possibilities and challenges at the intersection of MEC in smart healthcare systems. We seek to contribute to the ongoing dialogue shaping the future of healthcare technologies. The selection of our research object is carefully justified, emphasizing the relevance of MEC in smart healthcare systems. The criteria for this selection are elaborated upon to provide clarity on our focus. Furthermore, we emphasize the practical applications of our findings, bridging the gap between theoretical insights and real-world implications.

2. Analyzing the Literature

Recently, smart healthcare methods have garnered significant attention owing to their substantial economic and social advantages. The increased interest in utilizing wireless and wearable sensors to enhance healthcare performance has experienced a notable surge. This section explores the existing research to provide a comprehensive overview of the current state of knowledge, achievements, and gaps in understanding the application of MEC in healthcare applications.

The authors in [2] have outlined the foundational concepts of MEC, emphasizing its potential to revolutionize healthcare by bringing computation closer to the data source. The proximity of edge computing resources ensures reduced latency, facilitating real-time processing of health data a critical requirement for applications demanding prompt decision-making, such as remote patient monitoring and emergency response systems. Building on these foundational works, [3] conducted an insightful exploration of specific use cases and applications of MEC in healthcare. Their research highlighted successful implementations in areas like telemedicine, personalized medicine, and wearable health devices. These applications showcased the transformative impact of MEC, improving patient outcomes, enhancing diagnostics, and fostering a more patient-centric healthcare approach.

However, as we navigate through the literature, it becomes evident that the integration of MEC in healthcare is not without challenges. Ahmed et al. [4] outlined the complexities associated with ensuring the security and privacy of healthcare data in an edge computing environment. The unique nature of healthcare information demands tailored security protocols to safeguard patient confidentiality and data integrity. Furthermore, scalability emerges as a critical challenge, as discussed in [5]. The increasing number of healthcare devices, coupled with the growing volume of health data, necessitates scalable architectures and resource allocation strategies to maintain performance levels without compromising efficiency.

While the literature has made significant strides in uncovering the potentials and challenges of MEC in healthcare, there is a discernible gap in understanding how ethical considerations intersect with this integration. Rauniyar et al. [1] has explored the ethical implications, underscoring the need for further investigation into issues of data consent, transparency, and responsible deployment of MEC in healthcare settings. As we synthesize insights from existing literature, it becomes evident that while MEC holds immense promise for smart healthcare, there remains much ground to cover. The following sections of this paper will delve deeper into the challenges identified in the literature, proposing research directions to address these gaps and contribute to the ongoing dialogue in this rapidly evolving field.

To optimize resource utilization, a framework was introduced in [6] referred to as Scheduling-based Dynamic Fog Computing (SDFC). This framework incorporates an additional layer between the centralized cloud and edge/fog, facilitating the selection of the task execution location (either the edge/fog node or the cloud). Another scheduling technique based on the Internet of Things (IoT), known as Hash Polynomial Two-factor Decision Tree (HP-TDT), was outlined in [7]. This method aimed to enhance scheduling efficiency by categorizing normal and urgency conditions, consequently reducing response time and computational overhead.

Several techniques have been developed to improve IoT and MEC-based health facilities by addressing challenges related to task scheduling and resource allocation. For enhanced resource utilization, the Scheduling-based Dynamic Fog Computing (SDFC) framework was proposed [6]. This framework introduces an additional layer between the centralized cloud and edge/fog, aiding in selecting the task execution location. Another IoT-based scheduling technique, Hash Polynomial Two-factor Decision Tree (HP-TDT) [7], was introduced to enhance scheduling efficiency, decrease response time, and minimize computational overhead by categorizing normal and urgent conditions.

A cost-efficient MEC-based 5G health monitoring system aimed to reduce system-wide cost and energy consumption [8]. However, challenges arose concerning interference, channel multiplexing, and limited computation resources of MEC servers. In an effort to enhance patient data privacy and alleviate communication latency and data traffic, [9] introduced a MEC-based healthcare framework. Concurrently, [10] proposed a sophisticated in-home health monitoring system, leveraging the MEC concept to offer distributed storage and data mining services. Additionally, [11] devised a method aimed at minimizing latency, response time, and network traffic. This innovative approach involved intelligent caching implemented in a distributed manner, ensuring the provision of static data, with edge servers maintaining content locally.

Another significant development focused on the identification and understanding of disordered voices, as presented in [12]. The proposed system utilized smart sensors to interpret a patient's disordered voice. Initially, the collected data was transmitted to edge nodes for preliminary processing, and subsequently, it underwent further computations in the centralized cloud. The outcomes of this process were then sent to consultants for therapy or treatment. This comprehensive system was intricately designed to detect abnormalities, discern tones, and assess the sensitivity in a patient's voice. The results facilitated the classification of voices based on detected irregularities.

Furthermore, addressing the healthcare needs of patients with chronic diseases, [13] introduced the Fog Computing-Based IoT for Health Monitoring System (FCB-HMS). This technique not only gauged the security and deployment concerns of the edge/fog computing layer but also provided an effective means to monitor and process data for patients with chronic conditions. The systematic analysis of security and deployment issues showcased the comprehensive approach undertaken in developing the FCB-HMS.

Within the realm of healthcare frameworks, a noteworthy initiative named HealthFog [14] was introduced as a real-time application designed to monitor patients grappling with heart problems. This innovative system leverages edge computing devices seamlessly integrated with deep learning capabilities to efficiently process various operations on patients' heart data. A substantial improvement was asserted, emphasizing the system's adaptability to diverse edge computation environments and its configurability to meet various user requirements. The touted enhancement in Quality of Service (QoS), particularly in terms of prediction accuracy for heart patients, was a notable feature. Despite a comprehensive evaluation considering network bandwidth, power consumption, accuracy, jitter, latency, and execution time, it's important to note that the application's scope was limited to heart patients, and no other scenarios were assessed.

Similarly, in [15], a healthcare-oriented system named the resource preservation net (RPN) was proposed, aiming to assist queuing systems, urgency departments, and medical resources by integrating MEC with the centralized cloud. This proposed system demonstrated suitability for real-life applications, showcasing its capability to reduce patient waiting time while concurrently enhancing resource utilization. The system's performance was rigorously evaluated through metrics such as the average waiting time of patients, resource utilization rate, and the duration of patients' stay in the hospital. Noteworthy in its approach, the proposed work accounted for non-consumable resources, with each resource equipped with smart devices sharing real-time status updates with the cloud regarding the status of their resources. This multifaceted evaluation underscores the potential effectiveness of the proposed system in optimizing healthcare resource management and patient experiences.

In addressing the imperative need for continuous monitoring of diabetic patients, a dedicated system was developed as outlined in [16]. This proposed method, positioned as a practical e-health solution, emerges as an ideal healthcare intervention tailored for diabetic patients residing in rural or countryside areas. The overarching goal of this system is to leverage diverse computing technologies to enhance healthcare services, acknowledging the unique challenges faced by diabetic patients in specific geographic settings. Extending the realm of remote monitoring to patients with Parkinson's disease, [17] introduces a solution designed for in-home monitoring. This approach not only mitigates the risk of falls and injuries but also facilitates the monitoring of dosage alterations, providing a holistic healthcare solution for patients dealing with Parkinson's illness. The emphasis on at-home monitoring underscores the potential of technology in improving patient outcomes and ensuring timely interventions.

Furthermore, the integration of MEC into healthcare solutions is demonstrated in [18], where a proposed architecture integrates wireless body area networks (WBAN) with various modeling techniques. This integration aims at optimizing real-time data storage, processing, and transmission, with a specific focus on efficient energy usage and low-latency interactions. The nuanced approach outlined in this work aligns with the evolving landscape of healthcare technologies, emphasizing the role of MEC in enhancing data processing efficiency. Delving into QoS considerations in e-healthcare, [19] provides a comprehensive exploration of requirements in the context of MEC. The discussion encompasses the specific needs of healthcare Internet of Things (IoT) and telemedicine operations, highlighting the critical requirement of minimum round-trip time delay for uninterrupted service delivery. The article contributes through a detailed analysis and comparison of QoS requirements, informing the design and implementation of robust e-healthcare services.

Shifting the focus to task scheduling within MEC for medical applications, [20, 21] endeavors to address resource allocation challenges, aiming to reduce network usage, data traffic, response time, and latency in Internet of Things (IoT) environment. While commendable, it's noted that this research could benefit from further exploration into minimizing RAM consumption for process execution, presenting an opportunity for future refinement and optimization. Similarly, [22] leverages MEC to minimize latency, meeting QoS requirements for time-sensitive applications in smart healthcare. The authors propose a distinctive model for monitoring patient health conditions, incorporating various wearable devices to capture and record vital signs. The integration of a machine learning approach further enhances the adaptability and responsiveness of the proposed system, aligning with the evolving trends in healthcare technology. In [26], the authors employ the concept of computation offloading with a hybrid method to effectively minimize energy consumption and network traffic in IoT environments. This strategy underscores the importance of optimizing resource utilization while ensuring efficient energy use, contributing to the overarching goal of sustainable and responsive healthcare solutions.

In summary, the diverse approaches discussed showcase the versatility of MEC in addressing critical challenges in healthcare. Each method brings its own set of achievements and limitations, emphasizing the need for continued research and innovation in this dynamic field. For a concise overview, Table 1 provides a summary of these prominent techniques and algorithms, highlighting their key features and shortcomings.

Table 1 Comparative analysis of various techniques and algorithms proposed for the MEC paradigm for healthcare applications (The authors)

Article	Methodology/Algorithm	Research Domain	Achievements	Limitations
[14]	HealthFog Real-time Monitoring Framework	Smart healthcare system for heart diseases (IoT and Fog computing)	Efficiently uses IoT devices for medical data (heart patients' data)	Lacks data security considerations
[15]	Resource Preservation Net (RPN) Framework	Resource utilization and patient waiting time optimization	Improves resource usage for medical applications	Compromises data optimization
[13]	Fog Computing-Based IoT for Health Monitoring System (FCB-HMS)	Efficient Data Collection and processing	Monitors chronic diseases	Processing speed compromised
[12]	Voice Disorder Detection System	Deep learning-based voice disorder detection	Enables patients to convey voice samples for early detection	Higher bandwidth cost incurred
[23]	Optimal joint communication and computation resource allocation	communication and computation resource optimization	Efficiently allocates limited computation resources	Ignores energy consumption
[24]	Price-based Resource Allocation (PBRA) for MEC	MEC resource utilization with budget constraints	Maximize the resource utilization at edge node	Neglects data privacy considerations
[25]	NBIHA Algorithm	Task scheduling and resource management	Optimizes resource usage and reduces response time	Incurs higher task execution time
[6]	Scheduling-based Dynamic Fog Computing (SDFC) Technique	Resource utilization optimization	Chooses task execution locally or remotely	Complexity increases with user requests
[7]	Hash Polynomial Two-factor Decision Tree (HP-TDT)	IoT-based device scheduling	Improves scheduling efficiency and reduce response time	Incurs higher cost and power consumption
[9]	Bodyedge Architecture for Human-centric Applications	Efficient data collection for healthcare	Processes data from various devices to decrease communication latency and data traffic	Compromises security and privacy
[10]	IoT-based Remote Patient Health Monitoring System	Patient health monitoring with distributed storage	Provides distributed storage and data mining based on MEC	Faces reliability issues
[8]	Cost-efficient In-home Health Monitoring System	System cost reduction through bandwidth allocation	Reduces system-wide cost and energy consumption	Proves to be more costly

Numerous other research works in literature have diligently addressed diverse challenges within the MEC paradigm. A curated selection of these works is presented in Table 2, offering a comparative analysis across key attributes, including resource management, latency minimization, cost considerations, usability, security/privacy, energy efficiency, and more. The focus remains exclusively on MEC paradigms, providing valuable insights into the spectrum of challenges and solutions. Additionally, Table 3 delves into MEC solutions categorized by their distinct intentions, contributing to a nuanced understanding of the multifaceted applications of MEC in various contexts.

Table 2 Comparison based on different attributes focusing on MEC paradigms (The authors)

Articles	Resource Management	Minimize latency	Security/Privacy	Cost	Energy efficiency	Usability	Fog/Edge	Attention/Motivation
[27], [28]			✓		✓		✓	IoT technologies, protocols
[29]		✓					✓	Sensor types, uses
[30]	✓				✓		✓	Material and antenna types
[31]			✓	✓		✓	✓	Infrastructure reliability
[32]	✓						✓	Monitoring types
[33]		✓	✓		✓		✓	M2M communication
[34]			✓			✓	✓	Sensor and monitoring types
[35]			✓				✓	Architectures, sensor types
[36]	✓		✓			✓	✓	Wearable device types

Continuation of Table 2

[37]	✓	✓	✓	Architectures, sensor types

Table 3 Comparative summary of MEC based approaches (The authors)

Article	Maximizing throughput	Optimizing execution cost	Minimizing energy consumption	Reducing network latency
[38]			✓	
[39]		✓		
[40]			✓	
[41]		✓		
[42]		✓	✓	✓
[43]		✓	✓	
[44]	✓	✓		✓
[45]	✓			✓
[46]	✓			✓
[47]		✓		✓
[41]		✓		
[49]		✓	✓	
[50]		✓	✓	
[51]	✓			✓
[52]		✓		
[53]	✓			✓
[51]	✓	✓		

3. Challenges and Constraints in MEC for Healthcare Applications

The integration of MEC into healthcare systems introduces a complex set of challenges, demanding careful consideration and innovative solutions due to limited resources and the influx of heterogeneous data from wireless devices [54, 55]. One major challenge lies in resource constraints, where edge devices with limited processing power, memory, and storage capacities impact the performance of resource-intensive healthcare applications. The rapid generation of data from various wireless devices and medical sensors, adds complexity to real-time processing at the edge [56].

Network security becomes a critical concern as MEC introduces new challenges related to data protection, secure data sharing, and authentication in a distributed computing environment. Security risks arise from the decentralized nature of data storage, making sensitive healthcare data susceptible to hacking or unauthorized access. Another challenge is energy utilization, emphasizing the need for efficient and intelligent use of limited energy in mobile devices for continuous operation, necessitating advanced algorithms for decision-making and energy-efficient practices [57].

The coordination between MEC and centralized cloud infrastructure poses challenges in optimizing task distribution and load balancing for healthcare applications, known as edge-cloud coordination. Additionally, energy efficiency becomes a focal point, as MEC may increase energy consumption, necessitating the implementation of mechanisms like dynamic power management and load balancing. The awareness of offloading, involving the simultaneous interaction of multiple devices with MEC servers, may lead to network congestion, impacting overall reliability, latency, and energy usage [48].

Reliability and fault tolerance present challenges in ensuring continuous operation, especially in wireless communication environments. Random offloading of data from end devices to MEC servers without priority consideration poses difficulties in ensuring reliability. Intelligent resource management is crucial for resource placement, sharing, migration, and signaling overhead optimization in MEC, ensuring efficient resource utilization and optimal QoS [57].

Mobility management introduces challenges related to Virtual Machine (VM) migration in MEC, impacting low latency, efficient resource allocation, and service continuity, particularly with mobile devices moving between different edge nodes [48]. Intelligent caching mechanisms are essential for retrieving accurate information from noisy data packets generated by various smart mobile devices for real-time healthcare applications. Achieving interoperability in the heterogeneous MEC environment with multiple stakeholders and diverse platforms remains a challenge for seamless integration.

Dynamic workload variability poses a significant challenge in healthcare applications, requiring adaptation to changing workloads and priorities while maintaining efficiency. The management complexity arises from deploying and managing a large number of edge devices, introducing complexity and requiring sophisticated management systems for efficient resource allocation and task scheduling. Latency management is paramount for real-time patient monitoring and emergency response systems, but processing data at the edge introduces challenges in minimizing latency to meet stringent healthcare requirements.

Security and privacy concerns are critical due to the sensitivity of healthcare data. MEC introduces vulnerabilities, requiring secure edge infrastructure against cyber threats while preserving patient information confidentiality. Scalability becomes challenging as healthcare systems grow in terms of connected devices, data volume, and concurrent users. Balancing the benefits of MEC with associated costs poses a challenge, especially for smaller healthcare providers with limited resources. Determining data governance models and ownership rights in MEC environments becomes complex, involving multiple entities such as healthcare providers and technology vendors. Ethical considerations arise in MEC deployment, requiring adherence to informed consent, transparency, and responsible use of patient data. Designing user-centric healthcare applications at the edge to meet the diverse needs of healthcare professionals and patients becomes a crucial challenge.

Finally, overcoming challenges related to the integration and deployment of artificial intelligence models at the edge for intelligent health monitoring, including model size, accuracy, and computational efficiency, requires a multidisciplinary approach. Collaboration between technology experts, healthcare professionals, policymakers, and regulatory bodies is essential. Innovative solutions and best practices will be crucial to overcoming these challenges and maximizing the benefits of edge computing in healthcare. A summary of challenges discussed in this section, especially the integration of MEC into healthcare systems, is represented in Fig. 2.

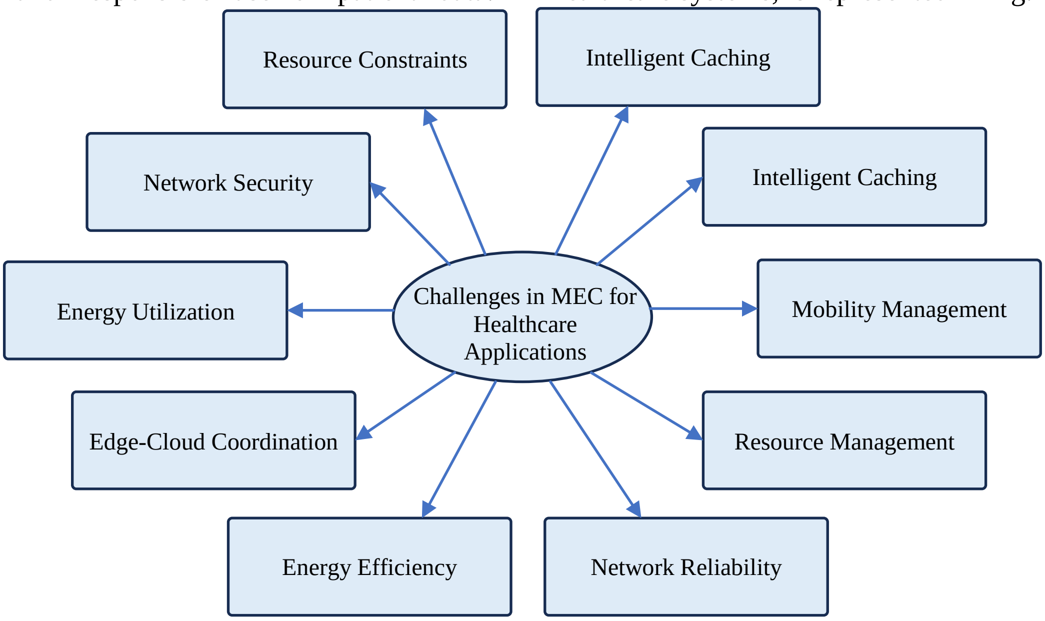

Fig. 2 Challenges in mobile edge computing for healthcare applications (The authors)

4. Research Directions

In addressing the challenges presented by MEC in smart healthcare systems, various research directions emerge to propel innovation and enhance the integration of MEC in healthcare applications. Most of these tend to focus on optimizing latency in healthcare applications at the edge. Investigating novel algorithms and techniques aims to minimize latency, thereby enhancing the responsiveness of critical healthcare systems through real-time processing optimizations. Additionally, there is a need to enhance security protocols for healthcare data within MEC environments. This involves the development and evaluation of robust security frameworks tailored specifically for healthcare data, addressing vulnerabilities, and exploring encryption methods to ensure the confidentiality and integrity of sensitive information.

Another vital research direction involves scalable architectures for growing healthcare infrastructures. Researchers need to delve into scalable edge computing architectures and resource allocation strategies that can accommodate the increasing number of devices and applications in smart healthcare systems. The exploration of solutions for seamless scalability without compromising performance is crucial for the sustainable growth of healthcare infrastructures. Integration of Edge AI for Intelligent Health Monitoring is also a key area of focus, investigating the potential of edge-based artificial intelligence models. This entails exploring applications such as predictive analytics, anomaly detection, and early intervention using machine learning algorithms at the edge to advance intelligent health monitoring.

Efforts should also be directed toward energy-efficient edge devices tailored for healthcare applications. Research in this area aims to explore energy-efficient design principles and investigate hardware and software optimizations. The goal is to prolong battery life, reduce energy consumption, and enhance the overall sustainability of edge devices in healthcare scenarios. User-centric design principles for healthcare applications at the edge represent another crucial research direction. Investigating the needs and preferences of both healthcare professionals and patients is essential to enhance the overall user experience and promote the adoption of edge technologies in healthcare settings. Proposing interoperability standards and protocols for edge healthcare systems is a significant research direction to facilitate seamless communication between diverse healthcare devices and systems at the edge. This involves promoting a unified and efficient healthcare ecosystem through standardized interfaces. Ethical considerations in MEC for healthcare form another critical area of investigation. This research direction requires an examination of ethical considerations related to data consent, transparency, and responsible deployment, ensuring alignment with ethical standards and regulations.

The role of human-machine collaboration in healthcare decision-making processes at the edge represents a noteworthy research direction. Exploring how edge computing can augment healthcare professionals' decision-making capabilities and improve patient outcomes is vital for the successful integration of MEC in healthcare. Lastly, the research direction of Edge Computing for Personalized Healthcare delves into exploring the potential of MEC in enabling personalized healthcare. This involves investigating how edge computing can support the customization of treatment plans, drug regimens, and interventions based on individual patient data.

In summary, these research directions collectively aim to address the identified challenges and open new avenues for innovation in the integration of MEC in smart healthcare systems. Researchers exploring these directions can contribute significantly to the advancement of technology, improvement of healthcare delivery, and the fostering of a more efficient and responsive healthcare ecosystem. Fig. 3 illustrates key research directions for advancing MEC in smart healthcare systems.

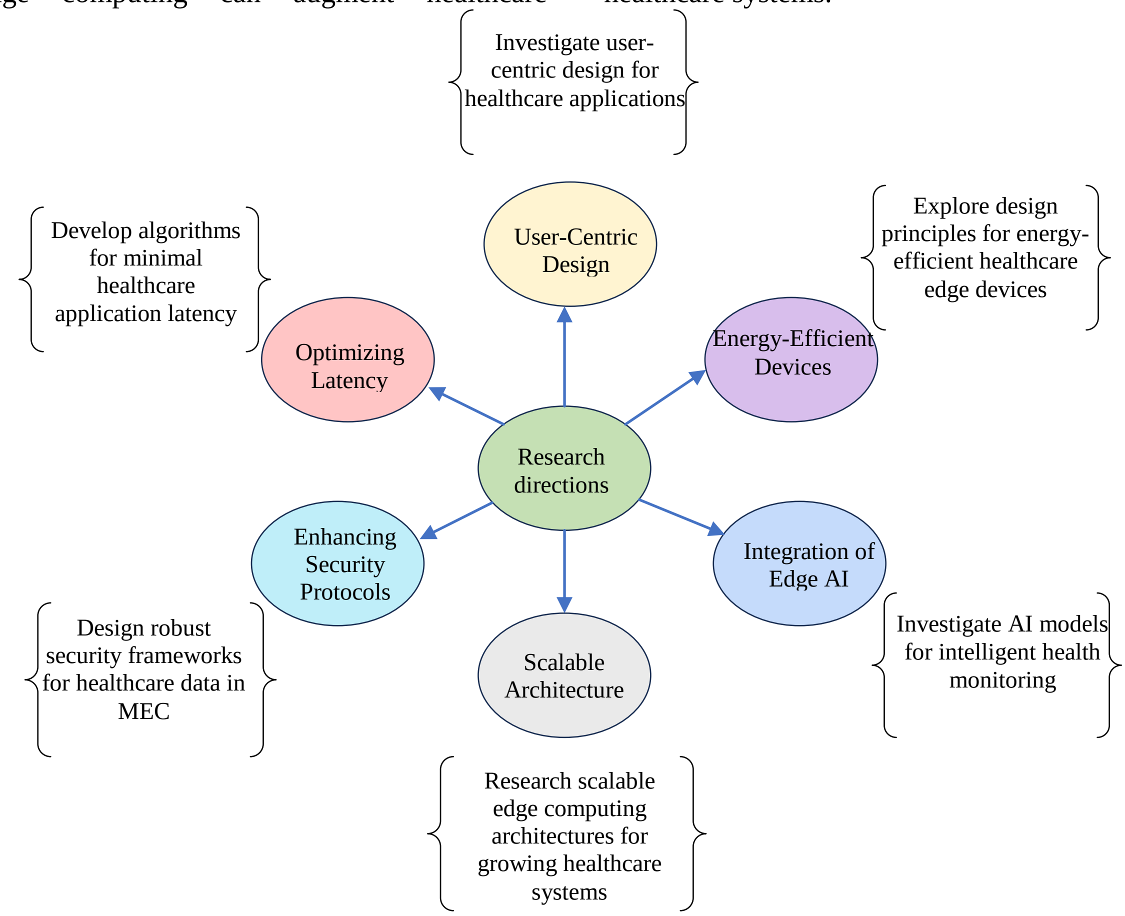

Fig. 3 Research directions for MEC in healthcare systems (The authors)

5. Conclusion

The integration of MEC into smart healthcare systems reveals transformative potential alongside formidable challenges. Addressing critical issues such as minimizing latency, fortifying security, and managing scalability underscores the complexity of MEC implementation. The research directions provided in the article offer targeted solutions, ranging from efficiency optimization to ethical considerations, providing a roadmap for future investigations. Collaborative synergy among academia, industry, and policymakers is paramount to overcoming these challenges. Embracing these opportunities can positions MEC as a catalyst for revolutionary advancements in healthcare technology. By strategically addressing critical issues and adhering to the right directions, we envision a future where healthcare services seamlessly blend efficiency with user-centric design, benefiting the patients and healthcare professionals.

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