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Telemedicine and Smart Healthcare—The Role of Artificial Intelligence, 5G, Cloud Services, and Other Enabling Technologies

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Abstract

This paper discusses telemedicine and the employment of advanced mobile technologies in smart healthcare delivery. It covers the technological advances in connected smart healthcare, including the roles of artificial intelligence, machine learning, 5G and IoT platforms, and other enabling technologies. It also presents the challenges and potential risks that could arise from delivering connected smart healthcare services. Healthcare delivery is witnessing revolutions engineered by the developments in mobile connectivity and the plethora of platforms, applications, sensors, devices, and equipment that go along with it. Human society is evolving fast in response to these technological developments, which are also pushing the connectivity-providing sector to create and adopt new waves of network technologies. Consequently, new communications technologies have been introduced into the healthcare system and many novel applications have been developed to make it easier for sharing data in various forms and volumes within health-related services. These applications have also made it possible for telemedicine to be effectively adopted. This paper provides an overview of some of the recent developments within the space of mobile connectivity and telemedicine.

Keywords

Telemedicine, Smart Healthcare, 5G, Artificial Intelligence, Machine Learning, Internet-of-Medical-Things

1. Introduction

Healthcare delivery is experiencing a paradigm shift due mainly to revolutions engineered by technological advancements, especially those related to mobile connectivity and its accompanying myriad of platforms, applications, sensors, devices, and equipment. As a result of the introduction of recent telecommunication technologies in the healthcare system, many novel applications have been created to facilitate the exchange of data in various forms and quantities within healthcare-related services [1] [2]. Thus, frequent network modernization is required to keep up with the introduction of the multitude of elements that are connected through telco operators' networks to form the Internet of Things (IoT) or Internet-of-Medical-Things (IoMT). This effort enables and facilitates the distribution, and what is promising to be ubiquitous healthcare systems. Network modernization in this context emphasizes the need to acquire the latest generation of technologies and adapt them to the use case of effective delivery of telemedicine and healthcare [1]. Telemedicine is a branch of medicine that entails the use of audio-visual technologies to promote patient health by facilitating interactions between patients and healthcare providers [3]. Videoconferencing, and e-health, which include patient portals, remote monitoring of vital signs, continuing medical education, and nursing call centers, are all examples of telemedicine [3]. The potential of telemedicine has expanded due to advances in technology, including high-definition cameras, strong encryption software, electronic stethoscopes, and broadband internet availability [3]. The importance of telemedicine has been underscored by the coronavirus disease of 2019 (COVID-19) as healthcare providers battled to combat the COVID-19 pandemic while the globe tried to live with it. This pandemic has further exposed the importance of robust and durable networks due to the unexpected surge in telemedicine [4]. The demand for IoT devices to link everything, anytime, and everywhere grew in response to the growing need for personalization of health care and communication with medical personnel. Medical gadgets utilized by mobile health workers, such as personal home-use diagnostic and imaging devices, are one of the key technology components [5]. Through connected healthcare technology, it is possible to reduce the prevalence of chronic ailments such as heart disease and diabetes by continuous monitoring of patients using data analytics and decision support systems. A connected healthcare system based on IoT creates, as shown in **Figure 1**, an environment in which essential parameters are collected by sensors, relayed through a gateway, and stored in the cloud, where data is aggregated and analyzed using the appropriate decision support system [5]. To achieve this reliable connectivity, a low-latency transmission network that can support massive connections with high data rates is a key requirement. The earlier generations of 3GPP technologies (e.g., 4G and its evolution) were not designed for massive connectivity. However, the Fifth Generation (5G) and 5G+ networks have proven to be superior to 4G [6] [7] in all the key performance metrics making 5G a strong and key enabler for telemedicine and massive IoT. **Figure 1** illustrates an example of an IoT-based connected healthcare environment. Some of the unique features of 5G include cloud-oriented devices, distributed and programmable architecture, high-data rates, milliseconds end-to-end roundtrip delay, and faster connectivity [8] [9]. Table 1 provides some notable differences between the 4G and 5G technologies [10] [11].

Considering these capabilities, integrating 5G technology into digital health care provides a host of opportunities. Remote robotic surgery, in-ambulance treatment, wearable device applications, robotic services for assisted living, and

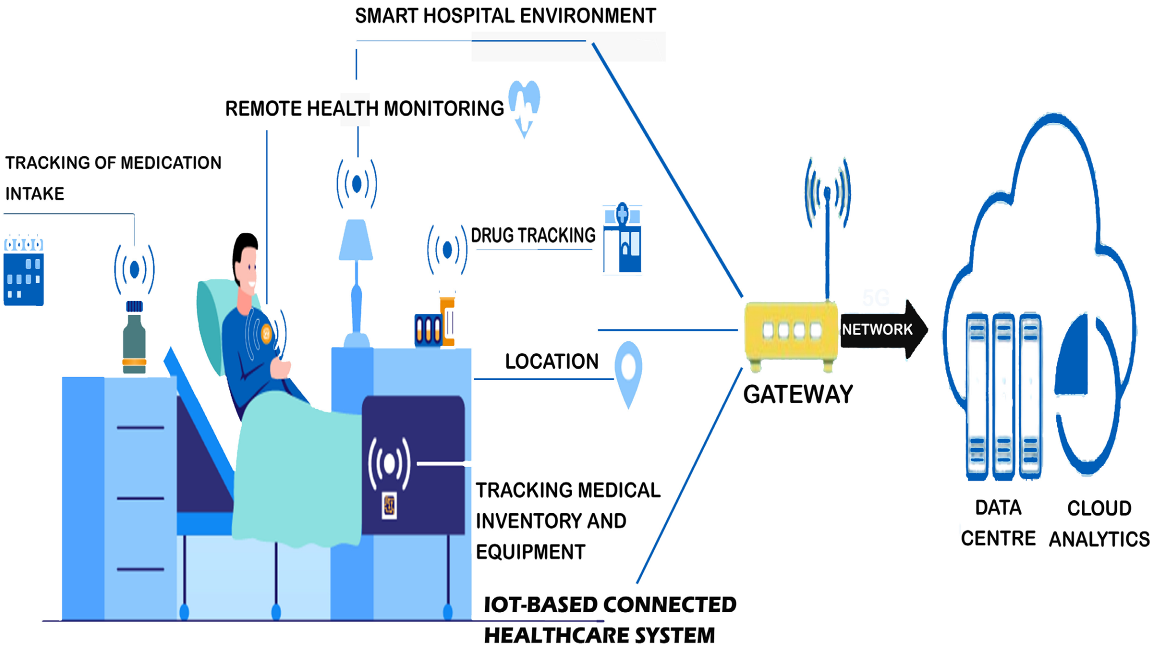

Figure 1. Illustration of an IoT-based connected healthcare environment.

Table 1. Notable differences between the 4G and 5G technologies.

Characteristics	4G	5G	Importance of 5G's enhanced features over 4G in telemedicine	References
Data rate (Gbps)	Up to 1	Up to 20	High data rate ensures data from the monitors and other IoT devices/wearables is transferred at a rapid speed, allowing for prompt notifications when medical intervention is required.	[8] [9] [10] [11]
Latency (ms) (Control/User plane)	100/10	50/1	Low latency ensures a stable and consistent connection, reducing connection loss, and lags. This is especially important in telemedicine as many IoT devices/wearables rely on real-time applications or live streaming.	[8] [9]
Device density (K/km2)	100	1000	This 5G superiority ensures mass medical outreach to citizens during any pandemic e.g., COVID-19.	[8]
Spectral efficiency (bits/s/Hz)	Up to 6	Up to 30	The high spectral efficiency of 5G networks is critical in telemedicine. Spectrally efficient network allows large data to be packed in a small bandwidth. Thus, real-time videos/holograms are essential and would facilitate the success of telemedicine.	[10] [11]
Mobility (Km/h)	Up to 350	Up to 500	With the support of high mobility in 5G, healthcare systems may be accessed from a larger range of locations, and telemedicine services can be provided even in high-speed scenarios, such as trains, metros, and the like.	[10] [11]
Energy efficiency (μJ per 100 bits)	100	0.1	Energy efficiency is crucial for the lifespan of IoT or telemedicine nodes. Most medical implants are expected to last for decades before battery replacement. The 6G networks may provide even much better energy efficiency.	[9] [10]

medical big data management are examples of potential use cases [12] [13] [14]. Artificial intelligence and machine learning are other emerging and promising techniques that when combined with 5G can help revolutionize the healthcare system.

2. Artificial Intelligence in 5G Technology

Artificial Intelligence (AI) is promising to be an important new concept with huge opportunities for optimizing systems, improving efficiencies in industrial operations, enriching healthcare platforms, and enhancing cellular technologies and connectivity. With AI, intelligent robots can operate in a broader, more sophisticated environment, opening new possibilities in robotics [15]. For several decades, the underlying algorithms that power smart devices have remained the same despite miniaturizing smart devices. As a result, 5G systems still use significantly more energy than desired and deliver lower data rates than expected [16]. Another intriguing use of AI in telecommunications is to address the fear that the expanding adoption of wireless technologies would overcrowd the space that smart devices use to communicate with one another. To address this, communication devices that do not broadcast on the same frequency every time must be developed. AI algorithms would then be utilized to discover available frequencies by allowing smart radio frequency-aware activity, which was previously not implemented. 5G with the Internet of Things (IoT) sensors, which may operate for years can enable remote monitoring of farmed irrigation levels and the condition of factory equipment. Hence, this is another application of intelligent networks in preventing mishaps due to faulty factory equipment. In healthcare, physicians would have more secure access to patient data [16]-[21]. All these 5G opportunities would be facilitated by AI. For instance, 5G networks can be used to integrate machine learning (ML) and AI into the network edge. The combined high reliability and capacity features allow several smart devices to connect at the same time, creating massive amounts of data that must be processed using advanced ML and AI tools. Network slicing is a popular application of network intelligence in 5G to enhance the operation of networks that extends to smart healthcare. The primary concept behind network slicing is the cost-effective creation of many logical networks (or slices) over a single physical piece of network infrastructure [22]. Thus, this enables the logical and physical separation of network resources and capability assignment by providing service customization and isolation on physical network infrastructure [23]. Additionally, by utilizing dynamic network slicing, numerous application scenarios with various quality of service requirements can be addressed [22]. **Figure 2** depicts a high-level network slicing procedure to address the numerous market segments of which health care is an example.

2.1. Artificial Intelligence & 5G Technical Features

Artificial intelligence & 5G technical features AI technology can be employed to

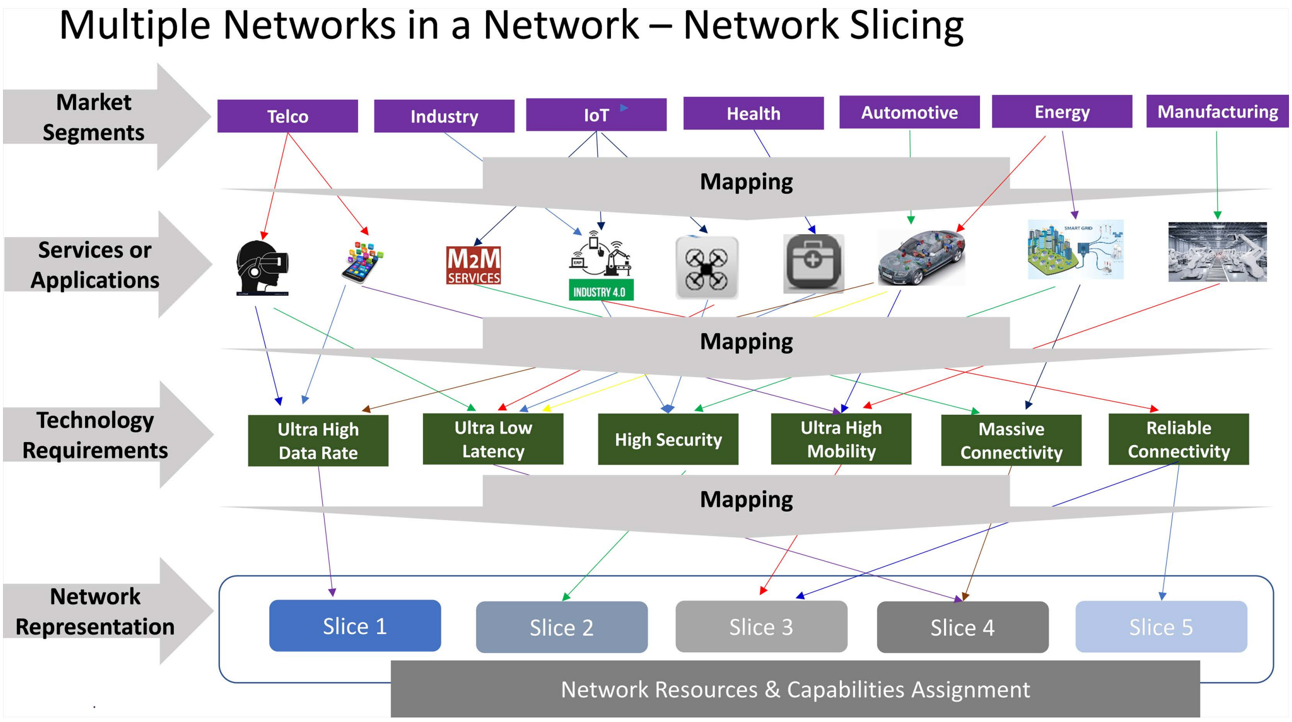

Figure 2. Mapping of multiple networks in a network (network slicing).

enhance many performance features of 5G, such as optimization and estimation [15] [24]. These are briefly discussed as follows:

2.1.1. Optimization

Efficient use of network resources is key to high-performing networks. Resource allocation algorithms or schedulers are relied upon to ensure the effective use of radio resources among network users as these resources, e.g., spectrum and power, are limited. Resource allocation problems are more complicated in 5G due to the multiple optimization dimensions involving virtualization, slicing, and self-organizing features. To do slicing in particular, several complex mappings need to be performed as depicted in Figure 2. The combined multi-dimensional optimization objective and constraints expose the challenges and opportunities in a heterogeneous network (HetNet) architecture. This is where AI, with the meta-heuristics approach, comes into play [15] [24]. The meta-heuristics are generic search methods for solving difficult combinatorial problems. Meta-heuristics approaches have been applied successfully to solve various complex problems in cellular telecommunication networks [11] [25], and medical applications are presented in [26] [27].

2.1.2. Estimation

To achieve and implement massive MIMO schemes, 5G needs an accurate estimation of channel state information (CSI). A popular approach includes a training sequence by sending a known signal and estimating the CSI based on the transmitted and received signals combined [15] [24]. In MIMO systems, it can be assumed that the CSI from each antenna at the base station has the same autocorrelation pattern in practice to improve the channel prediction quality of a specific terminal [28]. This allows the receiver to use well-known image recognition and image denoising techniques to forecast the pattern of CSI variation using the channel structure. This property is effectively employed by arranging the CSI from the numerous antennas into a matrix [29] [30] [31] for further processing. For the mmWave Massive MIMO system, a convolutional neural network (CNN) is used in [28] [32] for channel estimation to reduce noise from the predicted channel, surpassing traditional counterparts. **Figure 3** depicts two features of 5G that the AI approach can enhance.

2.2. Machine Learning Techniques And 5G

Machine Learning (ML) models are computational systems for characterizing the discriminative features of a system that cannot be represented by a mathematical model. ML models are commonly used to perform regression and classification analyses, as well as analyzing interactions between a human and an environment. These models allow computers to learn, automate, and optimize based on large data sets. As a result of training, once an ML model is developed, it can decide on unknown data and performs tasks based on arithmetic calculations [33] [34]. The three most common types of ML algorithms are supervised, unsupervised, and reinforcement learning. **Figure 4** summarizes the three most common types of ML algorithms and their applications in 5G.

2.2.1. Supervised Learning (SL)

Supervised algorithms are used for predicting, estimating, or classifying a variable based on trained data. The goal is to train a model that generates general rule mapping inputs to outputs from samples of a problem with a known solution. The model is then used to find optimal solutions from new samples. An example of supervised learning is labelled data pairs fed into a multilayer deep neural

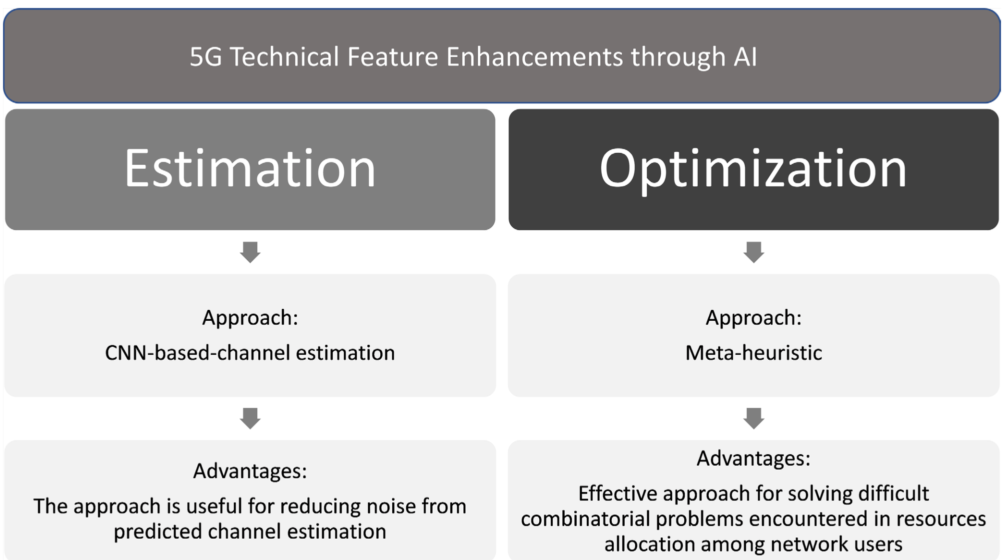

Figure 3. Illustration of features enhancement in 5G through the use of different AI approaches.

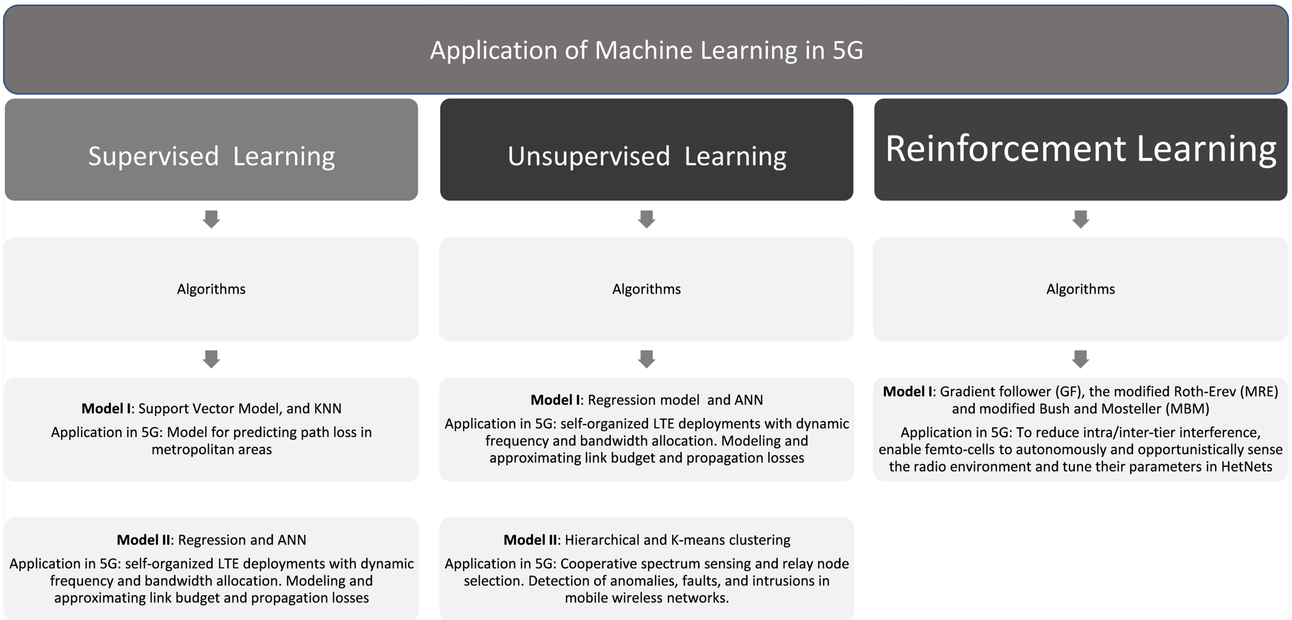

Figure 4. Application of ML in 5G.

network (DNN) so that the weight factor between the nodes of the DNN can be learned. DNN is trained offline, and after its convergence, the trained DNN is ready for inference on new inputs [24] [35] [36]. SL can be broken down into two learning tasks based on how continuous/discrete the output data is: regression and classification. For example, Bayes' theory, K-nearest neighbours (K-NN), Naive Bayesian (NB), and support vector machines (SVMs) use classification learning agents. Artificial neural networks (ANN) and generalized linear models (GLM) use regression learning agents [35] [37]. **Table 2** illustrates SL models and their applications in 5G networks.

2.2.2. Unsupervised Learning (UL)

During UL, no labels are provided to the learning algorithm, so its input structure is self-determined. An example of training using unsupervised learning is a neural network-based self-organizing map problem. With a self-organizing map, unlabeled data are fed into a neural network, which produces a two-dimensional, discretized representation of the input space of the training samples. Dimensionality reduction can be achieved with this method. In contrast to SL, UL is not monitored. In summary, the goal of labelled data samples is to find efficient inferences to describe hidden features or structures of data. The technique is used extensively for detecting patterns and relationships. Therefore, data can be used to identify anomalies, recognize patterns, or minimize dimensionality through unsupervised learning. Clustering, dimensionality reduction, anomaly detection, and latent variable models are among the well-known models of UL [24] [35]. **Table 3** illustrates UL models and their applications in 5G networks.

2.2.3. Reinforcement Learning (RL)

A system that uses reinforcement learning will have to learn the expected result

Table 2. SL methods and their application in 5G.

	Supervised Learning Model	Applications in 5G	Model Adoption in healthcare delivery	References
1	ML and statistical logistic regression	Self-organized LTE dense small cell deployments with dynamic frequency and bandwidth allocation	This model gives healthcare providers the chance to specifically target at-risk individuals who need a more individualized health plan to help them improve their everyday health habits.	[24] [35] [36]
2	Support Vector Machines (SVM)	Model for predicting path loss in metropolitan areas	This model is a potential classification strategy for the healthcare industry, and in smart hospitals, it is generally used to forecast drug adherence.	[37]
3	Neural-Network-based approximation	Channel learning to infer unobservable CSI from an observable channel	This model is generally applied for forecasting e.g. It can be applied to forecast kidney disease.	[24]
4	Supervised ML Frameworks	TDD uplink-downlink configuration in XG-PON-LTE systems is adjusted to optimize network performance based on current traffic conditions in the hybrid optical-wireless network.	This model can be used as a predictive analytics tool to identify and cure illnesses before they pose a serious threat to human life.	[35] [36]
5	Artificial Neural Networks (ANN), and Multi-Layer Perceptrons (MLPs)	For next-generation wireless networks, modeling, and approximations of objective functions for link budget and propagation loss are needed.	The cost of creating medicines is decreased by using these models to identify a safe and effective medication option from a set of databases.	[35] [37]

Table 3. UL methods and their application in 5G.

	Unsupervised Learning Model	Applications in 5G	Adoption in healthcare delivery	References
1	K-means Clustering, Gaussian Mixture Model (GMM), and Expectation Maximization (EM)	In automobile networks, cooperative spectrum sensing, and relay node selection are used.	Medical experts employ these models to develop more intelligent medical decision support systems, particularly for the treatment of liver diseases.	[35] [37]
2	Hierarchical Clustering	Detection of anomalies, faults, and intrusions in mobile wireless networks.	To discover the phylogenetic tree of animal evolution, this model can be used in conjunction with DNA sequencing. This is frequently crucial in determining the origin of a viral or disease outbreak.	[24] [35]
3	Unsupervised Soft-Clustering ML Framework	In heterogeneous cellular networks, latency is reduced by grouping fog nodes to automatically identify which low-power node (LPN) is converted to a high-power node (HPN). (LPN) is upgraded to a high-power node (HPN)	These models can be used to improve machine learning algorithms' ability to diagnose chronic diseases.	[35] [38]
4	Affinity Propagation Clustering	Data-Driven Resource Management for Ultra-Dense Small Cells	This model can be adopted to investigate important genes associated with ovarian cancer.	[37]

independently as it is in unsupervised learning. Unlike SL and UL, RL does not attempt to find categories and reconstruct the system model, nor does it attempt to find hidden structures, as supervised learning does. Rather, RL attempts to decide on the best solution within the constraints imposed by the inputs. RL involves a single or more decision-making agents. The learner agent interacts with the environment, receiving rewards and penalties as a result of actions taken, thus, the agent strives to maximize the rewards. If the system's selection decision is good, the reward is delivered; otherwise, the system is penalized. To reward positive behaviour, reinforcement learning seeks to map situations S into actions A. RL is excellent for tackling problems with no unique solutions because it offers a mathematical framework for simulating decision-making in circumstances where results are partially determined by chance and partially controlled by the decision-maker, simply to say it models the environment as a Markov decision process [35] [37]. **Table 4** illustrates RL models and their applications in 5G networks.

2.3. Deep Learning and 5G

Deep learning algorithms have attained outstanding performance in a variety of practical situations involving supervised and unsupervised learning [40]. Deep learning models, like many other application domains, can be utilized to solve infrastructure or resource management problems in 5G networks, such as radio and computer resource allocation, channel state prediction, and handover prediction [41]. Convolutional Neural Networks and Long Short-Term Memory are two typical examples of deep learning neural network schemes used in 5G technology. Each of them is best suited to deal with a specific type of classification

Table 4. RL methods and their application in 5G.

	RL models	Applications in 5G	Adoption of Model in healthcare delivery	References
1	RL algorithm based on long short-term memory (RL-LSTM) cells.	In LTE unlicensed (LTE-U) networks, proactive resource allocation is formulated as a non-cooperative game that allows small base stations to learn which unlicensed channel to use based on long-term WLAN behavior and LTE-U traffic loads.	These models can be adopted on electronic medical records of deceased patients to estimate life expectancy.	[35] [37] [39]
2	Gradient follower (GF), the modified Roth-Erev (MRE), and the modified Bush and Mosteller (MBM)	To reduce intra/inter-tier interference, enable femtocells to sense the radio environment and tune their parameters in HetNets autonomously and opportunistically.	These models can be used for a variety of critical care and chronic illness treatment plans, automated medical diagnostics, and many other scheduling or control issues relating to the healthcare system.	[37]
3	RL with Network assisted feedback	Selection of Heterogeneous Radio Access Technologies (RATs).	These models are utilized to create effective solutions in a variety of healthcare settings where diagnosis choices or treatment plans typically involve a long period of time with delayed feedback.	[35]

problem [40] [41].

2.3.1. Convolutional Neural Networks (CNN)

CNN models are designed to extract important features from data that comes from numerous arrays or multivariate arrays. In other words, the convolution layer is used to handle data of various dimensionalities, including 1D signals and sequences, 2D pictures or audio spectrograms, and 3D video or volumetric images [41] [42]. A typical example of CNN models utilized for CSI prediction for 5G wireless communications was reported in [43], where the authors adopted CNN models with the numerous factors that affect CSI as input; factors that include frequency band, location, time, temperature, humidity, and weather. To extract a frequency representative vector from CSI data, the authors also explored 1D and 2D convolutions [41] [43].

2.3.2. Long Short-Term Memory (LSTM)

Deep learning models incorporating LSTM layers have been used in several studies to process sequential data as in [44] [45] [46]. A multivariate LSTM model can be used to extract temporal aspects of mobile internet traffic and predict cellular network internet flows [41] [44] [45]. Reference [46] presented an LSTM model for predicting traffic in base stations for 5G ultra-dense network to avoid flow congestion. The model utilized data from uplink and downlink flows as input. Based on the projected data, the algorithm adaptively allocates resources for uplink or downlink channels based on the set objective function or metric [41] [46].

3. 5G Connectivity and Other Enabling Technologies in Smart Healthcare Delivery

Smart healthcare plays a critical role in today's economy. The average spending on smart healthcare in Europe is over 10% of the gross domestic product (GDP) [10]. IoT is playing an increasingly important role in smart healthcare, with applications such as smart medication, and assisted living, as well as remote and onsite asset monitoring in hospitals, patient behavioural change, and treatment compliance [10] [47]. In the event of a critical situation, smart health care allows patients to take appropriate action [48] [49]. Among the benefits are remote check-up services, reduction of treatment costs, and assistance to healthcare professionals in expanding their services beyond geographical boundaries. With the growth of smart cities, strong smart healthcare infrastructure is needed to ensure that people have access to the healthcare services that they need. Aside from general well-being, one of the most significant contributions is the reduction of healthcare costs through prompt diagnosis [49] [50]. **Figure 5** illustrates a typical smart hospital scenario.

3.1. Application of 5G and Other Enabling Technologies in Digital Medicine

The relevance of 5G technology in smart healthcare cannot be over-emphasized

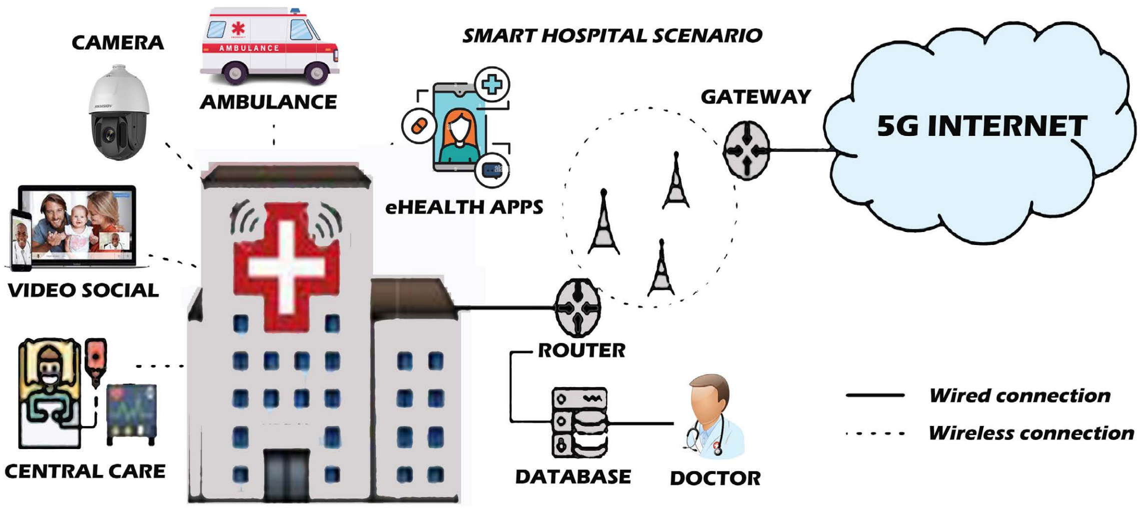

Figure 5. A typical illustration of a smart hospital scenario.

due to its superfast connectivity, intelligent management, and data capabilities [14]. 5G technology is required for mission-critical medical tasks that require high reliability and availability with latency intervals of a few milliseconds. It also opens new healthcare possibilities, including imaging, diagnostics, data analytics, and treatment [14] [50] [51]. Remote access to images and the capacity to quickly communicate information across geographic boundaries are two advantages of digital medicine that help to condense time and distance. In medical imaging, for instance, patients can get second or third views rapidly because of the high-speed transmission of X-rays or CT images, exposing them to highly responsive healthcare expertise that is ordinarily not available in their communities [50] [52]. Also, if doctors in another location (in a different country) want an opinion, they can send a high-resolution medical image or test result to get their peers' perspectives on the medical situation. This opportunity brings expertise to medical practitioners to overcome inequities based on geographical locations, income, or social class in the healthcare system [50] [52]. Furthermore, high-altitude platforms, drones, and satellites will be playing an important and complementary role in the ecosystem of terrestrial connectivity-enabled telemedicine. As gap fillers, these emerging aerial and satellite broadband technologies will act as additional last-mile opportunities for reaching the underserved in rural areas and difficult-to-reach terrains and conflict regions [53].

3.2. Applications of 5G, and Other Enabling Technologies in Medical Diagnostics

Telemedicine services can save lives in an emergency by remotely providing prompt diagnosis. This is effective because of the technological advancement brought by the application of 5G network to smart medical devices. This has further broadened the usage of monitoring devices and wearable medical equipment. A typical application can be seen in patients suffering from significant or chronic health concerns such as cardiovascular disease, diabetes, or cancer, for example, remote monitoring systems or wearable devices can track vital signs and glucose levels and electronically transfer this information to healthcare experts. Rather than waiting for an emergency, these devices and immersive connectivity create an early warning system that assists clinicians in detecting potential problems and providing proactive medical care to patients [50] [54]. These types of monitoring technologies are very beneficial to the aged. Many of these people are unable to travel to a doctor's office or a hospital due to their lack of mobility. Depending on their health care need, they can seek medical care via video conferencing and telemedicine. Physicians and nurses can monitor vital signs, motion, falls, and difficulty in speaking, among other things, to diagnose patients' health concerns in real-time. Remote controls are also useful for babies. The baby's body posture, activity level, and skin temperature are all monitored via clothing with breathing sensors. All this information is accessible to parents through advanced mobile connectivity to their smartphones. Finally, the billions of devices and sensors deployed with 5G will facilitate the collection of this data and with cloud applications, medical experts will have unfettered access to such patient data. The cloud gives clinicians the large storage capacities they require to leverage the benefits of these new technologies [50] [55].

3.3. Applications of 5G, and Other Enabling Technologies in Data Analytics and Treatment

Reliable data analytics provides tangible benefits in the field of real-time digital medicine. To be able to analyze data in real-time allows for fast learning about therapeutic impacts. Thus, treating physicians can combine and analyze information in new and inventive ways using data analysis. They can utilize this data to unearth meaningful insights, learn in real-time, and use what they have learned to select the most effective treatments. Artificial intelligence aids doctors in deciphering large databases, while wearable devices can send out medical notifications if the user experiences an acute crisis or medical emergency [50] [56]. The healthcare sector has enormous potential for data analytics. Diagnostic codes are the current industry standard for simplifying and changing complex health data. For patient contacts, these codes will aid in classifying and identifying diseases, symptoms, and negative effects of drugs. Without effective data analytics, this procedure could result in a considerable loss of information for the patient, the caregiver, and the health system. In fact, big data analytics made possible by 5G can drastically reduce the information to a code in addition to allowing researchers to have a better understanding of the drugs that patients take, how they react to them, and how a specific patient relates to them (precision medicine). In our connected world and always-on devices, advanced mobile connectivity including 5G allows us to move away from algorithms that are dependent on static data and towards those ones that can be improved in real-time, utilizing data from the user and the cloud [50] [56] [57]. **Figure 6** shows the applications of 5G and other enabling technologies in smart healthcare delivery.

Figure 6. Illustration of 5G and other enabling technologies in smart healthcare delivery.

4. Emerging 6G and Healthcare Delivery

As the 5G networks are being deployed and widely adopted, the component technologies for the 6G are being conceived. Thus, 6G has been highlighted in various studies as a substantial accelerator for modern healthcare [58]. 6G promises several advantages that can significantly transform smart healthcare into an advanced intelligent healthcare system with revolutionary consequences [59]. For example, 6G robotics can be used to perform surgery in such a way that remotely experienced surgeons can supervise the procedure using robotic systems with millisecond latency and high reliability [60]. Recently, the authors in [61] investigated a robotic telesurgery system by combining 6G and blockchain into unmanned aerial vehicles (UAVs) with consideration for network security challenges. Each robot operates as a data node, storing surgical data securely in the database sheet without the necessity of centralized authority. This will address the issue of slow healthcare response times, as the UAVs can be adopted as relays to transfer portable healthcare items, such as drugs and surgical tools, between hospitals in emergency situations, avoiding road traffic congestion and thus reducing data exchange latency [60] [61]. Furthermore, with the increasing availability of powerful cloud computing services, the emerging 6G integrated with cloud robotics, IoTs, nano-devices, implants, and on-body sensors can connect and transfer data in real-time to edge devices or cloud centers for short-term and long-term diagnostic testing [60] [62]. As detailed in [58] [63], the benefits of 6G-IoT healthcare applications include real-time identification of health conditions, extended reality-based telehealthcare applications, digitalized and streamlined healthcare records secured with blockchain, immersive remote surgery, and remote interactive healthcare through virtual platforms. Furthermore, with the implementation of holographic technology, tactile communication, and cognitive robotics in 6G, smart healthcare powered by advanced AI will be developed employing a variety of novel ways to provide healthcare services to humanity across the globe [58] [64]. We note that many patients are unwilling to give critical health information remotely, which is becoming a major impediment, which necessitates the employment of advanced solutions to offer and ensure entire user protection [58]. To this end, federated learning and holographic technology can help circumvent this resistance. This will be one of the most intriguing aspects of the emerging 6G in modern healthcare delivery. Based on the above applications scenarios, and as analyzed in [65], we anticipate five application scenarios supported by 6G communications: enhanced mobile broadband plus, big communications, secure ultra-reliable low latency communications, three-dimensional integrated communications, and unconventional data communications.

5. Challenges and Potential Risks Associated with Connected Smart Healthcare

Aside from natural phenomena such as earthquakes and floods, there are several risks associated with connected smart healthcare systems, and to properly leverage the 5G potentials, these risks must be overcome. For instance, the technologies that constitute smart devices have their own set of challenges and integrating them to provide services in many application settings also poses some challenges [8]. Privacy is a significant risk linked with a fully connected healthcare system, which could pertain to a video conference or a telemedicine session that contains personal information that the patient only wants to share with the doctor. Furthermore, without the knowledge of the owners, automated contact tracing tools accumulate sensitive location data. This user data, rich in advertisement value, may find its way into the hands of third parties, which is clearly a privacy infringement concern [66] [67]. Security breaches in connected and smart healthcare delivery are another major issue of concern as advanced mobile connectivity continues to facilitate a variety of new or better medical application scenarios. Thus, remote consultation, surgery, emergency rescue, and monitoring have all been rapidly developing with the introduction of 5G technology [22] [68] [69] [70]. While these application scenarios improve the quality of patients' experiences, they also introduce some security risks. The security component of these connected devices in healthcare will play a big role in national, and information security since medical information contains a lot of user privacy and some medical applications are specifically concerned with the safety of patients [10] [70] [71] [72]. **Figure 7** shows a comprehensive list of potential threats associated with smart healthcare delivery.

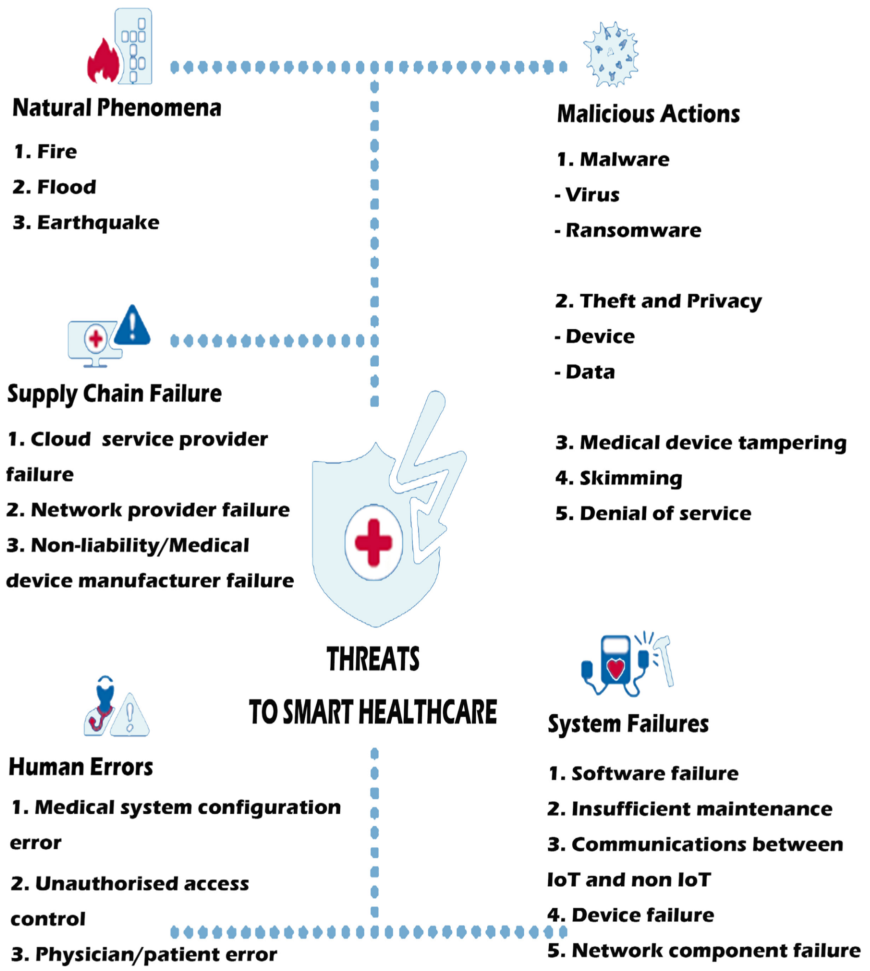

Figure 7. Potential threats associated with connected smart healthcare.

6. Conclusions

Smart health care entails a lot of connected components. These connected parts include telemedicine services, and wearable technologies from fitness trackers to heart and glucose monitors that record and transmit data to connected platforms. Consequent to these connected devices, a lot of data is being generated and used to improve patients' health through prevention plans and/or treatment. The availability of this massive data paved the way for the application of AI which promises to be a great assistive technology for performing tasks with high accuracy and efficiency with humans in the loop to make final decisions. Furthermore, the timely availability of healthcare information or data is essential and could be critical thereby, making it imperative to transmit these massive data needs with high speed, with as low latency and jitter as possible. This is where 5G technology becomes handy. Given the excellent connectivity quality of the 5G, this paper has identified and discussed the important roles 5G will continue to play in smart healthcare delivery, especially in processing and transmitting large medical images between medical facilities. Furthermore, in hospitals, 5G in conjunction with artificial intelligence and IoT-based technologies would facilitate remote monitoring, mobile nursing, and real-time access to diagnostic data of patients. The building blocks of the next-generation connectivity, the 6G, are being put together, which would further improve the experience of remote medicine. The benefits of these combined technologies include the reduction in the working intensity of medical staff, enhancement in service efficiency, and reduction in inter-departmental coordination time. The advancements in technology and network modernization will enhance the quality of service provided to patients and improve their level of satisfaction. In conclusion, this paper has presented several technological advancements in smart healthcare, emphasizing the important roles each of these technologies would play in enhancing the health sector. The synergy between these technologies, if properly harnessed, will enable full utilization as well as extend the miracle of modern medicine to humanity everywhere across the globe.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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