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Technological trends in 5G networks for IoT-enabled smart healthcare: A review

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Abstract

Smart healthcare is in the process of quick evolution from the traditional focused approach towards the specialist and the hospital to a patient-centric model. The following technological advancements have boosted this quick revolution of healthcare vertical. Presently, 4G as well as other communication standards like WLAN are applied in healthcare to offer smart healthcare services and solutions. The considers apply for the advancement of further smart healthcare services in the future. It is for this reason that as the healthcare industry expands, several applications are anticipated to generate a huge volume of data in various forms and sizes. Thus, the enormous and varying data requires a special approach towards the end-to-end delay, bandwidth, latency and other factors. Thus, it becomes highly challenging for current technologies in communication to effectively support complex and sensitive health care applications in the future. Thus, these 5G networks are being planned and implemented to address the multifaceted requirements of the healthcare applications for IoT. 5G assisted smart healthcare networks consist of IoT devices which need better network performance and extended cellular connections. There are issues with existing connectivity solutions namely how many IoT devices can be connected, achieving global standardization, optimizing for low power budgets, how many devices to fit into a given area and secure communication. This paper aims to provide an elaborate review of the smart healthcare solutions in IoT assisted by the 5G technology.

Keywords: Smart healthcare; IoT; IoHT; 5G Technology; Wireless Sensors; Latency.

1. Introduction

Smart healthcare assists sophisticated devices used to diagnose diseases and treat the patients while smart healthcare tools to improve the general healthcare standards since they display the patients' vital statistics in real-time. As noted in the case of stating the objectives of smart healthcare the primary concern is to help the patient through provision of information mainly from medical matters and their probable solutions. Smart healthcare makes it possible for the patients to perform necessary action when faced with life threatening conditions [2]. This facilitates remote check-up service which in a way helps in lowering the treatment costs and assists the healthcare organization to expand its services beyond borders. The generation of smart cities raises the necessity of developing a strong smart healthcare system to ensure health services to the users. Besides, wellbeing, one of the most important contributions is saving on

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the amount of money that is required to be spent on the treatment when the diagnosis is made early. For instance, Smart healthcare with the Internet of Things (IoT) market worth expected to be 158. 1 billion dollars in 2022 [2] For instance, Diwakar acknowledged in the interview that Kenyan based firms need to increase their exports from 75m dollars in 2007 to 1 billion dollars in 2022 [2].

IOT is going to transform the healthcare sector and cut down the cost of medical equipment's. 5G networks will be required to support the IoT as industry looks to expand it more [3]. Out of all the major applications in 5G networks, smart health care tops the list [4]. Fig. 1 shows a general architecture of smart healthcare network based on 5G.

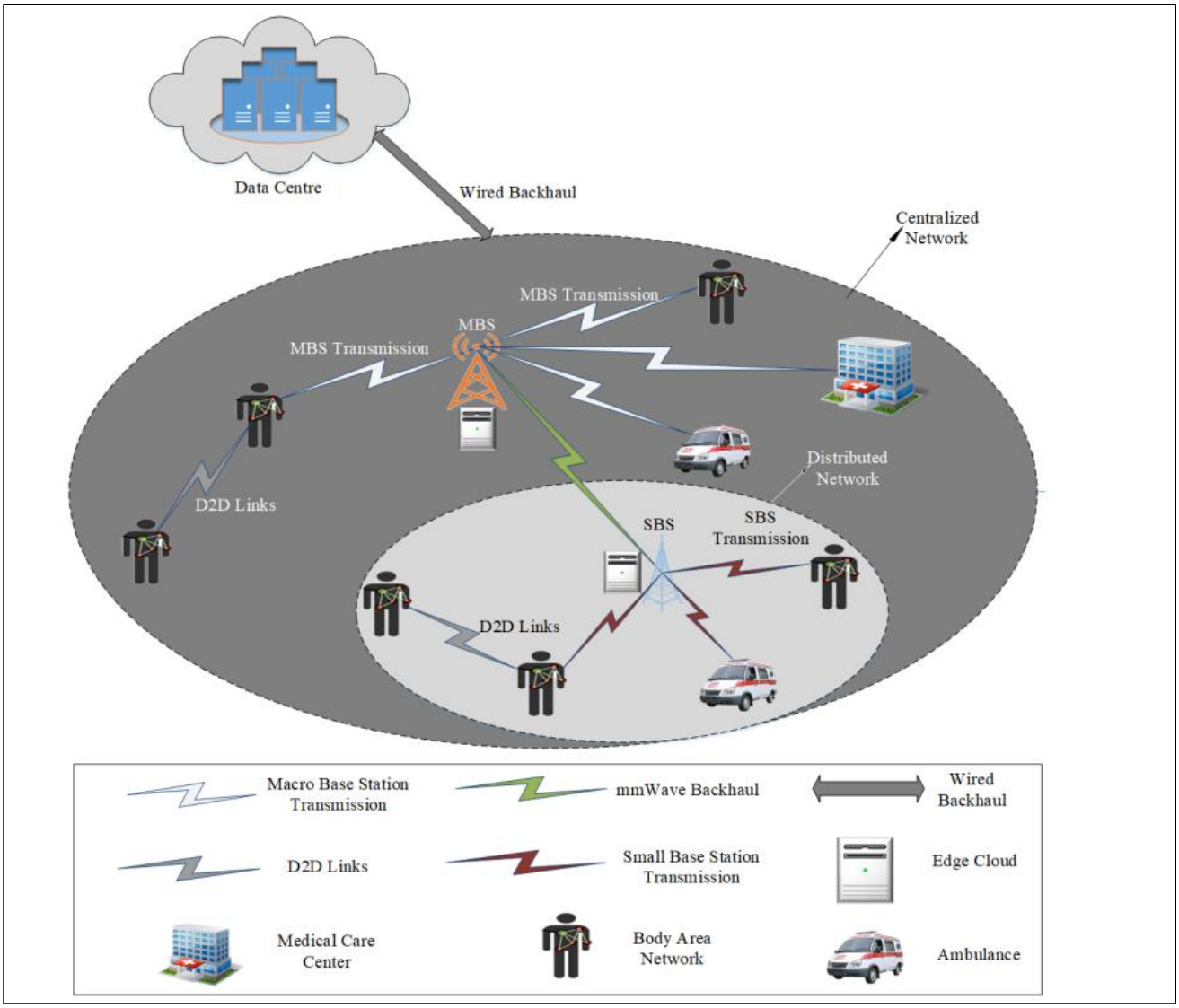

Figure 1 A general architecture of smart healthcare network based on 5G (Adopted from [1]).

In smart-health care, IoT can enhance various services, such as Asset tracking in hospitals, Behavioral change, Remote care services, Treatment tracking, Assisted living, Smarter medication, Tele-care [5]. These applications will be on the frontline to meet the increasing demands soon in medical business. Data exhibit that the market for Internet of Things in health care will be led to about $ 117 billion by 2020 [6]. Numerous scenarios for the use of mobile communication technology together with e-health and/or web services application are discussed. Proposed in [7], a portable health application dubbed as health inspection of health that electronically records pressure sore is suggested. The following is the list of papers reviewed in this study: [7] proposed an intelligent health application for assessment and diet inspection. Thus, in [9] the author describes a new approach to mobile health applications. In [10], Wearable solutions concerning mobility support for the living environment are presented. [11] proposes an IoT application called the mobile gateway that focuses on providing smart help in the context of MHealth. In [12], this IoT is viewed as a possible

influential element for medical use's platform in e-health. Regarding the future work, wearable devices are suggested for inspection of healthcare in a wireless network of sensors in [13].

Thus, there are numerous critical areas that have been identified with regards to 5G network communication, smart antennas included [14,15]. Fig. 2 shows the advancements in technologies up to 5G [28]. As it can be observed from diagram that the start has been taken from voice calls. Now you can have the ability to use the internet with ultra-high speed which we can't imagine.

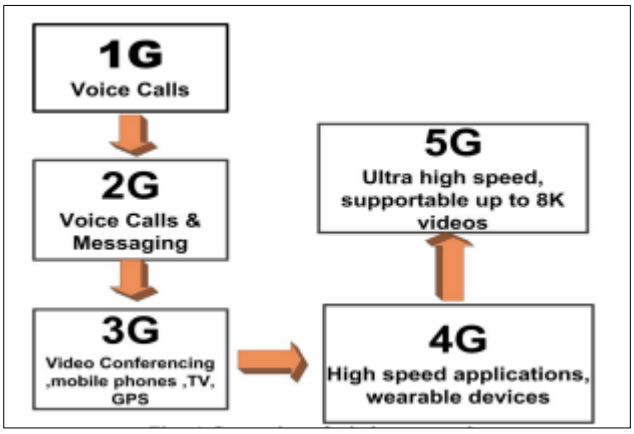

Figure 2 Generation of wireless network [28]

Smart Antennas apply many significant innovations to enhance 5G coverage and network capacity [16,17]. Among the such innovation is beamforming (i. e. , vertical and horizontal), in which RF energy is focused in a contract beam to precisely where it is required instead of radiating the same energy in a wide area [16][17][18][19]. Beamforming proves to be very useful in 5GNR as the higher frequency mmWave RF is more susceptible to fading over authentication loss and distance due to objects hitting such as vehicles, buildings and so on [20,21]. They have a better probability of promising penetration of radio frequency energy and optimal transmission capacity and signal quality due to a more directed beam [22,23]. However, it is significant to recall that line of locate is still a problem, for beamforming points of interest are fewer with attenuation [24, 25].

As for the 5G networks, the key niche that primarily defines the concept of smart healthcare is machine-to-machine (M2M) communication and internet of Things (IoT) [27].

2. IoT Based Healthcare Applications

According to reports submitted by P&S Market Research, there will be a compound annual growth rate (CAGR) of 37.6 percent in the healthcare Internet of Things (IoT) industry between 2015 and 2020. If one thing is certain, IoT has transformed healthcare in a variety of ways over the past several years and will continue to do so for years to come. Fig. 3 illustrates the taxonomy of smart healthcare. The described taxonomy consists of the following parameters: communication technologies, network types, services, applications, requirements, and characteristics.

2.1. Implantable Glucose Monitoring Systems

Patients who suffer from diabetes can have devices with sensors implanted in them, just below their skin. The sensors in the devices will send information to a patient's mobile phone when his or her glucose levels get too low and will record historical data for them too. This way, patients will also be able to tell when they are most likely to be at risk for low glucose levels in the future, as well as in the present.

2.2. Activity Trackers During Cancer Treatment

Usually the right treatment for a cancer patient relies on more than just his or her weight and age. Their lifestyles and fitness levels also play a huge role in what the proper treatment plan for them will entail. Activity trackers track a patient's movements, fatigue levels, appetite, etc. Plus, the data collected from the tracker prior to treatment and after treatment has started will tell healthcare professionals what adjustments need to be made to the recommended treatment plan.

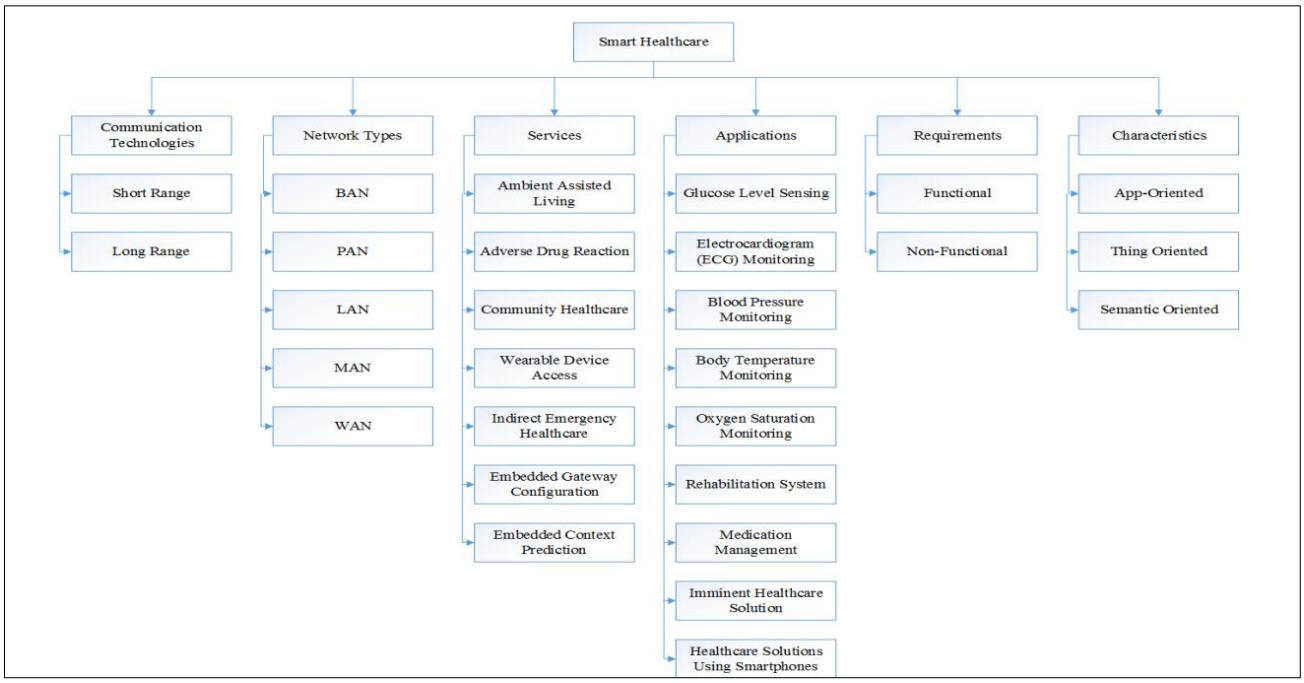

Figure 3 Taxonomy of smart healthcare and its parameters (Adopted from [1])

2.3. Heart Monitors with Reporting

Patients can wear devices that monitor their heart rates, and that can determine whether they have high blood pressure. Healthcare providers will have access to reporting of patient's heart monitor data when they need to pull it during checkups and exams. The wearable devices can even alert healthcare professionals when patients are experiencing arrhythmias, palpitations, strokes, or full-blown heart attacks. Ambulances can then be dispatched in a timely fashion, which can be the difference between life and death.

2.4. Medical Alert Systems

Individuals can wear something that looks like jewelry but is designed to alert family members or friends in case of an emergency. For instance, if an individual is wearing a medical alert bracelet and fell out of bed in the middle of the night, the people they designate to help in the case of an emergency would be immediately notified on their smartphones that their help was needed.

2.5. Ingestible Sensors

Patients can now swallow devices with sensors that look like pills. Once the sensors are ingested, they relay information to a patient's mobile app that will help them follow the proper dosages for their medications. Most medications aren't taken as prescribed due to forgetfulness or other human error. This ingestible sensor works to ensure patients are taking the right medications, at the right time, in the right dosages. Some ingestible sensors are also being used to more accurately diagnose patients with things like irritable bowel syndrome and colon cancer.

2.6. Medication Dispensers

Devices can now be implanted in a patient that dispense medication in steady doses throughout the day. Patients will be notified when they need to refill their medications. Doctors can also be informed of missed doses during routine visits.

2.7. Wireless Sensors

Wireless sensors are being used in labs and hospital refrigerators to ensure blood samples, chilled medications, and other biomedical materials are always kept at the proper temperatures.

2.8. Trackable Inhalers

IoT inhalers are telling patients what they're doing or experiencing to cause asthma attacks, by transmitting information to their smartphones or tablets. That information can also be shared with their physicians. The connected inhalers also remind patients when to take their medications.

2.9. Wearables to Fight Depression

Apple has designed an app for its Apple Watch that helps manic depressive patients cope with their depression. The app tracks a patient's episodes outside of their scheduled appointments and helps to monitor cognitive and mood functions.

2.10. Connected Contact Lenses

Currently, connected contact lenses are reading glucose levels of diabetes patients. But soon enough, they'll be able to help restore the eye's focus and improve vision.

3. Applications of 5G

The components of future world concern smart technology in transport, health and mobile robots, medical which create the environment of the IoMT. 5G is simply high data rates and low latency technology, but it enables the foundation for IoMT applications. It incorporates many a different distinct and progressive feature in technologies. Some of the IoMT devices are biomedical products and sensors; all these devices come with GPS systems, and most have enhanced M2M traffic requiring higher capacity, high bandwidth, and multiple radio access technologies [31]. The wearable sensors acquire data about various human body parameters such as EEG, ECG, blood oxygen and EMG etc The IoMT has to integrate the technologies and standards such as biosensors, wearable devices, protocols, memory, variable data and video transmission. Thus, to enhance the performance of the video transmission energy management algorithm, a method is proposed which enhances the lifetime of the sensor [33]. Big data and perpetual connectedness are needed to fold every system from home to hospital [30]. The benefits which IoMT provides are given with high accuracy below.

- It should be the adaptive quality of service (QoS).
- It will experience a monumental boost in the network and spectral efficiencies.
- The system has high capacity and also manages the large devices having the connectivity of the different traffics.
- There will be a range of low bandwidth to high bandwidth both in terms of the communication link provisioned and usage.
- Network is known to have low latency and it is energy efficient [34-38].

3.1. Smart Clothing

The smart clothing provides multi-modal physiological signal data by incorporating multiple micro physiological signal data [34]. The most essential requirement for diagnosis is the bioelectric signal of the human body. The usage of electrode is one of the main concerns to get signal bio signal acquisitions technology. In recent days, the textile structure of this electrode is designed in such a way that it collects and tracks the bioelectric signal of the human body. This structure is soft and washable and long-life usage. It can collect range of bioelectric signals of the human body [35]. The benefit of smart clothing is to track the ECG signal and it can be used for diagnosis purposes. The ECG can be measured by placing electrode in specific part of human boy surface. It can also measure blood oxygen and EEG signals. In short description the smart clothing can overcome the usage of wearable devices. It can be used in variety of diseases diagnosis and tracking of chronic health diseases.

3.2. Diagnosis Services in Rural Areas

The rural areas of developing countries having of health resources, so it is important and necessary to incorporate these health care resources and develop IoMT services. The farmers can have availability to get these diagnosis services at any time and can get the health care information accordingly. The monitoring of healthcare can be provided at rural area clinic at any time concerning patient health condition. The urban cities hospitals connected to all rural areas clinic, the new advanced medical monitoring devices and system would use at rural side for treatment. This will give the farmers to get facilitate of advanced health care services at their hometown. This will enhance healthcare services quality of farmers and helps to improve the condition of a patient having chronic diseases. The management team used professional monitoring system to estimates the risk of diseases, it may help patient to get prevention before the illness found, and it also reduce the occurrence of diseases.

3.3. Hospital management system

The diagrams shows that which services can be perform in hospitals. This is further illustrated in Fig. 4.

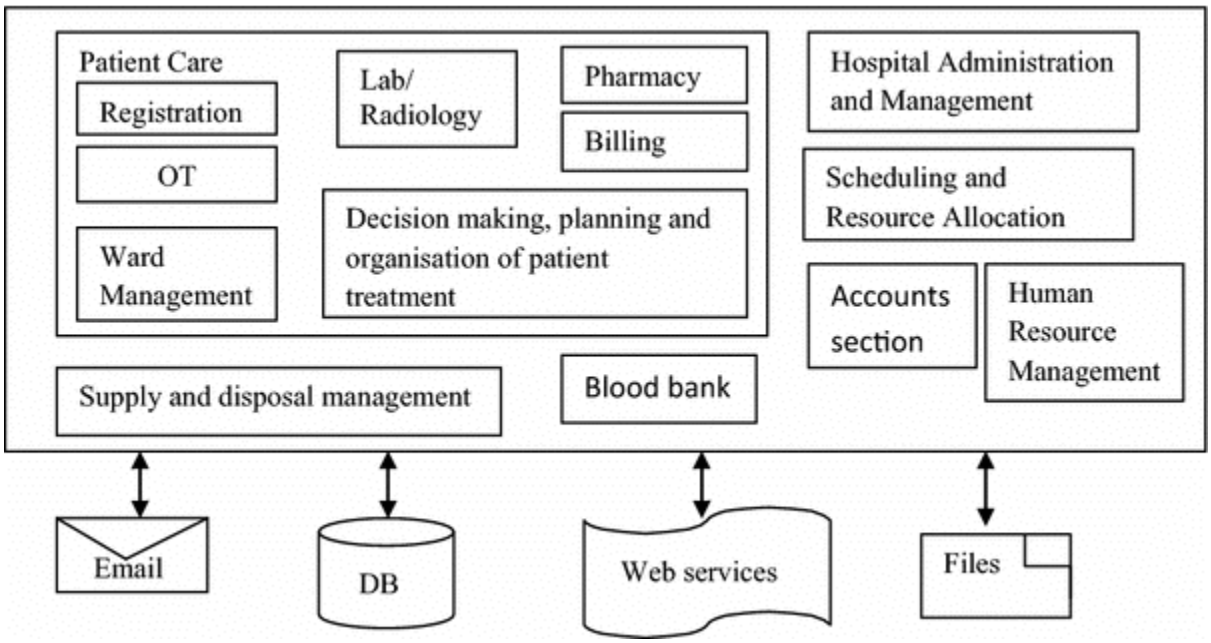

Figure 4 Hospital management system [39]

3.4. Use of Robots

The integration of 5G technology in healthcare enables the use of robots to accurately transmit and receive medical data, significantly enhancing patient care. Robots equipped with 5G connectivity can facilitate precise and timely medical interventions, remote surgeries, and real-time health monitoring. This advanced communication network ensures that data is transmitted with low latency and high reliability, allowing healthcare providers to deliver accurate and efficient medical care to patients, even in remote locations [40-43].

4. Technology Trends for 5G Network Requirements

To meet the essential requirements of future 5G networks, such as ultra-high connection density, high traffic capacity and data rates, ultra-high reliability, ultra-low latency, high energy efficiency, and long-distance communication, several technology trends have been identified. These trends are essential to support various smart healthcare scenarios, each with specific communication needs as summarized in Table 1.

Table 1 Summary of 5G Network Requirements [44-47]

Scenario	Drivers	Communication Technologies	Required Latency	Required Data Rate
M2M Wearables	Connection for data gathering	NB-IoT (interconnected devices), LoRa (sensor applications), Zigbee (data collection), Bluetooth (D2D sensors)	10-700 ms	Few Kbps to Mbps
Digital Hospital	Communication inside building	Wi-Fi	10-100 ms	Few Mbps
Emergency Medical Services	Emergency communication and high-speed reply	LTE, LTE-A, LTE-A Pro	20-100 ms	From 100 Mbps to 3 Gbps

Remote Surgery	URLLC service between many locations	5G	20-30 ms	Few Gbps
Tactile Communication	URLLC (Ultra-reliable and low latency communications), eMBB (enhanced Mobile Broadband)	5G, 4G, Wi-Fi, Bluetooth	sub-ms	Few Gbps
Combination of all scenarios	Communication, latency, bandwidth, applications	5G, 4G, Wi-Fi, Bluetooth	up-to few ms	Few Mbps to 3 Gbps

4.1. Massive MIMO (Multiple-Input Multiple-Output) and 3D MIMO:

MIMO technology increases the channel capacity by using multiple antennas at both the transmitter and receiver ends, enabling higher data rates [48, 49].

4.2. Millimetre-Wave Communications

Utilizes higher frequency bands (30-300 GHz) to provide larger bandwidths and higher data rates, essential for applications requiring ultra-high-speed data transfer.

4.3. Small Cells, Ultra-Dense Networks, and Heterogeneous Networks

Deploying many small cells in dense areas enhances coverage and capacity, supporting a higher number of connected devices and improving overall network performance.

4.4. Device-to-Device (D2D) Communications

Allows direct communication between devices without routing through a base station, reducing latency, enhancing reliability, and improving energy efficiency.

4.5. Cognitive Radio

Enables dynamic spectrum management by allowing devices to intelligently identify and utilize available frequency bands, thus optimizing spectrum usage.

4.6. Artificial Intelligence (AI) and Machine Learning (ML)

AI and ML algorithms can optimize network operations, predict and manage traffic, enhance security, and provide personalized services by analyzing vast amounts of data in real-time.

These technology trends are crucial for realizing the advanced requirements of 5G networks, ensuring efficient and reliable communication for various applications, including those in smart healthcare.

These scenarios outline the diverse and demanding requirements that 5G networks must meet to support various applications in smart healthcare, ensuring robust, reliable, and efficient communication systems.

5. Challenges and open research issues

1. Challenges and open research issues in adopting 5G for smart healthcare are described below [50-62]:

5.1. Achieving Interoperability

It provides a significant platform for communication between different IoT devices using various protocols.

- **Research Challenges**:
    - Incorporating devices for retailer-secured administrations.

- **Key Requirements**:
    - Adaptable, universal, and integrated models for incorporation and communication (e.g., CoAP, IP) for IoT devices.

5.2. Analysis of Big Data

It enhances network performance by processing data from valid sources, such as intelligent analysis of patient data, to minimize network congestion.

- **Research Challenges**:
    - Limitation of useful tools to process the large amount of information generated by devices in the network.
    - Lack of centralized and distributed resources.
- **Key Requirements**:
    - Need for a centralized big data center for processing.
    - Public appreciation on how to utilize available resources securely.

5.3. Performing IoT Connectivity

It assures communication among IoT devices from various domains.

- **Research Challenges**:
    - Ensuring connectivity of various devices from different domains in high mobility.
    - Optimizing resources in an ultra-high dense network.
    - Achieving energy efficiency in an ultra-high dense network.
- **Key Requirements**:
    - Efficient usage of the spectrum for IoT device communication.
    - Intelligent algorithms to guarantee connectivity of devices from various domains.
    - Clustering schemes to support mixed workloads and enhance resource availability.

5.4. Achieving Security

It provides a secure platform free from attacks to deploy services.

- **Research Challenges**:
    - Secure deployment and integration of cloud-based services at both network and device levels.
    - Detection of threats from both insiders and outsiders before execution.
- **Key Requirements**:
    - Recognizable proof of vulnerabilities at different levels, serving as entry points for various attacks.
    - Intelligent security solutions to maintain data integrity and prevent delays.

6. Conclusion

Smart healthcare and IoT applications will be prominently aided by next generation which is the popularly known as the 5G network. Regarding the functionality and the aspect of the economy, health care and IoT are very influential in the 5G network. Several applications were referred in this paper having different views and short and long-range communication technologies were compared based on range, frequency, power and data rate for smart healthcare zone.

In addition, four various situations are taken into consideration, depending on the different demand towards 5G community (i.e., enhanced cellular communication, low latency and high dependability communications, M2M communications, and Internet connectivity for WRAN) and offered different technology trends\ toward the realization of these demands in 5G network and are discussed elaborately. At last, we discussed the open issues and future research directions in the vicinity of smart healthcare in the 5G network. This offers the chances for researchers intending to commence research within the field of 5G based smart healthcare applying various strategies including machine learning, scheduling, routing, handover and clustering.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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