Towards fostering the role of 5G networks in the field of digital health

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ABSTRACT

A typical healthcare system needs further participation with patient monitoring, vital signs sensors and other medical devices. Healthcare moved from a traditional central hospital to scattered patients. Healthcare systems receive help from emerging technology innovations such as fifth generation (5G) communication infrastructure: internet of things (IoT), machine learning (ML), and artificial intelligence (AI). Healthcare providers benefit from IoT capabilities to comfort patients by using smart appliances that improve the healthcare level they receive. These IoT smart healthcare gadgets produce massive data volume. It is crucial to use very high-speed communication networks such as 5G wireless technology with the increased communication bandwidth, data transmission efficiency and reduced communication delay and latency, thus leading to strengthen the precise requirements of healthcare big data utilities. The adaptation of 5G in smart healthcare networks allows increasing number of IoT devices that supplies an augmentation in network performance. This paper reviewed distinctive aspects of internet of medical things (IoMT) and 5G architectures with their future and present sides, which can lead to improve healthcare of patients in the near future.

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1. INTRODUCTION

Fifth generation (5G) networks are new cellular networks technology and a successor of 1G, 2G, 3G, and 4G networks, 5G has different implementations: low band millimeter (mm) radio waves (600 to 700 MHz) with data transmission rate up to 250 Mb/s, mid-band mm radio waves (2.5/3.5 GHz) with data transmission rate up to 900 Mb/s and high band mm radio waves (24 to 39 GHz) with data transmission rate up to 3 Gb/s. Service area is divided into smaller geographical cells, the cell connects all 5G enabled wireless devices and provide them with both telephone and Internet services. The main advantages of 5G networks include, but not limited to, superior bandwidth (up to 10 Gbit/s), ultra-low latency and increased availability as shown in Figure 1 [1]. 5G will enable new applications in machine-to-machine (M2M) and internet of things (IoT) domains as they produce huge amount of data [2], [3].

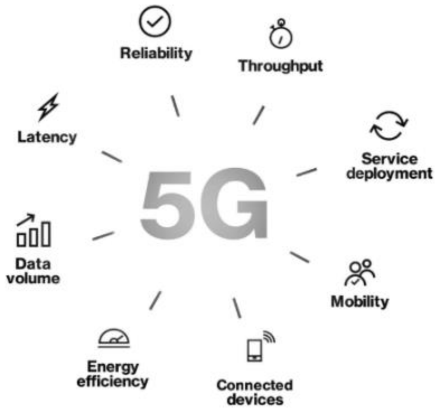

Figure 1. The main advantages of 5G networks

E-health term is an examples of eHealth services include electronic health records (EHRs), electronic prescribing, and other digital processes, communications, and technologies, it is used in a range of contexts. It may also include mobile health, or resources and programs for mobile devices. term implies virtually everything related to internet and computers usage in the medication, [4]; the internet of medical things (IoMT) is used where medical devices and sensors are connected to the internet and exchange data with healthcare centers and physicians. IoMT encompass both hardware components (sensors, routers, and servers), and software components and applications [5].

Figure 2 illustrates some possible prospects of E-health in the medical care [6]; E-health encompasses a wide range of services and systems such as [7]; electronic health record: enabling the electronic exchange of patient's medical record between different healthcare providers.

- Telemedicine: enabling remote identification and treatments, it also includes patient's vital signs telemonitoring.
- Mobile health: that uses mobile devices to collect data about patients' health.
- Healthcare information systems refer to software solutions for electronic patients' appointment scheduling and medical data management.
- Virtual healthcare professional teams: who work together and share medical and scientific information electronically.

Figure 2. Some prospects of e-health in the medical care

5G networks fulfill the requirements of highly dynamic and time-sensitive health care applications, tackle the distinct communication needs of E-health applications, and fulfills the E-health better network performance and superior wireless coverage. Also, 5G supports a substantial number of diverse devices, standardization, security, and energy efficiency. For situations of remote place far from urban area that do not have high quality healthcare centers, 5G networks share the medical services with healthcare centers remotely as illustrated in Figure 3 [8]. On the other hand, 5G and E-Health can rescue life by enabling physicians to diagnose medical cases, describe medicines to patients faraway or during transmitting them by ambulances [8], [9].

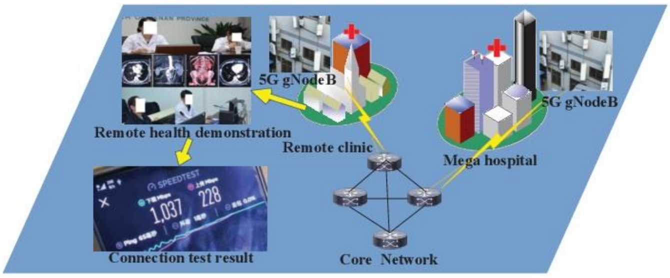

Figure 3. E-health and 5G network

This review paper summarized the cases concerning the integration of 5G wireless networks in the healthcare domain. Also, highlighted the availability of 5G technologies, present and future research trends, challenges, interests, and appreciation of 5G and healthcare. It also reviewed state of art, opportunities, and cutting-edge perspectives of this integration.

Scopus platform data source and analysis tools such as VOSviewer [10], [11] were used to explore the scientific publications related to 5G, IoMT. Many keywords mentioned in this paper were used such as 5G, internet of things (IoT), machine learning (ML), and artificial intelligence (AI). In addition to software-defined network (SDN) and network function virtualization (NFV), mobile cloud computing (MCC), wireless software defined networks (WSDN), wireless network function virtualization (WNFV), and mobile edge computing (MEC). Figure 4 indicates that these topics got more attention recently, in particular from 2017 to 2022 date range. After that, using analysis option provided by Scopus platform, Figure 5 shows where and when different publications got published, recent papers mainly published in IEEE access, IEEE IoT, and Advances in intelligent systems and computing.

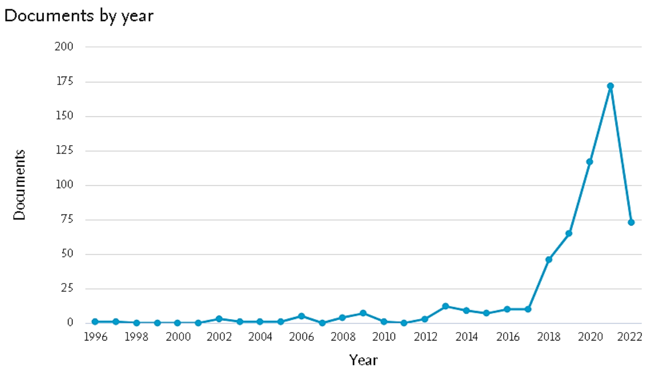

Figure 4. Documents by year

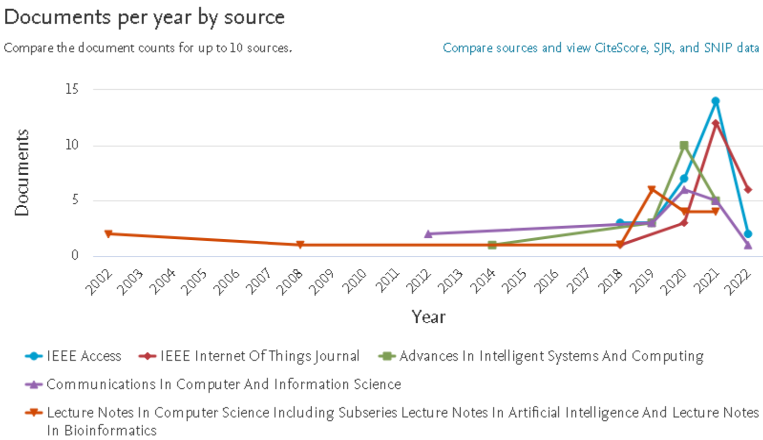

Figure 5. Documents per year by source

Mainly, the explored publications tackled computer science and engineering subject areas as shown in Figure 6. To get more insights, VOSviewer was used to analyze data collected from Scopus; Figure 7 shows density clusters of co-occurrences of keywords, about four-five clusters were distinguished and highlighted by following colors: green, red, blue, cyan, and oily. In addition, several labels were observed such as 5G mobile communication system, IoT, deep learning, edge computing, queueing networks, and reinforcement learning; Table 1 summarizes the clustering of co-occurrences main keywords in the context. For further exploration, a network diagram was used to depict connections between keywords; seven clusters and their connections were identified as shown in Figure 8.

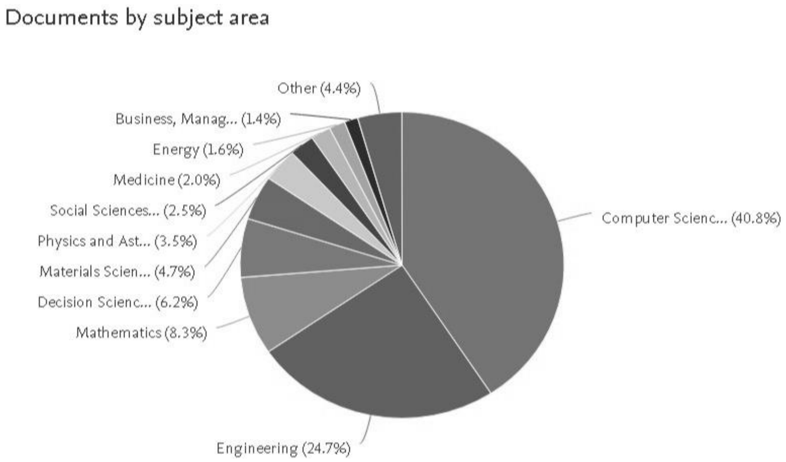

Figure 6. Documents by subject area

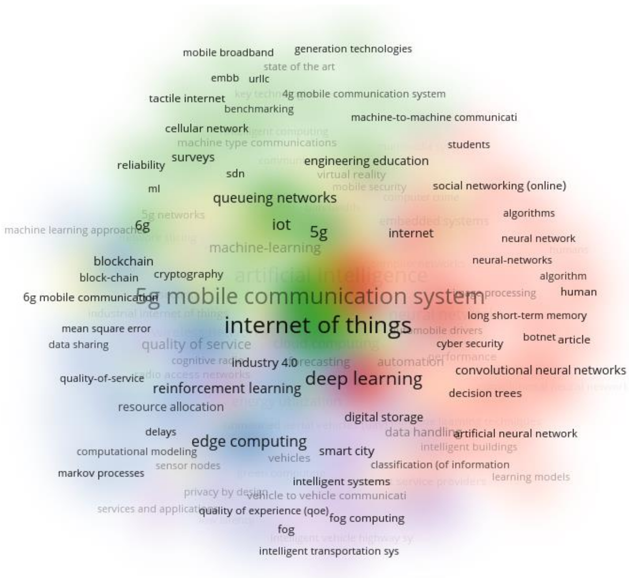

Figure 7. Density clustering of co-occurrences of keywords

Table 1. Clustering of co-occurrences keywords

Custer #	Most observed keywords	Cluster color	Total items
1	ML and deep learning	red	54
2	5G mobile communication system internet of things 5G IoT	green	50
3	Edge computing, wireless networks, blockchain	blue	50
4	Artificial system, learning system, learning algorithms	oily	44
5	Internet of things, network architecture, reinforcement learning, data storage, smart city	purple	37
6	Data analytics	cyan	15
7	Big data	orange	8

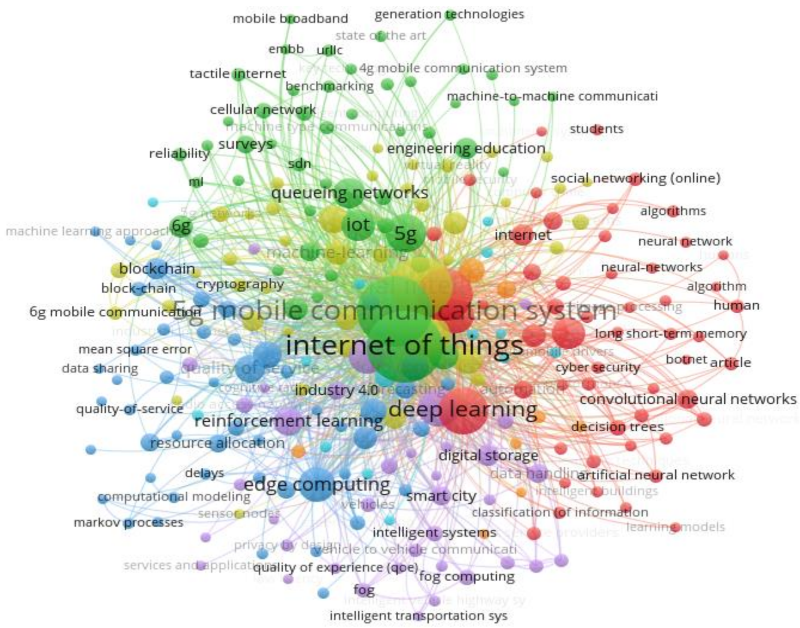

Figure 8. Network diagram of co-occurrences of keywords

2. 5G AND SMART HEALTH ENABLED TECHNOLOGIES

The dispersed patient-focused paradigm of smart health care is quickly replacing the old specialist and hospital-focused model. Numerous technical innovations have aided in this speedy change in the healthcare sector. Currently, 4G and other industry communication protocols are used by smart healthcare services and applications. Numerous applications are expected to produce vast amounts of data in numerous types and sizes as the health care industry grows. With regard to end-to-end delay, bandwidth, latency, and other aspects, such enormous and varied data demands specific management. Future applications in the health care industry will need to be extremely dynamic and time-sensitive, which will be difficult for current communication technologies to handle. 5G networks are being developed in order to meet the various connectivity needs of IoT applications used in the field of healthcare. 5G supported smart health care networks, which are made up of an assortment of IoT devices, require improved network performance and increased cellular coverage. In this review study, papers' themes are classified based on 5G and smart health (S-health) enabled technologies and classified by special application domains of S-health utilizing 5G networks.

2.1. Core technology

Long range (LoRa) and narrow band (NB) IoT network use cases in a healthcare were described in [12]. A description of the actions and challenges of deploying a long-term evolution (LTE) network at a healthcare center, LTE were used by both LoRa and NB IoT sensors to send medical records using the 5G network to the final desired data storage location. New circular polarized sensors and antennas for E-health systems were proposed in [13], where Sabban proposed to use an energy harvesting unit that was connected to the circular polarized sensors. The energy harvester collects RF waves circulating in the air and converts them to direct current (DC) power to recharge the medical wearable sensors and devices.

2.2. Security architecture for S-health

A security awareness 5G smart healthcare and the associated protection structure was proposed in [14], the proposed architecture is a zero-trust architecture for smart medical systems based on 5G. The proposed architecture considered four security dimensions for 5G smart healthcare, those dimensions are: i) subject: deals with users' applications, terminals; ii) environment; iii) behavior; iv) object: deals with platforms and services. Authors reported that their proposed zero-trust security still poses challenges from the implementation, difficulties, and growing community awareness.

Deep neural network (DNN) with convolution neural network (CNN) for providing S-health security was proposed in [15]. The proposed new deep learning model (CNN-DMA) was used to detect malware attacks based on a CNN classifier. The model used three levels: flatten, dense, and dropout. To train the model, batch sizes of 64, 20 periods, and twenty-five classes were used. For the first convolutional layer, an input image of 32 X32 X1 was used; the achieved accuracy of the proposed model was 99%.

Comprehensive security analysis and privacy threat identification for IoMT medical data was presented in Koren and Prasad [16], where authors focused on general data protection regulation (GDPR). They highlighted possible IoMT security threats: weak IoMT cryptographic systems, bargained or rogue IoT devices, eavesdropping of communication channels. Therefore, medical data could be theft from IoMT devices and IoMT devices signal jamming; the authors also underlined possible general security solution ideas and some open security questions.

2.3. Utilizing blockchain in S-health

Utilizing blockchain in S-health can deliver technological solutions to medical health records challenges such as security, integrity, and interoperability. Using blockchain, data can be encrypted to prevent unauthorized data revealing. In addition, blockchain can lower data fraudulence by computerizing most of the claim mediation and financial transactions events. Medical data records transaction can by tracked by logging any activities of medical prescriptions and medications.

Viable model for promoting the S-health applications was proposed by Capossele *et al.* [17], they discussed the S-health present challenges, and explored the role of blockchain to tackle some of the challenges. The authors analyzed the estimation of 148 articles published between 2016 and 2020 in 76 academic journals. The review results demonstrate that the number of articles devoted to the study of blockchain applications and smart cities has increased exponentially in recent years.

Blockchain with elliptic-curve cryptography (ECC) algorithm was the base of proposed system in Helen and Senthilsingh [18] to secure S-health data together with 5G networks for vast transmission rates. Patient's medical data is examined remotely using IoT sensors. These data in turn were stored in the cloud using blockchain and ECC to prevent data forgery. The architecture diagram used objects such as hospitals, patient, and cloud storage. The proposed S-health system was more secure compared with Diffie-Hellman and Rivest-Shamir-Adleman (RSA) as stated by the authors.

2.4. Edge computing

Tang *et al.* [19] proposed S-health architecture based on 5G networks; it combined both the healthcare networks and multi-access edge computing (MEC). They presented industry multi-access edge platform (iMEP) and industry gateway (iGW) as new network elements. The proposed architecture used the iGW as the core and improves the most recent technical architecture standardized by Third Generation Partnership Project (3GPP) and European Telecommunications Standards Institute (ETSI) about the integration of 5G and MEC for different S-health deployment setups. Likewise, the network architecture fulfilled all-around S-healthcare deployment setups; the performance of the proposed architecture was significantly acceptable.

Edge computing and 5G network were leveraged to produce cross spectral generative adversarial network (CSGAN) as a real time fever screening technique [20]. The proposed method is used for combination and orientation of cross-spectral image and thermal data streams. The CSGAN had two novel key characteristics: the first is feature-preserving loss function that produces high quality pairing of corresponding cross-spectral pieces, and the second is dual bottleneck remaining layers with skip connections. The authors stated that their proposed system achieved 98.5% accuracy.

A multi-layer 5G mobile edge computing (MEC) positioned E-health system was proposed in Wang *et al.* [21], where authors firstly studied existing frameworks for wearable devices in 5G E-health applications and challenges; then presented a multilayered-system for integrating medical wearable sensors with open-source electronic medical records (OpenEMR). The proposed system is composed of four layers: IoT, MEC, network, and application layers. Finally, they used the proposed system to detect atrial fibrillation.

Multi-access edge computing (MEC) moves the computing of traffic and services from a centralized cloud to the edge of the network and closer to the customer. Instead of sending all data to a cloud for processing, the network edge analyzes, processes, and stores the data essentials such as the architecture, its enabling technologies SDN NFV certain disputes and resource management were studied by Chakraborty and Sukapuram [22]. They also explored future research in the field of urban computing: urban information systems (UIS).

2.5. Authentication of S-health using 5G networks

Fuzzy evolutionary model to improve transfer authentication was proposed in [23], where fuzzy logic used to provide the assignment and key management authentication performance in 5G networks based on nanocore technology. The proposed model aimed to minimize the complexity and delays during authentication in 5G networks and mitigated authentication attacks when it is trained properly with the related attack datasets. Simulation results showed that the proposed method is effective in improving authentication performance and in attacks mitigation for S-health purposes.

A three phase authentication lightweight authentication protocol for E-health was proposed in [24]. The proposed authentication protocol intended to defeat the weaknesses of existing authentication protocols; the proposed protocol composed of three phases: registration, login, and authentication. The casual security analyses show that proposed protocol repels main known security attacks.

2.6. 5G-networks slicing

Kapassa *et al.* [25] studied the medical data collected and analyzed from diverse IoT medical devices 5G networks. They proposed an approach to the facilities coexistence of heterogenous requirements of IoT medical devices and smartphones based on dynamic slices allocation of 5G infrastructure. Also, they evaluated their proposed solution by developing web application to manage mobile application.

Performance controlling of S-health applications constraints based on slicing of network resource (PRIMUS) was proposed in [26]. The proposed performance management architecture aimed to supply high-reliability and low-latency for S-health purposes. Network slicing ability of 5G networks manages network. PRIMUS created network slices for the S-health dynamic routes choice. The choice of dynamic routes had packet loss rate and low latency metrics; the simulated results showed that the latency was low as 10 ms.

The performance of both vertical and horizontal slicing methods of 5G networks were compared in De Silva *et al.* [27]. The authors simulated three different S-health application scenarios: IoMT with control traffic, augmented reality assisted surgery (ARAS) produced video and audio traffic and robotic aided surgery (RAS) produced Audio, video, and control traffic. Their obtained results showed that horizontal slicing can support further S-health purposes than vertical slicing.

2.7. Multi architecture layers for S-health

An architecture for the IoT architecture that adopted most of the new technologies was proposed in [28], the proposed architecture encompassed the constraints of future applications, services, and generated data are addressed. Mainly, the proposed architecture entailed of Nano-chip, IoT using 5G, heterogeneous networks (HetNet), device-to-device (D2D) communication, millimeter wave, machine-type communication (MTC), mobile cloud computing (MCC), wireless software defined networks (WSDN), wireless network function virtualization (WNFV), and mobile edge computing (MEC). They stated that their proposed architecture will satisfy most of the requirements of the new IoT application.

A new model for S-health using 5G and IoT was proposed in [29], the proposed model encompass distinctive Industry 4.0 (IoT) standards layers; these layers are: storage layer, fog layer and edge layer. Medical sensors collect patient's data present the edge layer, while wireless access points, routers and base station present the fog layer that receive edge layer data wirelessly. Data from fog layer are stored and analyzed at the cloud-based storage (storage layer).

Distinctive research projects on the architecture of 5G and IoT such as NFV, cloud computing and SDN were discussed in Gupta *et al.* [30]. The authors proposed a new scalable, and responsive architecture for 5G and IoT. The proposed architecture is composed of six interconnected layers for secure data transfer, higher data rate and lower latency. Those layers are:

Perception layer: that collects information from the genuine sensors, actuators, and microcontrollers.

- Network layer that supplies connectivity between the sensors, actuators, microcontrollers, and servers.
- Management and orchestration layer: orchestration of software and device resources
- Cloud computing layer: where data is stored.
- Application layer: for message delivery between services and users
- Business layer: management platform for controlling distinctive applications.

Two architectures for integrating 5G and IoMT were proposed in [31]; the first architecture utilized 5G new radio (NR) architecture combining both control and user planes. The function of control plane is to exchange data between IoMT end devices, user plane function (UPF) enables the data plane flow for control and user plane. The second proposed architecture is four-layer 5G architecture with network slicing; the simulation results showed that 5G is10 times lower latency than 4G architecture.

A three-layered framework for 5G-secure-smart healthcare monitoring (5GSS) with intention of exact and fast E-health documentation context awareness with low latency and with aid of blockchain for more medical data security was proposed in Hu *et al.* [32]. The proposed framework entailed health service, data acquisition and edge cloud layers. The authors used 5G and IPv6 E-health documentation context awareness and blockchain for securing medical data; they achieved 92.46% and 93.62% for sensitivity and accuracy, respectively.

The importance of medical devices management is an important part of the whole hospital management and the application of IoMT for medical devices management were analyzed in Ren and Wu [33], the authors proposed three-layered automated medical devices management system:

- Perception layer: that observes medical devices and sensors through radio frequency identification (RFID). The perception layer collects medical data identity and environmental status.
- Network layer: that transmits data collected from medical sensors in a secure and reliable manner.
- Application layer: that provides an interface between the IOMT and distinctive users.

The authors examined current issues with hospital equipment management, spoken about how the IoT can be used to manage medical equipment, and advocated for a more intelligent and automated approach to managing medical equipment. The proposed plan may be one of the reliable automated systems, preferably technology supported, for the proper management of medical equipment, notably in hospitals, according to experimental results. Conducted experiments to evaluate their proposed management system, the obtained results showed that their system is a reliable automated management system.

3. REVIEW PAPERS OF 5G AND S-HEALTH TECHNOLOGIES, PERSPECTIVES, AND APPLICATIONS

In their review paper, Ahad *et al.* [34] presented a review of distinctive research prospects of both 5G and smart healthcare. They described the architecture of 5G smart healthcare and related techniques such as device-to-device communication, small-scale cells, edge computing, SDN and NFV. Then, they analyzed the 5G requirements from ultra-low latency, high communication bandwidth, and extremely high reliability. Lastly, they reviewed the network layer solutions namely: routing, scheduling, and traffic bottleneck management.

Quality of service (QoS) requirements, emerging technologies and challenges of the deployment 5G in the IoT domain were reviewed in [35]. Modern IoT applications (particularly in the field of healthcare) on top of 5G networks demand high data transmission rates with lowest latency; they reviewed distinctive architectural components of the 5G networks, with exclusive prominence to the important improvements of 5G networks physical and network layers. The challenges include lack of standardization as medical devices are heterogenous and QoS requirements due to needed transmission high data needed transmission.

Divers applications developments of triboelectric nanogenerator (TENG) and human-machine interfaces (HMI) were reviewed and analyzed in Sun *et al.* [36]. TENG had effective development into HMIs, involving exoskeleton, S-health, electronic skin, touchpads, glasses and much more with artificial intelligence (AI) and haptic feedback technologies. Additionally, the authors discussed using ML for advanced applications such as biometric authentication, human gait analysis and automatic feature extraction. They also reviewed possible integration of self-powered TENG sensors and wireless energy to achieve battery free TENG devices and sensors.

The application of 5G network and AI for remote monitoring of eye diseases was thoroughly studied and explored in Yuen *et al.* [37]. Both real time monitoring and store-and-forward are used in showing, treatment, diagnosis, and monitoring of eye diseases. The authors showed treatment efficiency, patient satisfaction, and constant improvements; the deployment of ophthalmology telehealth might lead to improving eye assessments and treatments as well as enlarging the geographic coverage area of eye telehealth.

Telesurgery is an expanding branch of Telemedicine where new medical technologies such as imaging video, sensory devices and robotics enable physician to run surgery remotely over long distances. A scientific review of the telesurgery were carried by Bailo *et al.* [38]; they identified major legislation differences between geographical areas which had significant impact cases of misuse. In addition, they considered the impact of malicious attacks wither on stealing transmitted data, revealing patient sensitive data or even worse threaten patient’s safety by changing transmitted data.

As medical sensors are resource constrained to fulfill the security requirements, Kathamuthu *et al.* [39] proposed deep Q-learning-based neural network with privacy preservation system (DQ-NNPP), the proposed system aimed to provide secure data transmission with less encryption and decryption time. Their reported system defeated certain standard methods, such as multi-scheme privacy-preserving deep learning in cloud computing (MSCryptoNet), the secure and anonymous biometric based user authentication scheme (SABUAS) and privacy-preserving disease prediction (PPDP). The authors stated that their proposed system approached 93.74%, 92%, and 92.1% for accuracy, sensitivity, and specificity, respectively.

A real-time blood sugar (BG) prediction and predictive hypoglycemia detection system was proposed by Zhu *et al.* [40]. The authors proposed system used an attention-based suggestive repeated neural network and IoMT wearable device to employ the embedded system; which encompassed Bluetooth and edge computing connectivity for system on a chip (SoC).

Wireless body area networks (WBANs) comprise only one element of connected healthcare that makes use of tiny, intelligent physiological sensors that can be worn by or implanted in people. WBANs. had limited power resources, so there is a real need for saving their battery energy by using energy efficient algorithms; one of these algorithms is the channel state estimation- based transmission power control (CSE-TPC) which was proposed in [41]. This algorithm is designed for quality of optimization (QoE) across SG networks; the CSE-TPC modifies the power level of the transmitter transmission in correspondence to the vibrant environment of wireless channel.

3.1. Special application domains of S-health utilizing 5G network

A framework for connecting ambulances using the 5G networks promising features from very high data transmission rates, huge connectivity, trustworthiness, high spectral efficiency to very low-delay transmission was proposed in Usman *et al.* [42] proposed framework based on 5G wireless communication, the transmitted data could be ultrasound videos, patient's vital signs and in ambulance video surveillance; it focused on two-way audio-visual multimedia flow between ambulances and healthcare center.

A smart ambulance solution utilizing 5G architecture was proposed in [43], the purpose of the smart ambulance achieve high response time in medical emergency cases. The proposed smart ambulance is composed of three major components: telehealth medical data transfer, 5G network and remote video. The three components interlinked to enhance transfer time and method of ambulance services. Paramedic staff send Patient's vital signs and medical data to health care center to get advice about the suitable rescue procedure.

Elucidation to the challenges in battling global pandemic of coronavirus disease 2019 (COVID-19) and the crucial need to employ emerging and existing technologies with their full capabilities were discussed in [44]. They argued that IoT is one of the most promising technologies with a great contribution in the battle against COVID-19. They examined the application of IoT applications correlated to COVID-19, found their operational and deployment challenges. Besides, they examined the IoT implementation with possible influence of internal and external factors. They suggested light weight cryptography (LWC) algorithms, blockchain-based for end-to-end secrecy, and 5G for IoT devices to accommodate the bandwidth needs for scalable IoT networks.

The combination of technological functions and people's experiences during COVID-19 pandemic to devise an appropriate theoretical base for guaranteeing safe access to medical was studied in Alshammari *et al.* [45]. The authors exposed distinctive strategic areas for technological control of COVID-19 pandemic beyond guaranteeing convenient information system (IS). They assessed the five key facets of the use of information by people during the pandemic they were access to COVID-19: information, literacy, quality of life, and depression after COVID-19 infection, worry, and anxiety.

The vast spread rate of COVID-19 pandemic purifies the need of continuous wireless connectivity between wearable IoT devices, where 5G network plays a particularly key role. Sengupta *et al.* [46] studied the role of 5G network in the battle against COVID-19 pandemic. In addition, they discussed open research areas and challenges faced 5G adaptation in COVID-19 battle.

COVID-19 impacted medical sector as other sectors in most countries, a review paper [47] highlighted approaches for 5G utilization in E-health. The paper addressed the implementation concerns security, privacy, scalability, and societal issues possible medicines. The paper also figured probable future research directions for 5G to relieve the health trials related to COVID-19.

5G-enabled fluorescence sensor for quantitative detection of spike protein and nucleocapsid protein of COVID-19 was proposed by Guo *et al.* [48]. The proposed sensor is composed of a focusing lens, high-speed camera, a light emitting diode (LED), motor driver, Bluetooth module, and a micro controller unit (MCU) to record medical data remotely. The Bluetooth module connects the sensor with either smartphone or computer.

A new healthcare specialist care system for autism center named "AutiLife" was proposed in [49], the proposed system used ML and 5G network. The proposed system can collect diverse health data and signals from autistic children to detect any health collapsing illnesses. In emergency cases, autism centers use "AutiLife" to improve real time healthcare services. Appropriate application of "AutiLife" may conserve valuable autism children who are unable to communicate with others and talk about pain they feel.

To improve the throughput 5G networks, a hybrid latency detection technique was proposed by Kumar *et al.* [50]. They aimed to reduce latency and increase spectrum. The proposed technique based on a hybrid detection technique based on the non-orthogonal multiple access (NOMA) system quick response (QR), beam forming (BF), codes decomposition, the M algorithm-maximum likelihood detection (QRM-MLD) and for massive multiple-input multiple-output (MIMO). They compared their proposal with conventional detection techniques and told that, their hybrid detection technique improves the throughput of the 5G network system as compared to the conventional BF, zero-forcing (ZF) techniques and conventional QRM-MLD algorithm based on peak power, bit error rate (BER) and computational complexity.

Rghioui *et al.* [51] proposed a smart system for examining diabetic patients using both ML algorithms and 5G technology. To analyze diabetic patients' big data, they created an intelligent algorithm built on AI; the proposed algorithms will send alerts for medical center in case of emergency. They classified diabetic patients using the WEKA tool and six classifiers: ZeroR, OneR, random forest (RF), J48, naïve Bayes (NB), simple logistic, sequential minimal optimization (SMO). Their obtained simulation results showed that SMO classifier achieved the highest accuracy of 99.66%, a sensitivity of 99.85%, and a precision of 99.66%. compared with the remainin2222g five classifiers.

A S-health multidisciplinary diabetes disease recommender for early diabetes detection system was proposed in [52], the proposed recommender based on deep ML and data fusion perspectives. Data fusion was used to eradicate the unrelated problem of system computational capabilities which leads to improvement in performance of the proposed recommender. After all, the ML model was trained to predict diabetes disease. The recommender system was evaluated based on a well-known diabetes dataset (e Hospital Frankfurt Germany diabetes dataset and Pima Indians diabetes dataset) and it showed an accuracy of 99.6%.

A smartphone was the base of S-health that utilized progressive web apps (PWA) proposed in [53]; the proposed system captured clinical data, integrates it with distinctive medical knowledge source and deploys AI to support disparity diagnosis and patient stratums. S-health can recommend activity and therapy strategies with special concern to cyber protection. The S-health combines up-to-date technologies of the next generation web such as Bluetooth, PWA, Web Speech API, access USB devices on the web (WebUSB), and web real-time communication (WebRTC). Patients and physicians can use WebRTC secure video conferencing to send vital signs.

A framework for voice pathology detection system was proposed in [54]; electrocardiography (EGG) electrodes and microphones were used to capture signals of EGG and voice. Spectrograms voice and ECG signals were the seed of pretrained CNN. CNN extracted the features. After that they were fed and processed using a bi-directional long short-term memory ((BILSTM)) network. The evaluation of the proposed system Saarbruecken voice database showed that the proposed system was 95.65%.

S-Health enabled technologies such as ML, big data analysis, cloud computing as described in [55]. Those technologies combined with beliefs of AI algorithms such as: anomaly detection, assistant decision-making system, activity recognition and behavior recognition. The authors described applications of S-health in patients' remote diagnosis and treatment, neonatal intensive care unit (NICU), venous thromboembolism (VTE) and cardiac care unit (CCU). They summarized in a systematic manner an AI algorithm for medical image recognition and then categories the early threats of patients in NICU and CCU-and possibly-endorse medication plans and the prediction of medication.

Smart route control algorithm (S-RCA) to build a smart route in the network between patients, doctors and telesurgery was proposed in [56]. The smart path can accelerate the receiving of emergency traffic during ordinary or tele-surgery. An IoT smart algorithm creates a high-priority route to classify traffic depending on emergency priority.

Samriya *et al.* [57] proposed chicken swarm optimization algorithm, built on energy efficient multi-objective clustering scheme. The proposed system was applied in the framework of IoMT ecosystems. They designed an efficient fitness function for cluster head choice, the fitness function used multiple factors: link quality, queuing delay, node centrality and balance energy.

C-shape imprint slot (CSES) and an absconded ground to form textile antenna was presented in [58], the proposed antenna is suitable for the lower band (4.23 to 5.65 GHz) of the 5G-network applications. It was agreed that its best specific absorption rate (SAR) is 0.353 W/kg which is less than 1.6 W/kg averaged over one gram mandated by federal communications commission (FCC).

Microstrip patch antennas are a very popular type of antenna due to their light weight, small size, and low manufacturing cost. ML techniques were used in [59] for the determination of the optimal location of the frequency selective (FS) reflector and the ground dimension of the monopole in composite antennas structure for 5G purposes. They said that the proposed technique can save up to 99% of the computational time compared with the conventional approaches.

Medical applications of drones were presented in [60]. That study aimed to understand the role of institutions and organizations that have utilized cloud service providers to store and share data as ensuring third-party access to storage is a major challenge to avoid data theft and unwanted access. The authors categorized medical applications of drones and presented some major challenges in these applications. They gave initiations of 5G and blockchain and investigated their fundamental characteristics to supply reliable communication and enhanced information security.

An effective fall detection framework for elderly people built on deep learning (DL) algorithms and mobile edge computing (MEC) within 5G networks was proposed in [61]. Al-Rakhami *et al.* [61] aimed to enable IoMT applications; they proposed the use of a deep gated recurrent unit (DGRU) NN to expand the accuracy of current DL-based fall detection methods. DGRU had the advantage of dealing with time-series IoMT data.

A summary of the 5G and S-health enabled technologies is in Table 2, from research scope and topics covered in reviewed papers while in Table 3, a summary of special application domains of S-health utilizing 5G networks is given. Comparing different purposes such as core technology, application domain security architecture, blockchain and other perspectives.

Table 2. Summary of reviewed 5G and S-health enabled technologies

ID	Research scope	References
1	Core technology	[17], [53]
2	Security architecture for S-health	[16], [30], [37]
3	Utilizing blockchain in S-Health	[22], [31], [61]
4	Edge computing	[24], [34], [46], [48]
5	Authentication of S-health using 5G networks	[36], [61]
6	5G- networks slicing	[18], [29], [33], [34], [41]
7	Multi architecture layers for S-health	[15], [23], [39], [40], [43], [44]
8	Review paper of 5G and S-health technologies, perspectives, and applications	[14], [21], [38], [50]–[52]

Table 3. Summary of reviewed special application domains of S-health utilizing 5G networks

ID	Purpose	References
1	Connecting ambulances using the 5G networks	[13], [46], [55]
2	5G in COVID-19 battle	[26], [41], [42], [52], [54]
3	Healthcare specialist care system for autism center	[19]
4	5G networks a hybrid latency detection technique	[20]
5	A smart system for examining diabetic patients	[25]
6	Diabetes disease recommender for early diabetes detection system	[27]
7	Mobile phone-based S-health that utilized progressive web apps (PWA)	[28]
8	Framework for voice pathology detection	[32]
9	Anomaly detection, assistant decision-making system, activity recognition and behavior recognition in S-Health in patients' remote diagnosis and treatment	[35]
10	Smart control ration control algorithm (s-RCA) to build a smart route in the network between patients, doctors and telesurgery	[56]
11	Chicken swarm optimization algorithm, built on energy efficient multi-objective clustering scheme.	[57]
12	C-shape imprint slot (CSES) and an absconded ground to form textile antenna	[58]
13	ML techniques for the determination of the optimal location of the frequency selective (FSS) reflector	[59]
14	Medical applications of drones	[60]
15	An effective fall detection framework for elderly people built on deep learning (DL) algorithms, blockchain	[61]

4. CONCLUSION

S-health, as one of the most commonly applications using 5G-networks of nanomaterials, has been the topic of widespread research for the last few years. 5G-netwroks have been widely used in a wide range of applications due to their high frequency, vast speed, low latency, and low errors. S-health is a modern healthcare way established by advancement in electronic processes and communication technologies 5G and 6G networks. As a result, the integration of S-health and 5G networks can improve the healthcare level and reduces medical data transfer latency. Besides different application of the S-health such as: care system for autism center, a smart system for examining diabetic patients, framework for voice pathology detection, telesurgery, medical applications of drones and connecting ambulances with high-speed networks.

In this paper, we highlight widely investigated essential properties of 5G and their applications for S-health. From different perspectives demonstrating key challenges it imposed. However, there is still a need for more research about medical data privacy, integrity, and nonrepudiation.

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