Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 1829876, 10 pages
https://doi.org/10.1155/2022/1829876

*Review Article*

# Home Based Monitoring for Smart Health-Care Systems: A Survey

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Received 26 February 2022; Revised 8 April 2022; Accepted 11 April 2022; Published 12 May 2022

Academic Editor: Alireza Souri



Internet of Things (IoT) is one of the greatest advancements in technology especially in the medical field. The interconnection of medical devices with the internet makes it easier to identify problems and adapts with patient conditions. The sophisticated devices may either be worn or implanted in the users' bodies to continually examine their wellbeing. But due to the availability of several sensors and communication systems, standardization has become a key issue. This survey paper presents the state-of-art research relating to the various sensors and communication models that are used to provide home based monitoring. The small sensor nodes with IoT and its influence on every patient's life in reducing their anxiety of risk when they are inaccessible to medical support are studied. This study helps the researchers in choosing the best available protocols to implement in health-care devices. The contribution to the development of smart cities and data from home or at work for smart health care is discussed. The key findings of this study are the benefits of 5G technology for smart health care, as the most often utilized communication method in the literature to date is 4G. Also, the challenges faced in implementing the models in real time are discussed with the options of future scope mentioned.

## 1. Introduction

In today's era of digitalization, smart health care has become one of the major advancements in the health field. With the advancement of technology and scientific theory, traditional medicine, which is based on bioengineering, has gradually begun to digitalize and informationize [1]. The Internet of Things is one such technological innovation (IoT). The Internet of Things refers to the interconnection of devices, applications, sensors, and network connections that improves these entities' ability to collect and share data. The differentiating feature of the Internet of Things in the health-care system is the continuous monitoring of a patient by examining numerous parameters and inferring a favorable outcome from the history of such continual monitoring [2]. This is frequently used in hospitals to continually monitor patients in intensive care units (ICUs) and communicate the data with clinicians. This assists in the early diagnosis of anomalies in patients and the provision of prompt assistance.

In the same way, IoT is utilized in homes to monitor patients remotely. IoT allows for real-time monitoring, which saves lives from a variety of ailments such as diabetes,

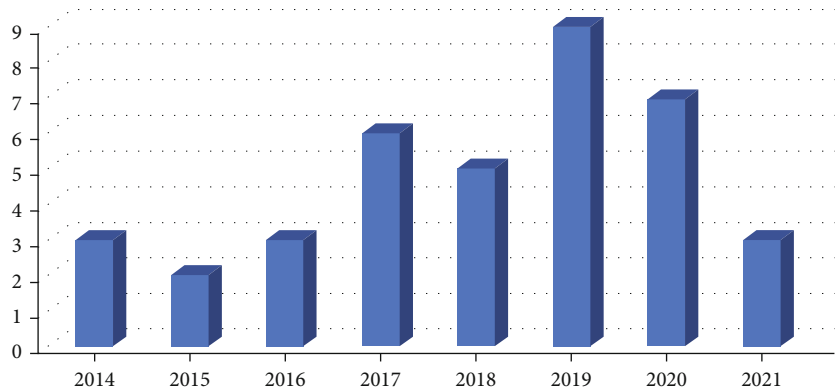


Figure 1: Distribution of the review articles based on year of publication [1].

heart failure, asthma attacks, and high blood pressure. Smart medical gadgets link to a smartphone to seamlessly send needed health information to clinicians. These devices also capture information such as oxygen levels, blood pressure, weight, and blood sugar levels [3]. The motivation to this study is that home-based monitoring can save lives by eliminating the time required for patients to travel to hospitals for checkups. This can also diagnose several diseases at an earlier stage. During these difficult times of pandemic, it is necessary that health monitoring can be done at home with ease. To support this technology, highly robust and reliable standards need to be followed. There is lack of standardization and awareness about new technologies in the society which this paper will cover.

Several prior studies have examined certain topics and technology linked to IoT health care. However, there is a lack of standardization due to the availability of many protocols and sensors. This paper provides a detailed study about various IoT methods that can be used at homes for health care. This research based on the literature could help experts in deciding the best methods for home-based monitoring with IoT. This literature survey covers papers published between 2014 and 2021. Papers were collected journals and conferences published in reputed cites such as IEEE Xplore and PubMed. The keywords applied in the search were "IoT AND Smart Healthcare," "wireless AND sensors," and "communication models". Figure 1 shows the distribution of chosen articles based on their year of release.

The main contributions of this study are:

(i) It provides a detailed review on the various body sensors that are used for remote health-care monitoring is discussed

(ii) This study focuses on the different models of temperature sensors, heart rate, and blood pressure sensors that are available at low cost and are presented along with their limitations

(iii) This study also has a major contribution towards the communication models that can be used for remote health care. It mainly focuses on the short-range and long-range communication systems. This study also highlights the usage of 5G communication model over 4G

(iv) A comparative analysis is presented for 4G, 5G, and Wi-Fi with the characteristic features of communication system - latency, reliability, throughput, speed, energy and density of connections

The paper is structured as follows: Section 2 begins with the study of various health sensors that is being used predominantly in IoT-based health care. Followed by that the same section includes a detailed investigation on the communication models involving short-range, long-range, and 5G-based communication. Section 3 discusses on the need for the society to incorporate a home-based monitoring system. It also elaborates the limitations in usage of such devices focusing on the communication models. Section 4 wraps up the paper by encapsulating the important findings and providing future directions for the research.

## 2. Methods and Materials

Smart health care enables individuals from diverse types of backgrounds (e.g., doctors, health workers, physician caregivers, older relatives, and patients) to obtain the proper information and discover the right solutions, with the goal of minimizing medical errors, improving efficiency, and lowering costs at the proper moment in the health-care profession [4]. Smart health care employs a variety of techniques, including the use of mobile phones, computers, and televisions, as well as the use of different networks, including wide area networks, local area networks, and body area networks. Body temperature, pulse rate, blood pressure, and motion detection are the most often monitored metrics. In this part, we will look at the several sensors that are used to measure physical characteristics.

*2.1. Body Temperature Sensor.* The body temperature is an important measure for identifying different disorders such as hyperthermia, fever, and cold. RTD, thermocouple, semiconductor, and infrared temperature sensors are the most common. The resistance temperature detector (RTD) sensor detects the varying resistance value of metal through which

Table 1: Comparison of various temperature sensors [6].

| Temp. Sensor type | Temp. Range | Advantages | Disadvantages |
|---|---|---|---|
| RTD Sensors [6] | -196°C +850°C | (i) Incredibly accurate<br>(ii) Stable<br>(iii) Reliability<br>(iv) Consistent<br>(v) High temperature ranges | (i) Costly<br>(ii) Less robust than thermocouple<br>(iii) Requires a constant power supply |
| Thermocouples [7] | 95°C–1260°C | (i) Wide temperature range<br>(ii) Highly rugged<br>(iii) Best for high temperatures | (i) Nonlinear<br>(ii) Low voltage<br>(iii) Least stable |
| NTC Thermistors [8] | -40°C to 125°C | (i) Extremely sensitive<br>(ii) Ideal for tiny temperature variations<br>(iii) Simple to use<br>(iv) Quick reaction<br>(v) Standard two-wire interface | (i) Fragile<br>(ii) Current source required<br>(iii) Self-heating<br>(iv) Limited temperature range<br>(v) Nonlinear |
| IR sensors [9] | -20 to 350°C | (i) Hand-held and simple to use<br>(ii) Highly precise and accurate<br>(iii) Fast reaction time<br>(vi) No need to touch with target item | (i) Debris, pollutants, and blackbody radiation all have a negative impact on accuracy |

an electrical signal passes. The resistance is then translated into temperature. The thermocouple sensor is made up of two distinct metals that come together to form a junction. The junction output voltage varies as the junction temperature varies. The voltage is then translated into temperature. A semiconductor sensor is a single-chip integrated circuit (IC) that contains a variety of circuits. The temperature of a bipolar junction transistor is determined using the base-emitter voltage and collector current (BJT).

The infrared temperature sensor is a type of noncontact sensor [5]. The infrared photons generated by the human body are converted into electrical energy by the light sensors in the IR sensor. The input impulse is then transferred to the detector, which converts it to temperature. In [5] DS18B20, a 1-wire programmable temperature sensor is designed to evaluate temperature of the body for the Thai people and produced good results. Table 1 presents a comparison of various temperature sensors.

*2.2. Heartbeat Sensors.* Heartbeat rate is a vital parameter that is measured which can help in the identification of several underlying diseases. Heartbeat sensors are used widely in all smart health-care devices. They are mostly used in wearable devices. [2] uses a microcontroller-based heartbeat sensor. It uses infrared (IR) radiation and operates on the idea of light alteration by blood circulation through thumb or finger for every pulse [10].

The module contains a light detector and bright LED of red color. The device is placed at the fingertip, and when the reflected light falls on the light detector, a signal is produced. This signal varies when blood flows through the vessels because the finger gets opaquer. This variation in the signals is used to determine the heartbeat rate. Working of heartbeat sensor presented in Figure 2.

*2.3. Blood Pressure Sensors.* Blood pressure is helpful to detect various ailments like hypertension, heart attacks, and stroke. Controlling or reducing blood pressure can aid in the prevention or postponement of significant health issues such as renal disease, cardiac arrest, cardiovascular disease, brain hemorrhage, and perhaps Alzheimer's disease. Among all the signals acquired by the detectors, the blood pressure signal provides critical information on heart rate, blood vessel flexibility, and biological variation [11]. Narasimhan et al. [12] developed a finger wearable blood pressure measuring system that contains a 30-element capacitive tactile sensor array for measuring contact stress with the thumb, a pump-driven pneumatic bladder for steadily pressing the tactile array and the finger towards one another, and a wristband that encloses the sensing system and bladder. A finger wearable blood pressure sensor is showed in Figure 3.

The result of this device has also satisfied the global standard-specified accuracy criteria. Other low-cost MEMS pressure sensors are also used in various IoT-enabled health monitoring systems. Body temperature, pulse rate, blood pressure, and motion detection are the most often monitored metrics, and these sensors are used to measure physical characteristics. The sensors data can be transferred to the hospitals through latest communication models for analyzing the data and providing immediate support in case of emergency.

P. A. Shaltis et al. developed a wearable noninvasive blood pressure (NIBP) sensor based on photoplethysmography (PPG) approach. The authors have taken into consideration that the sensor not only must be compact and power efficient, but also it has to be attached to the skin stably and comfortably without requiring a large pressure [13]. So, a compact device which can be worn at the finger base is developed which requires less than 5 V power for operation. The experiments were conducted in controlled environments which leads to the drawback that measurements may become unreliable in environments with varying temperatures.

*2.4. Body Fat Sensor.* With the increase in growth of fitness tracking devices, one important development is the body

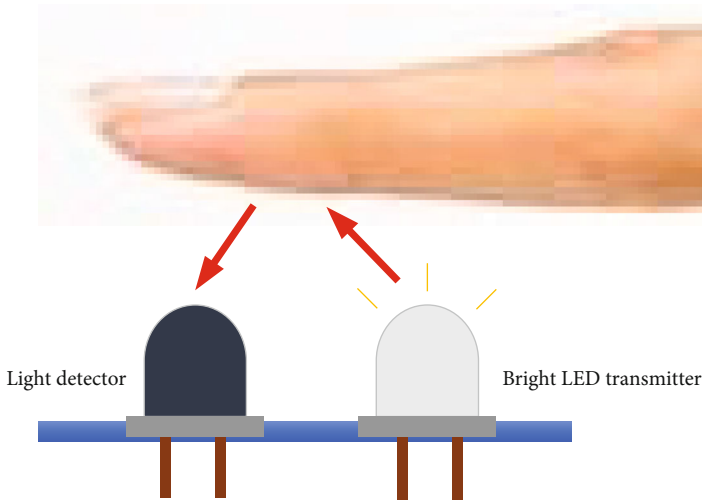


Figure 2: Working of heartbeat sensor [2].

Figure 3: Finger wearable blood pressure sensor [12].

fat sensor. This helps the individual to keep track of the body composition on a daily basis. It provides an early detection of improper balance in the body composition. These sensors are embedded in measuring scales and also in smart watches. Body fat sensor works on the principle of bioelectric impedance analysis (BIA) which is when electric current is allowed to pass through the body, there is resistance caused due to the body tissues and fluids. This resistance is used to calculate body fat. Tissues that contain large amounts of fluid and electrolytes, such as blood, have high conductivity, but fat and bone slow the signal down.

Some of the limitations of this sensor are that, though BIA is said to be harmless it is advised not to be used by pregnant women and also people having other electronic medical devices inside the body such as pacemakers are recommended not to use it, so incorporating body fat sensor in smart health-care devices along with other sensors is a challenge.

*2.5. Body Water Sensor.* North Carolina State University researchers have created a wearable, wireless sensor that can monitor a person's skin hydration for use in applications that require identifying dehydration before it becomes a health issue. The technology is light, flexible, and stretchy, and it has already been put into model wristbands and chest patches. Two electrodes constructed of an elastic polymer combination with conductive silver nanowires make up the sensor. The electrical characteristics of the skin are monitored by these electrodes. The readings from the electrodes can indicate how hydrated the skin is because the skin's electric characteristics fluctuate in a predictable way depending on an individual's moisture.

In addition to that, there are also other body hydration detection sensors which work on near-infrared spectroscopy. The effect of water on tissue reflectance at specific wavelengths is used in near-infrared spectroscopy to determine the water content of human tissue.

*2.6. Pulse Oximetry Sensor.* More medical experts are testing blood oxygen saturation after assessing pulse rate, respiration rate, body temperature, and blood pressure. It is also referred to as the fifth vital sign. Pulse oximetry is a noninvasive way to check one's oxygen saturation. Pulse oximetry sensors assess deoxygenated and oxygenated hemoglobin using red and infrared LEDs. More infrared light is absorbed by oxygenated hemoglobin, allowing more red light to flow through. Deoxygenated hemoglobin, on the other hand, absorbs more red light while allowing more infrared light through.

The oxygen saturation (SPO2) may be measured using two different approaches. The transmission and reflectance methods are the two options. The LED transmitter and the photodetector receiver are situated on opposite sides of the finger in the transmission technique. This finger will be put between the LEDs and the photodetector, which is often used in hospitals, in this manner. The LED and photodetector are arranged on the same side, adjacent to each other, in the reflectance technique. This approach is perfect for

monitoring at home because it is already utilized in many smartwatches and fitness trackers.

*2.7. Nasal Sensor.* The respiratory rate is usually measured in breaths per minute or the number of times the chest rises. These breathing rates may be affected by external elements such as temperature, humidity, pressure, and chemical composition. When a patient is at rest, their respiration rate must be examined. The average person's breathing rate is between 15 and 20 breaths per minute. A breathing rate of less than 12 is considered bradypnea, whereas a respiratory rate of more than 30 is considered tachypnea. The condition of sleep apnea occurs when a person's respiratory rate is zero. Monitoring breathing might help with early detection of such illnesses.

The use of a thermistor-based nasal sensor to monitor breathing rate is a highly cost-effective technology. It operates on the principle that exhaled air is warmer than ambient air. A stretch sensitive device worn to the torso is another form of respiratory sensor that measures the relative amount of expansion that happens during respiration (breathing). Breathing causes the rib cage to expand, stretching the device. The stretch relaxes as users exhale, and the sensor returns to its neutral position. On the screen, the resultant waveform is presented, and the respiratory rate is determined.

*2.8. Communication Model.* IoT has made doctors and patients communication easier. With the help of smart health care today even during this pandemic period, patients are able to carry out their consultation with doctors in an easy way. For this few communication models are responsible. They can be broadly classified into short-range and long-range communication systems. Wireless neighborhood area network (WNAN) is a medium-range network (5-10 km), with Wi-SUN and WM-Bus as examples. Long-distance (up to 100 km) technologies include both authorized (2G/3G/4G, LTE, and soon 5G) and nonlicensed networks, such as low-power wide area network (LPWAN), which encompasses but is not limited to long range (LoRa), Sigfox, narrowband Internet of Things (NB-IoT), and others [14, 15].

*2.8.1. Short-Range Communication.* Communication protocols are classified into three categories as short-range protocols [16], medium-range protocols, and long-range protocols [17]. Sakina Elhadi [18] focus on the Short-range protocols, namely, Bluetooth, Zigbee, and NFS.

Bluetooth, which is widespread in handsets and desktops, is getting popular in remote monitoring technologies. BLE (also known as Bluetooth smart) was launched in 2010 with the purpose of broadening Bluetooth's application for usage in power-constrained portable devices such as mobile sensors and wireless controllers [19]. Not only does the use in sensors and controllers necessitate low-energy consumption, but also the quantity of data transmitted is minimal, and communications occur infrequently. However, the idea of reduced power and a small form factor raises the difficulty of meeting confidentiality needs while relying on unreliable, low bandwidth wireless connections and restricted computational power and storage [20, 21].

The ZigBee protocol was developed by the ZigBee Alliance and is centered on the IEEE802.15.4 low-power wireless communication benchmark [22]. ZigBee is designed to be a standard for high-level, low-cost communication systems that enable the creation of personal area networks using tiny, low-power digitized devices that transport data over extended distances. Simultaneously, it will be employed in applications requiring less data usage, greater battery capacity, and private network connections. Also, ZigBee may handle a variety of configurations such as mesh, star, and tree networking topology.

NFC (near-field communication) is a form of advancement that includes a set of rules that enable radio recurrence correspondence between two gadgets within a close proximity of 10 cm or less. It operates at a frequency of 13.56 MHz and transfers data at a rate of 424 Kilobits per second. This is widely used in home-based automation to control devices across a short distance. Vagdevi et. al [23] presented an IOT-based home automation system based on NFC. However, NFC is subject to a variety of networking vulnerabilities, such as tag manipulation, as discussed in [24].

*2.8.2. Long-Range Communication.* In this section, long-range communication protocols available such as Sigfox, long-range (LoRa)-low-power wide area network (LoRaWAN), and narrowband Internet of Things (NB-IoT) are discussed.

SigFox technology is a member of the LPWAN (low-power wide area networks) group of advanced technology that is mainly used for the evolution of the internet networks whenever the volume of data sent from sensory modules is negligible, the operating frequency is wide, and energy consumption rates are very. This protocol is designed in the first four levels of the OSI model. The encryption between linked terminal and the Sigfox cloud offers an end-to-end authentication solution that relies on a cryptographic key maintained in nonaccessible storage and paired with a recognizable and specific ID saved in ROM (read-only memory) on the end devices [14]. Messages delivered by end devices employ the secret key to produce a code that is distinct for every message, primarily for the purpose of authenticating the sender. This code would have a sequence number, which is added into radio frames so as to prevent them from being replayed.

Semtech Corporation invented LoRa technology [14]. It is a patented wireless communication technology. It utilizes spread spectrum encoding in the sub-GHz band to provide long-range service, high-energy efficiency (up to a decade battery lasts), higher bandwidth (higher than or equal to one million nodes), robust connectivity, and localization features. It is being utilized to connect sensors to cloud and provide live data analysis exchange. LoRa wireless technology employs a low-powered broadcast of tiny data packages (0.3 kbps to 37.5 kbps) over a large distance to a receiver. A gateway may manage several of devices in one go [25]. LoRa wireless technology employs the LoRa wide area network (LoRaWAN) protocol, which was designed to provide wireless-powered devices by the LoRa Alliances. The LoRaWAN Network design may be built in a star topology, with bidirectional end to end communication between nodes and

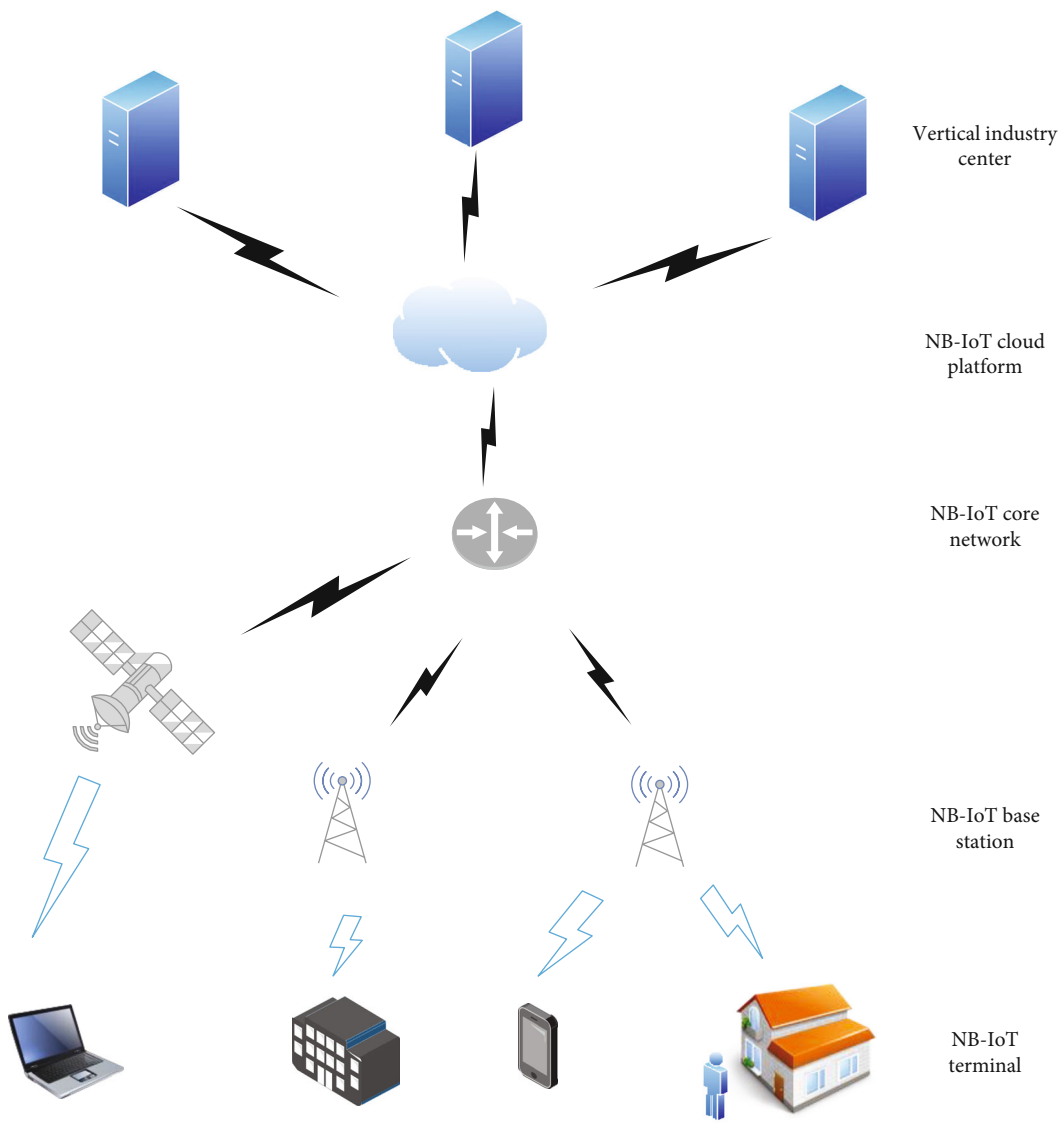


Figure 4: NB-IoT network [14].

connector. As terminal nodes transfer data to the gateway, this is referred to as "Uplink," and when the gateway transmits information to end node, this is referred to as "Downlink." Parts of LoRaWAN packets can be signed and encrypted using the LoRaWAN protocol. Before an end device can connect with a network server, it must first be enabled. However, there are certain things to think about when it comes to LoRa/LoRaWAN [26], such as the necessity of cloud system to manage stream from low bandwidth connectivity.

The narrowband Internet of Things (NB-IoT) is a large-scale low-power wide area (LPWA) technology suggested by 3GPP for information detection and acquisition in smart low data rate systems. Two common applications are adaptive monitoring and proactive environmental sensing [27]. Huge interconnections, super energy usage, large distance availability, and bidirectional activation between the signaling and information planes [28] are all supported by NB-IoT. Figure 4 represents the NB-IoT network architecture which has 5 layers from NB-IoT terminal through vertical industry center. Furthermore, it is backed up by an efficient cellular communication network. As a result, NB-IoT is an exciting technology. LTE protocols are used for NB-IoT encrypting data [14]. Encryption is done within the NB-IoT network, but it is accessible to other entities after it exits the NB-IoT network.

*2.8.3. 5G Network Communication.* WBAN networks are the most prominent ones. Sensors are either wearable or attachable to the body. Ahad [29] discusses about the 5G-based smart health care. He presents the network challenges in IoT that can be overcome through 5G networks which can meet the majority of needs like ultralow latencies, large bandwidth, hyper reliability, high density, and low-energy consumption. Future intelligent health-care systems are predicted to include a hybrid of 5G and IoT devices that will improve phone reception, signal strength, and solve security breaches [29–31].

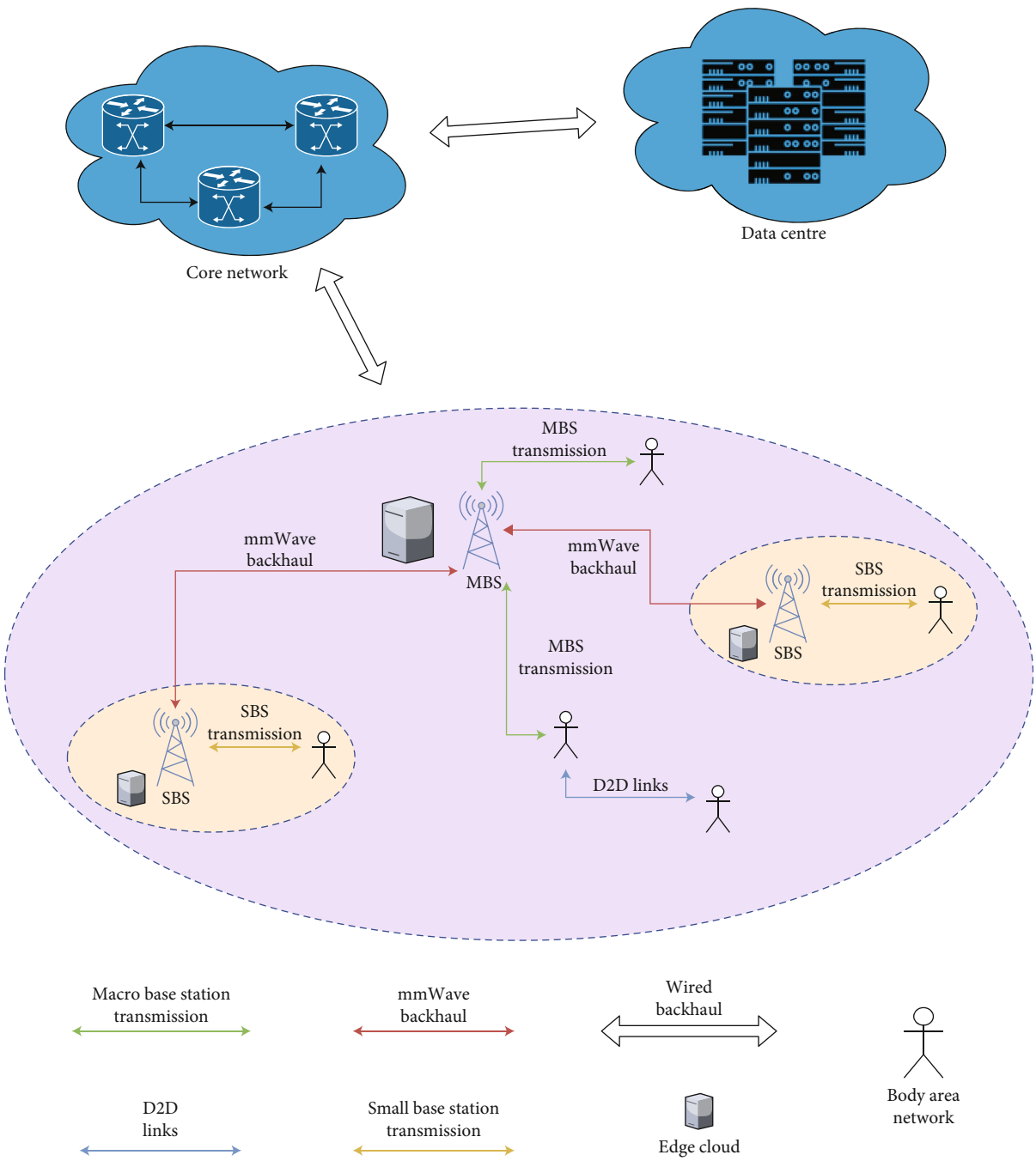


Figure 5: 5G smart health-care architecture [29].

Figure 5 shows the architecture of 5G smart health care. D2D is device-to-device direct communication between in the network without engaging base station (BS) or the core network. High path loss problem can be reduced by using millimeter waves (mmWaves) communication that has a band of spectrum between 20 GHz and 300 GHz. mmWaves are millimeter wave communication having spectrum band between 20 GHz and 300 GHz [29], and they work the best in reducing high path loss problems. Edge cloud or edge computing is an advanced networking technology in which the information is analyzed at the edge of network, close to the source of origin. It has the advantage of proving reduced decision time so it can be used in health devices in the future where the response time is a crucial factor [32]. Some of the major requirements of smart health care for home-based monitoring are low delay, high throughput, high dependability, and better battery life.

5G has the ability to achieve bandwidth that are nearly 100 times faster than 4G while still managing significantly more interconnections [33, 34]. These benefits are bolstered by ultralow delay, or the amount of time it takes for the system to execute a query [35]. Table 2 represents a comparison between Wi-Fi6 and 4G and 5G networks against various measurement criteria. The delay between transmission and

Table 2: Comparison of network models [36].

| Feature | Wi-Fi6 | 4G | 5G |
|---|---|---|---|
| Latency | 20 ms | 30–50 ms | 1–10 ms |
| Reliability/availability | 99.99% | 99.99% | 99.99% |
| Throughput | 9.6 Gbps | 300 mbps–1 Gbps | 10 Gbps |
| Speed | 1 Gbps | 20–50 mbps | Up to 1 Gbps |
| Density of connections | 8 per part | 12 per part | 100 per part |
| Energy | Medium | High | Medium |

reception of information is referred to as latency. As a result, the shorter the latency, the more "real time" the event experience will be. The delay of 5G is between 1 and 10 milliseconds [36]. The efficiency of the network in transmitting data between the transmitter and receiver without loss of data packet is referred to as reliability. The availability of all three networks under review is 99.99 percent. The absolute maximum quantity of information transferred between a location and another in a particular period is called throughput. From source to destination, 5G may transport 10 GB per second. Connection density refers to the number of connected devices per unit area, which may reach 1 Gbps in 5G networks but only 20–50 Mbps in 4G networks. In addition, with a 5G connection, the comparative power consumption levels are medium.

## 3. Discussion

As mentioned, the IoT is one technological innovation. The Internet of Things refers to the interconnection of devices, applications, sensors, and network connections that improves these entities' ability to collect and share data [37–42]. In this survey, the various technologies available for smart health care in home-based monitoring are discussed. A number of systems are available in health care with IoT that has made life easier and healthier. Quality health care is very crucial especially during these tough days of pandemic. So IoT and smart health care can be the best choice to maintain good health while being at home.

Different kinds of detectors capable of detecting physiological characteristics of human body have been discussed. There are a variety of heart rate sensor choices available, with thermistor-type temperature sensors being the most precise and dependable. One major issue faced in usage of thermistor is that it has high resistance which requires shielded power cables. There are a variety of blood pressure sensors that may be integrated into an IoT system, but just a few models, such as the finger wearable pressure sensor and MEMS pressure sensor, have been proven to be the most effective. The finger wearable [12] type of blood pressure sensor has brought a truly comfortable device due to its low weight and design structure. Body temperature is the third most often measured physiological parameter. This is one of the most important parameters evaluated in most home-based health-care studies. The most reliable and effective temperature sensors have been discovered to be infrared temperature sensors. It also has the advantage of being contactless which aids during this pandemic time [43]. However, studies show that there is more accuracy in contact-based temperature sensor than the contactless sensors. This brings to the fact that home-based monitoring devices using IoT should not be shared with other individuals.

All the sensors are connected to a controller like Raspberry Pi or Arduino which is interconnected with mobile devices through Wi-Fi [44]. This provides the measured data to be displayed on the mobile phone for patients view. Also, the data can be transferred to the hospitals for analyzing the data and providing immediate support in case of emergency [45]. In terms of short-range communications standards, Bluetooth was discovered to be the most efficient for health care, and many devices have also implemented Bluetooth technology. It is of low cost and versatile among all hardware devices. While in the long-range communication models, NB-IoT was identified to be more appropriate for health care due its ability of having huge interconnections. This makes it suitable to be implemented in large hospitals which keeps account of many users.

Existing communication technologies are incapable of meeting the complex and dynamic demands placed on communication networks by a wide range of smart health-care applications [46, 47]. As a result, the upcoming 5G network is projected to serve smart health-care applications that meet the majority of the requirements, including ultralow latency, high bandwidth, ultrahigh reliability, high density, and high-energy efficiency. Future smart health-care networks are predicted to include a hybrid of 5G and IoT devices that will improve cellular coverage, network performance, and solve security problems.

## 4. Conclusion

In this study, the significance and beneficial effects of implementing IoT in remote health monitoring systems is discussed. A systematic overview of every sensor that is used for home-based monitoring system is presented. Also, the emerging 5G technology is discussed with a comparison across 4G and Wi-Fi models. It is also shown that there is very little implementation of proposed 5G architecture which can be taken as a future research suggestion. The small sensor nodes with IoT will have a significant influence on every patient's life, reducing their anxiety of risk even while they are away from family and friends and physician. They also greatly contribute to the development of smart cities. The sensory data might be collected at home or at work.

Also discussed are the problems in sensing, analytics, and illness prediction, which may be overcome to create a smooth interconnection into the medical industry.

The limitations identified in this research are that cloud-based 5G communication models pose the threat of security vulnerability. Hence, strong security protocols and encryptions need to be developed in order to overcome the security threats. The personal patient data has to be encrypted during communication and storage to comply with the medical ethics. This is an area identified as future work to develop systems that are more secure and does not pose any security threats. This would ensure the person's privacy and confidence in the usage of home-based monitoring devices. Limitations of this research include the absence of the usage of artificial intelligence or deep learning in smart health care. These new technical advancements are taking shape leading to a practical AI-based smart health-care system. Machine learning is a vast area in medical field for diagnosis of several illness. It is identified as a future research area to develop systems that are capable of diagnosing diseases at home with minimal intervention of physicians which may be big boon to the personalized health care.

## Data Availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

## Conflicts of Interest

The authors declare that there is no conflict of interest.

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