A Survey of SDN Enhanced Edge Computing and its Enabling Technologies

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Abstract— **The rapid advancement of Information and Communication Technologies (ICT) and the forthcoming implementation of the Internet of Things (IoT) are driving the vision of smart healthcare. However, the rigidity of current network designs makes it challenging to meet the growing demands of the healthcare sector. These challenges can be effectively addressed if network devices can be managed end-to-end across diverse heterogeneous components, topologies, and communication protocols. Software-Defined Networking (SDN) has emerged as a prominent technology because it offers a programmable and flexible network design that provides end-to-end visibility and control over the network. To meet real-time healthcare needs, edge computing utilizes distributed local resources for critical computations instead of relying on centralized cloud services. This study introduces an SDN-edge enhanced healthcare framework for Ambient Assisted Living (AAL) applications, highlighting both the advantages and limitations of smart healthcare systems. The benefits of the proposed framework are discussed, along with potential new research opportunities in smart healthcare.**

Keywords— Ambient Assisted Living, Edge Computing, Internet of Things, Quality of Service, Software-Defined Networking, Smart Healthcare

I. Introduction

In recent years, the world has witnessed another technological revolution in the smart healthcare industry with the growth of the IoT. It is estimated that the proliferation of the installed base of devices connected to the IoT is about to reach 30.9 billion units by 2025 [1]. Specifically, the global IoT medical gadgets or wearable’s market is projected to reach $94.2 billion by 2026 [3]. In 2017, major wearable competitors such as Apple, Fitbit, and Xiaomi accounted for nearly 115.4 million units [2]. The Internet of Things (IoT) connects disparate devices ranging from smart phones to home appliances, and from industrial systems to ordinary people [7]. The developments in cloud computing enabled availability across these IoT objects to allow various functions such as sensing, actuating, processing, and storing data. The data is utilized for classification, analysis, and interpretation. IoT is promoted in a wide range of real-time and pervasive zones like cognitive assistance [19], smart home [20], industrial automation [39], smart healthcare [14], [15], etc.

Recently, smart healthcare has realized that there has been an expanding interest in creating effective and practical medical care arrangements that encourage healthcare centers and professionals to provide patient-centric services [9], thus benefiting not only patients but the administration staff and hospitals as well. It involves a framework integrated with wearables, biomedical or assistive devices, medical centers, and hospitals, in which full access to patient information is guaranteed through the internet [14]. The evolution of smart health monitoring devices combined with improved connectivity in the IoT communication infrastructure has led to the development of remote healthcare applications for low, medium, and high-risk patients. The IoT-enabled health monitoring framework is a keystone healthcare technology that provides constructive and preventive remote health interventions [15]. This innovative application comes to fulfill the quality of service (QoS) demands of growing business and reduce the high medical costs. It interconnects accessible medical resources and delivers smart, secure, and affordable healthcare services.

Traditional network infrastructure lacks the ability to implement high-level network policies and manual command-line interfaces, thus becoming a hurdle in healthcare networks. To react to the real-time critical scenarios in the medical field intelligently, various technologies such as edge computing [8], cloud computing [36], machine learning [34], deep learning [35], SDN [4], NFV [7], blockchain technology [12], etc., can be integrated. These technologies assist advancement in the healthcare modernization process. Smart healthcare achieves several benefits compared with traditional healthcare practices, as follows: 1) Meeting individual QoS requirements; 2) Enabling early detection of critical diseases and more personalized treatment processes; 3) Achieving low latency services; 4) Enabling emergency response, and 5) Avoiding long-distance transportation for life-critical patients.

Edge computing [8], an emerging technology, is considered a boon to integrated service frameworks like smart healthcare. It distributes its applications and services near to the end-users by utilizing the dispersed compute, storage, and networking capabilities of the network edge. Therefore, it is able to provide low delay, high network bandwidth, and emergency response to real-time use cases. On the other hand, traditional network infrastructure, which consists of application- and vendor-specific networking devices such as switches, routers, and gateways, are difficult to reprogram with multiple rules to promote optimal network services [5]. The healthcare industry is rolling out new innovations and services to achieve low latency while handling an increasing number of healthcare users. As a result, conventional technologies are ineffective at adapting desired policies to satisfy the QoS requirements of time-critical applications like healthcare.

SDN (Software-Defined Networking) is a paradigm shift that has emerged as the future of networking in both wired and wireless communication systems [6]. It is a programmable technology to design, build, and manage networks by transforming conventional black-box network elements into white-box ones [4]. The separation of the control plane from the data plane of hardware-oriented switches simplifies network management, optimization, and configuration with the centralized topology view of the network. Furthermore, the programmable feature of SDN encourages the potential for addressing heterogeneity and interoperability in IoT, thereby providing QoS. Because of SDN's unique control and data plane separation, healthcare devices can be monitored very efficiently and remotely. Edge computing can be coupled with SDN to reduce the management complexity of the network and avoid bottleneck issues of a single SDN controller by having multiple controllers in scattered edge servers [16], [17].

To provide reliable and effective healthcare services at the individual and clinical levels, the SDN integrated Edge computing framework is promoted for the smart home or AAL use case. AAL focuses on several services to allow people to have an autonomic life while monitoring their daily health status. It derives the advantages of both technologies to achieve QoS, reliability, interoperability and scalability. The major contributions to this paper are as follows:

1. A short description of the AAL or smart home use case, associated services, and its features is given. In addition, the benefits and the challenges of AAL in IoT impacting the healthcare ecosystem are discussed.
2. An SDN-enhanced edge IoT architecture for AAL is proposed inheriting the advantages of both technologies to overcome the challenges addressed in smart healthcare
3. The complementing technologies assisting the IoT networks are explored in terms of various aspects of the healthcare framework. Future research directions in the field of smart healthcare are presented.

The rest of this article is organized as follows. Section 2 presents a state-of-the-art survey and the motivation for this survey. Section 3 outlines the AAL environment and its features, advantages, and challenges in the IoT. An architecture integrating SDN and edge computing technologies for smart healthcare is discussed in section 4. In Section 5, various enabling technologies that assist the healthcare IoT with respect to multiple aspects are studied. Finally, we conclude this review in section 6.

II. STATE-OF-THE-ART SURVEY

This section focuses on existing surveys related to SDN and edge computing domains and derives the necessity for this review. Researchers have been interested in SDN and edge computing in recent years for developing tailored healthcare IoT applications.

Rushit et al. [8] provide a literature survey on how edge computing behaves as a driving force in enhancing the quality of services in the healthcare sector and other real-time IoT applications. The distributed edge computing-related IoT architecture for healthcare systems is elaborately surveyed in [9] along with its research opportunities and challenges that remain unaddressed.

A comprehensive survey of the AAL platform and all its essential quality attributes is presented in [10], targeting the end-users, especially the elderly population. It handled the interoperability feature as well, integrating manufacturer-differing medical devices and wearable gadgets for measuring the vital parameters of senior citizens. Another review of AAL technologies, sensors, and various methodologies for data analysis is discussed in [11]. The data collected from AAL is of various types, such as medical, ambient, activity, and behavior-related, and thus analytics and interpretation are required. Thomas et al. [13] concentrated a study on the various domains and requirements of AAL systems. Adoption of novel technologies such as SDN, NFV, and cloud technologies can benefit the AAL environments.

The works in [12], [18] present a systematic review of blockchain and SDN features suitable for healthcare applications and how the issues of security, privacy, and integrity of medical data are preserved. The applicability of emerging technologies such as WBAN, blockchain, SDN, NFV, and edge computing in the smart healthcare sector to improve the quality of service is reviewed in [14], [15]. In addition, the challenges involved in implementing IoT-based healthcare services are discussed.

The integration of SDN and edge computing paves the way for a lot of improvements to IoT frameworks, and the benefits are investigated in [16], [17]. To deal with the rising business requirements of diverse IoT applications, it can be beneficial to construct dynamic, programmable, managed, and adaptive networks.

From the discussion of the state-of-the-art, we can identify the various aspects and technologies involved in healthcare IoT. However, there are a number of comprehensive surveys that explore these technologies as standalone systems or a combination of a few technologies, as reported in Table I. This research, on the other hand, attempts to combine edge computing with SDN and all of their related technologies, as well as provide an assessment of their potential use in future healthcare systems.

III. AMBIENT ASSISTED LIVING (AAL) IN SMART HEALTHCARE

This section elaborates on the advantages of smart healthcare and discusses AAL use case scenarios in healthcare ecosystems.

With the massive adoption of IoT technologies, smart healthcare offers various patient-centric advantages, as follows: 1) ensuring QoS for each user; 2) achieving early diagnosis and timely therapeutic intervention for critical or chronic diseases or disorders; 3) achieving dependable and low-latency healthcare service at the patient and clinical levels; and 4) enabling emergency response for critical patients.

TABLE I. COMPARISON OF THE STATE-OF-THE-ART FOR AAL IN SMART HEALTHCARE

Paper	SDN	AAL	Edge Computing	AI, ML, and DL	Blockchain	Healthcare	NFV
[8]			Y			Y	
[9]			Y			Y	
[10]		Y					
[11]		Y		Y			
[12]	Y				Y	Y	
[13]	Y	Y					Y
[14]	Y		Y		Y	Y	Y
[15]	Y		Y		Y	Y	Y
[16]	Y		Y				
[17]	Y		Y				
[18]	Y				Y	Y	
Proposed	Y	Y	Y	Y	Y	Y	Y

Aging decreases physical activity, social, cognitive, and mental functions, and global spontaneity of movement. Monitoring lifestyle changes and suspicious behaviour is helpful in the early onset of neurodegenerative diseases [10]. AAL is intended to develop innovations in terms of products and services to keep people connected to ensure their active and healthy lives. It is meant to monitor the elderly, people with diseases or disabilities, and healthy independent-living individuals to reduce their regular physical assistance and prolong their autonomous life [11].

AAL functions include methodologies ranging from the activation of simple alarms when monitoring parameters fall out of range or during critical events such as falls, environmental dangers, excessive ambient heat or cold, prolonged inactivity, and so on, to complex behaviour analysis that allows for the early detection of risk factors for functional decline [13]. Some of the services associated with AAL for disease management and behavioral change management are sleep monitoring, fall detection, diabetes control, depression treatment, hypertension control, medicine and diet adherence, psychological support, smoke or fire detection, calorie intake monitoring for diet and exercise, and physical activity level monitoring. AAL further affords vital parameter monitoring, remote monitoring, telemedicine and teleconsultation, video consultation sessions with medical professionals, patient geolocation awareness, medicinal product procurement monitoring, and the electronic storage of patient records [10], [20].

To offer timely intervention and reduce the risk factors of diseases or critical events, continuous monitoring of biological and environmental data and assessing their outcomes is accomplished in AAL. For example, wandering and cognitive impairment are common risks found in the elderly with dementia. In these scenarios, the main objective of AAL systems is to assist them by preventing them from wandering away, providing route guidance to their homes, evaluating motion and abnormal activities, and so on.

The AAL environment is composed of different kinds of sensors or devices to sense the individual health data or environmental data. They are categorized as 1) medical gadgets aiding disease diagnosis, prevention, monitoring, and treatment, 2) ambient sensors such as motion capture sensors, surveillance or monitoring cameras, smoke detectors, smart home appliances, and 3) interactive devices aiding human-application or human-environment interaction through smartphones, speech recognition devices, wearable devices, etc. [11]

The following are the advantages of AAL for the independently living elderly or those who require constant monitoring.

1. Varying types of applications require different levels of service, such as high bandwidth and low packet loss or latency [13]. In that case, service level agreements between stakeholders and network service providers have been executed.
2. In AAL systems, reusability of already installed network elements such as set-top boxes, gateways, mobile phones, and PCs, as well as remote or over-the-air upgrades and dynamic software downloads to roll out new features, are all feasible [10]. It leads to a low infrastructure setting and operational cost.
3. Efficient user-friendly interface to enhance usability among diseased or disordered patients, the elderly, and senior citizens who may not be aware of the technology [13].

However, some challenges, such as those described below, go unmet, reducing the healthcare ecosystem's favorable impacts.

1. Sensor Interoperability: In healthcare systems, different types of sensors, special-purpose gadgets, and smart devices developed by different vendors work under a common umbrella, which leads to interoperability issues. Such challenges must be adequately addressed in order to provide a continuous flow of information that allows for the aggregation of healthcare services to produce

meaningful results [13].

2. Data security: Privacy and security of the sensor data in remote monitoring applications have to be ensured without disclosing the actual identity of the patient while transmitting via the public network [11].
3. Sensor Characteristics: The data produced by the sensor and the transmission protocol it follows are of various types. On the other hand, most of the sensors produce continuous data. To avoid the network becoming overburdened with superfluous large amounts of data, it can be transferred several times: upon request, in the case of an abnormal event, or continuously [13].
4. Decentralization: Healthcare systems are rapidly moving towards a distributed patient-centered model where patients and doctors use body sensors, smart devices, smartphones, cyber-physical devices, and high-end communication technologies so that patients can be treated from any location with the same confidence and support under the surveillance of medical professionals [10].
5. Real-time capability: The real-time monitoring of patients from a remote location to provide the exact amount of medication is required to maximize therapeutic effect and is an essential requirement of the healthcare ecosystem [11].

IV. SDN-BASED EDGE IOT FRAMEWORK FOR AAL IN SMART HEALTHCARE

In this section, a framework combining edge computing and SDN is proposed and discussed to solve the foregoing issues in AAL environments and to successfully enjoy the benefits of smart healthcare systems.

At the forefront of transformation, the healthcare sector is data-rich and digitizing every aspect with IoT and analytics to offer the best remote patient care. The bigger difficulty is ensuring the security of cross-platform communication solutions while injecting a consistent yet healthy dose of next-gen technologies into smart healthcare delivery systems.

A. Edge Computing

The edge computing model sets up cloud resources for networking, storage, and computing at the edge of the network, with one or a few hops from the end-users. It deploys the services close to the consumers [8]. Edge capabilities provide high network bandwidth by lowering data transfer to the cloud, local data processing and storage, low latency with fast response from adjacent services, and dependable network management all within the same network premise. Edge computing is an extension of cloud computing, rather than its replacement. Its platform allows user mobility, location and content awareness, close proximity to the users, and data and device heterogeneity [8], [9].

In spite of the above-discussed benefits of edge computing paradigms as standalone systems, there are some issues to be highlighted. 1) complex resource allocation and scheduling in the face of increasing and dynamic network resource demands; 2) heterogeneity poses challenges to dynamic routing methods and achieving optimal network utilization, and 3) complex network management of heterogeneous infrastructures at the edge.

B. SDN

SDN technology, a novel paradigm, promises significant flexibility and manageability of the whole network through the virtualization of network device functions to suit the requirements of the network in real-time [4], [5]. The main drive behind the philosophy of SDN is that network intelligence is decoupled from hardware pre-programmed and application-specific networking devices and logically centralized in a software-based device called a controller (control plane), with an abstraction of the network infrastructure. To enable less complex network structures, SDN has well-defined open interfaces between the controller, the application, and the data plane. The network control plane can be realized as freely programmable software, which can be defined as a network operating system, using these interfaces [6], [7].

By fixing those constraints, namely manual configurations via command-line interfaces, monitoring, protection, usability, and functionality, SDN replaces existing, inescapable, and complicated networks. Therefore, it leads to efficient energy utilization, improved resource allocation and management, and enhanced security and privacy [38]. It facilitates network users with efficient use of network resources and resource provisioning [37]. The control plane also takes care of routing and fault recovery when the switch sends the packet to it [4], [5]. There are several benefits offered by SDN [12], [26], particularly for healthcare providers, which include:

1. Centralized network provisioning and management: Healthcare organizations may supply all of their network resources in all required locations using a centralized SDN controller, saving time and money by lowering the amount of staff required at each medical center.
2. Better security through improved control: Centralized management of SDN eases the implementation of security policies over the network. It can ensure security for all devices connected to the network and add additional security to critical data like protected personal and medical records.
3. Application performance control: Centralized data traffic management and control ensure that critical data, such as abnormal vital signs or disease diagnosis information, are prioritized and delivered first.
4. Lower network operating costs and administration costs at the hospital or organization level
5. Lower network equipment costs with the externalization of the control plane and reusability of existing vendor-independent network elements.

C. SDN-Edge Framework for AAL

To inherit the advantages of both SDN and edge computing, an SDN-edge architecture is introduced for the AAL scenario in healthcare ecosystems. As shown in Fig. 1, four layers are observed: (1) the IoT access layer, (2) the edge layer, (3) the virtual management layer and (4) the cloud layer

1. IoT access layer: Gadgets or sensors to gather health data, behaviours, activities, ambient temperature, pressure, and humidity, or smartphones are attached to a sink device. They interact with the sink device by forwarding all their data through short-distance communication standards such as WiFi, ZigBee, LoRA, Bluetooth, etc. These devices are securely connected to the network and their secure data transmission is performed with a smart contract scheme using blockchain. This layer is the first layer in the data plane in SDN architecture.
2. Edge layer: Home gateways and edge computing servers to capture, filter, compress, and analyze raw sensor data act as edge nodes, through which the cloud services are delivered to end-users. They act as gateways between healthcare devices and services deployed in the cloud. They have local computing and storage capabilities to apply learning models. Edge gateways possess routing tables with entries about how to treat the incoming traffic and the entries are configured from the SDN controller. This layer also contributes to the SDN's data plane and communicates with the control plane using southbound APIs. The predominant one is OpenFlow and the edge nodes are made certain to follow OpenFlow protocol.
3. Virtual Management layer: It forms the SDN's control plane and contains the centralized controller. It remotely configures the forwarding devices in the edge layer using southbound APIs. It communicates with the applications via northbound APIs, the most commonly used is RESTful. It offers various capabilities with a global view of the network such as service discovery, VM discovery, VM migration, load balancing, resource provisioning, fault recovery, security, traffic routing and optimization, achieving QoS and interoperability.
4. Cloud layer: Cloud servers belonging to various providers for long-term storage and analysis of data that is less time-critical, contribute to this layer. From the cloud storage, patients' data can be easily accessed via a user interface and medical history can be accessed by the medical professionals. This layer contributes to the application plane of SDN functionality. It facilitates multitenancy which means different applications can use the same network resources without viewing data of other applications or the network infrastructure can be shared virtually among different applications.

The proposed architecture enhances healthcare service performance in terms of delay and response time by enabling local data processing at the edge nodes. It reduces the energy consumption of low-powered biomedical sensors or wearables and network traffic by preventing the need to transfer the rich healthcare data to a remote cloud. Patient information like their location, network status, mobility, behaviour, and surrounding environment can be easily tracked with the framework. To deal with resource-constrained edge computing nodes, it streamlines load-balancing procedures through task offloading and service migration among other edge nodes or to the cloud layer.

V. ASPECTS OF SMART HEALTHCARE AND ITS ENABLING TECHNOLOGIES

This section discusses various aspects of the smart healthcare framework and how they can be ensured with the help of new emerging technologies such as blockchain, NFV, cloud computing, artificial intelligence (AI), machine learning (ML) and deep learning (DL) algorithms.

A. Features of the Healthcare IoT Framework

The following are the various aspects involved in an IoT-enabled framework for healthcare applications.

1. QoS

Guaranteeing QoS in terms of end-to-end delay and jitter for real-time medical applications is the foremost priority. In this context, delays can be minimized with the integration of edge computing technology with healthcare IoT networks. The computing resources at the edge layer have to be efficiently scheduled to process the healthcare tasks to improve QoS and reduce network latencies and bandwidth. So the tasks have to be assigned to the proper computing node, either the local or edge node, with the help of task offloading and resource allocation strategies [21]. The authors [22] introduced a QoS optimization algorithm in the mobile edge computing environment intended for remote and interactive healthcare services like Telesurgery.

In this edge technology, SDN plays a major role by supporting service discovery, load balancing, and optimal traffic routing between the edge and cloud. SDN enabled edge framework [23] designed a classifier to predict possible gait impairment and the leading cause of neurodegenerative diseases for remote gait monitoring services. It achieved ultra-low latency in the 6G network.

2. Scalability

The ever-increasing healthcare business poses challenges to supporting application scenarios with different scales. Though the edge paradigm is resource-restricted, efficient VM migration and dynamic task offloading methods are helpful to achieve scalability. With the centralized view, the SDN controller can provide better performance than traditional networking infrastructure [21], [22].

3. Reliability

Another key issue in a complex scenario like healthcare is the reliability of data collected from various heterogeneous sensors and providing differentiated services in an AAL environment. When data source and data processing are completed in the same network domain, data analytics at the edge node ensure the system's decision is reliable [19].

4. *Security, privacy, integrity*

To ensure the security, privacy, and integrity of medical data, a blockchain-based healthcare IoT framework [24] is proposed to access medical records with authorization control using public and private blockchains. It guarantees data replication and smart contracts for correct data access at the right time.

5. Interoperability

Medical data should be shared among various care providers so that they can work collaboratively. Existing

infrastructure is an enclosed domain that is hard to interoperate across multiple domains. The edge-basedplatform [20] for the AAL scenario guarantees a satisfactory level of interoperability among different IoT devices. To address scalability, flexibility, and interoperability requirements, it used both edge and cloud paradigms and supported a variety of communication protocols
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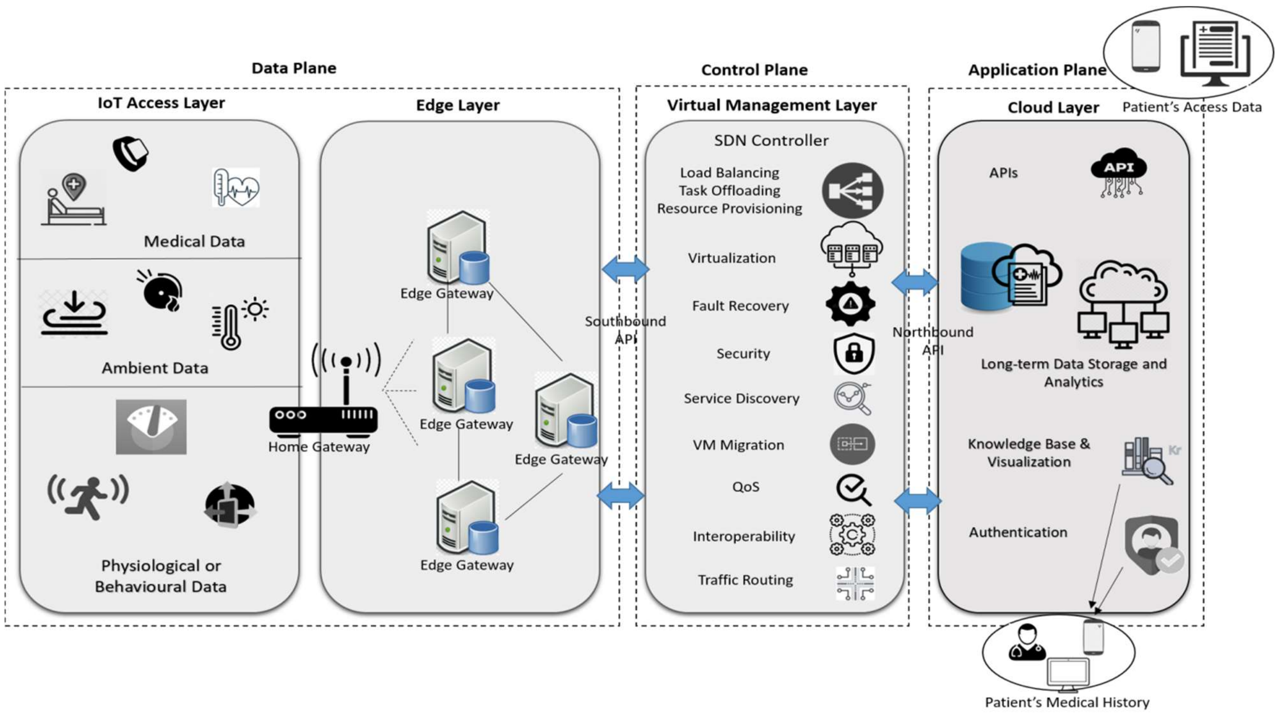

Fig. 1. SDN-enhanced Edge Architecture for AAL in Smart Healthcare

B. Enabling Technologies

1. Blockchain

In the healthcare industry, patient-related personal information, as well as health data, has to be transferred through the network securely and privately. During transmission, the security of the patients' health data should be ensured by prohibiting data injection and falsification by intruders. Blockchain can be a solution with its transparency and security. It can be applied to various healthcare services such as emergency traffic prioritization, network failure reduction, sharing of health data to avoid repeated lab tests for the same purpose, preservation of personal identity, prescription records, and lab test data [12].

Combining different technologies such as SDN, Edge computing, and Blockchain can be a solution with a direct positive effect, not only to ensure a trusted healthcare service but also to enhance interoperability of data and remove third parties for access control [29]. The SDN application and control planes are thereby used to enhance the security feature to facilitate protection. It also strengthens the security of the forwarding plane's centralized controllers and numerous networking devices.

To prevent critical medical data alteration, SDN and blockchain-based healthcare monitoring systems [29] were introduced to preserve the privacy of personal data and the authentication of medical data. The centralized controller is meant to distribute the security policies to all the network domains to securely monitor the data gathered from the distributed medical sensors. In the medical domain, a fog computing architecture merging SDN and Blockchain elements [25] maintained patient health parameters and protected transactions.

The resource-constrained fog environment has to be assigned optimally the computation-intensive tasks. In the absence of optimal task allocation, they might introduce considerable delays, which increase service response time and make them inappropriate for real-time applications. A secure and optimal task offloading algorithm [27] to implement a decision-making technique is presented for the IoT-based healthcare framework. The centralized and global control ability of the SDN controller intelligently schedules the tasks to the optimal node in the edge layer. A smart blockchain-enabled healthcare IoT network safeguards data from remote monitoring applications while simultaneously minimizing delay and communication overhead using a multi-objective optimization algorithm [28].

2. Artificial Intelligence

As the AAL environment involves a set of heterogeneous sensors, complex decision-making is a challenging task when integrating various sensor data sources. In view of this, artificial intelligence technology has been adopted to interoperate with various edge devices. A reliable and intelligent edge framework [19] is presented to support critical medical-related decision-making in a highly complex AAL fashion.

3. Machine Learning (or) Deep Learning

Machine learning algorithms can be incorporated to make real-time decisions with the help of end-to-end network visibility, supporting mobility and context awareness [31], [30]. Such application-specific customized algorithms will be useful in increasing the performance of response time with optimized management of network resources and security attacks.

The introduction of learning methods at different tiers of the IoT protocol stack is helpful in analyzing and interpreting data in the IoT network, as well as improving the performance of healthcare services. For security, error correction, and signal processing, machine learning is applied at the application layer. The learning algorithm anticipates traffic, distributes channel resources, and evaluates connection quality at the data link layer. Machine learning is used by several routing systems to find the best routes at the network layer. [33], [30]. It performs functions including resource management, data processing, and application optimization at the higher layers of the protocol stack [32].

SDN can be combined with machine learning techniques to make a network more intelligent and self-adaptive. The authors proposed an SDN architecture [34] using a machine learning technique to efficiently manage the network resources and to provide security for the clinical data. It utilized an optimal routing algorithm and an intrusion detection algorithm on the Internet of Medical Things network.

With the increased consumption of medical devices, the big healthcare data introduced into the conventional network seeks guidance from the deep learning and SDN paradigms. A deep learning-enabled classification and recommendation system [35] is presented to categorize and respond according to the criticality of a patient's health state to enable dynamic network management of real-time massive healthcare data transfer.

4. Network Virtualization

The network management challenge in traditional physical networks is being burdened by the expanding scope of the healthcare network. To make modifications to the network, you must first access and modify each device on the network. Only if it has complete control over the individual IoT devices, and if they are all from the same vendor, the required changes can be made to the application layer. With the integration of SDN and NFV into the IoT ecosystem, these responsibilities and associated issues are removed. It allows for the quick and easy creation, updating, and modification of virtual devices as needed. SDN allows for network configuration and maintenance to be done from a single location [36].

NFV offers dynamic and customizable network capabilities in this scenario. Virtualized dedicated functions are implemented in software and run on conventional hardware server. Not only may services on the Internet be created, but also components of the network architecture can be offered in a flexible manner, just like in the cloud. Features that are available and written in software can be used interchangeably on many hardware platforms, resulting in cost savings [7].

VI. Open Research Issues and Future Research Directions

This section summarises the different research disciplines that have worked with the enabling technologies to develop real-time healthcare IoT applications. The benefits of SDN and edge computing always open the door to new research directions in the healthcare sector.

As multiple fields with differing degrees of sensitivity are common in medical records, more advanced access control systems are required. As a result, standard all-or-nothing encryption algorithms fall short of meeting this criterion. Instead, the regulations are needed to allow for fine-grained access and privacy management, as well as sophisticated semantics. The use of attribute-based encryption is a viable option. Such encryption systems, on the other hand, currently impose a significant burden on user revocation. The solution to this challenge will have a significant impact on its applications [24].

The search efficiency of encrypted medical data should be better. Given the multi-domain collaboration in the medical business, query efficiency would be a barrier for encrypted medical information. It allows for keyword searches on encrypted data, avoiding the need for decryption and thereby improving query efficiency. However, the topic of how to efficiently make a query and obtain an aggregated query result from disparate and separately managed databases remains unanswered [24].

Software-defined networking is required to make domain management and collaboration easier. The SDN controller serves as a centralized control point for policy distribution. The disadvantage of concentrating control on one entity is that it creates a single point of attack. Furthermore, the SDN platform's programmability increases its security concerns. As a result, SDN-based healthcare data systems must consider how to correctly and safely build an SDN controller without adding too many complications [12].

VII. Conclusion

The IoT has been adapted into our daily lives in the form of AAL, smart homes, and remote monitoring applications, thanks to the widespread use of smart healthcare wearables and devices. Patients' vital health data is collected and shared via IoT devices all around the world. Emergency response is triggered in the event that an irregularity is detected. This is the foundation of smart healthcare, a new automated platform driven by IoT for remote patient monitoring and accurate diagnosis. Edge computing for real-time analytical computation and SDN for diverse and intelligent network operations are altering network architecture to satisfy expanding commercial demands. In this research, we present a picture of an SDN-integrated edge-IoT framework for providing clients with reliable and cost-effective healthcare services while addressing challenges that arise in real-world AAL scenarios. The authors describe some of the new technologies that empower healthcare ecosystems, as well as major future research prospects, in this paper. The integration of novel methodologies enables healthcare to evolve and extend to meet the users' and service requirements as a result of all of the studies considered collectively.

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