Real-Time Health Data Transmission Using 5G-Enabled Wearable Devices: A Review

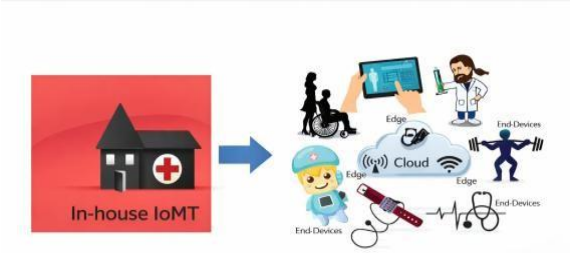
Nitesh Rajput[1], Rishabh Raghav[2], Raj Singh[3]
[1,2,3]*Department of Electronics and Communication Engineering Noida Institute of Engineering and TechnologyNoida, India*

***Abstract*—Wireless wearable devices are literally changing the way we maintain our health- it is the new level of self-care. Smartwatches and fitness bands are able to measure heart rate, oxygen-in-blood, temperature, and activity. Fitness trackers and smartwatches, which are connected wirelessly, are transforming the process of patient monitoring in healthcare. They check vital parameters like pulse, SpO 2, skin temperature, and movement. Nevertheless, the majority of the existing systems in use are based on Bluetooth, Wi-Fi or 4G connections, which add significant delays and poor connectivity when transmitting data constantly. This kind of latency is not appropriate when using a critical healthcare system, such as a fall detector, cardiac monitor or emergency alert system. The fifth generation (5G) communication has provided ultra-low latency, high reliability and high data transmission rates, which has made it a prospective solution in the transmission of real-time medical data. The present review paper presents the recent research works associated with the wearable health monitoring systems and wireless communication technologies. There are five research papers that are related closely and analyzed in details. Their system structure, technologies employed, strengths and weakness are talked about. According to the review, the gaps in the research and the reasons that underlie the creation of a 5G-enabled real-time wearable health monitoring system are outlined.**

***Index Terms*—5G communications, wearable devices, real-time health monitoring, bio- sensors, IoT health technology.**

I. INTRODUCTION

Continuous healthcare monitoring, which is remote and continuous, is a key issue in research due to the fast growth of the number of chronic diseases, the aging population, and the necessity to intervene in medical care at an early stage. During my studies, I have observed that the conventional hospital-based surveillance mechanism is a costly and cumbersome system to use in the long term. Therefore, wearable health trackers such as fitness watches became very popular during the past years in smartwatches. The gadgets are small, light, and can be used to measure physiological data like heart rate, steps taken, sleep habits and body temperature.



IoMT in Home

Even though the majority of wearable devices in the market are free, I have observed that they are usually programmed to track fitness not those intense medical type real-time notifications that we should be taught during health classes at college. The information of these toys tends to skip about using Bluetooth, Wi-Fi, or 4G after some time, translates to additional lag that is simply murderous should you be using instant feedback on such issues as fall warnings, weird heartbeat hiccups or emergency shoutouts.

The fifth generation (5G) wireless technology has also provided the possibility of whole bunch of new opportunities in the field of real-time healthcare applications, with its features, such as ultra-reliable low-latency communication (URLLC), high data rates, and massive connectivity of devices, which is

quite necessary in modern medical technology. Practically, 5G latency is down to 1-10 ms latency, which is 30-80 ms in 4G and 100-300 ms in Bluetooth-based systems. These characteristics enable 5G to be highly appropriate to the constant transmission of medical information in real time. Therefore, making wearable devices connected to 5G connections would potentially significantly enhance the reliability and responsiveness of remote healthcare monitoring systems.

Thus, this review paper is essentially examining the current research on wearable health monitoring and the data streaming in real-time. In order to have a sense of the existing approaches, what is cool about them, and their shortcomings, we explore five closely related papers. Based on that, we identify some gaps in the research and outline a future concept of a 5G-enabled wearable health monitoring device.

II. BACKGROUND AND TECHNICAL OVERVIEW

A. Wearable Health Monitoring Devices

Wearable health monitors include small electronic devices that are designed to be used on the torso or limbs of a human, and usually are made in the form of wrist watches, arm bands, or patches. Such systems typically have a microcontroller unit, one or more biomedical sensors, a rechargeable electric power source, and a wireless communication interface. The main sensor modalities used in these devices include photoplethysmographic heart-rate sensors, pulse-oximetry units to measure the saturation of arterial oxygen (SpO 2), thermistors to monitor body-temperature, and triaxial accelerometers to measure physical activity and detect falls.

The common ranges of operation of these sensors are: heart rate 40-180 beats per minute, SpO 2 90 100 and body temperature 35 40 o C. These sensors are used to capture physiological data of the user at all times. This data is received by the microcontroller which then sends it to a mobile phone or cloud server where it is stored and analyzed. Fitness tracking, elderly care, and patient monitoring are commonly used in wearable devices.

B. Wireless Communication in Healthcare

Wireless communication is also very important in remote healthcare monitoring system. Data transmission is often carried out with the help of such technologies as Bluetooth Low Energy (BLE), Wi-Fi, and 4 G LTE. BLE is designed to be used in short-range communication and low power consumption, but it needs a nearby smart phone or a gateway. Wi - Fi has a higher data rate but uses more power and is not always available. 4 G LTE is less latent and has a broader coverage.

As an example, common latency is about 100300ms for Bluetooth, 50150ms for Wi-Fi, and 3080ms for 4G networks. These are delays that are normally intolerable in those applications that require real time monitoring and instant creation of alerts.

C. Role of 5G in Healthcare Applications

The 5G communication brings forward some advancements to the past wireless technologies. The most relevant characteristics with regards to healthcare application include exceptionally low latency, high reliability, high data transfer rates, and the ability to support a high number of devices that are connected at the same time. Latencies of 1 10 ms are very beneficial in real-time applications, including the constant patient monitoring and emergency alerting systems.

Through combining wearable technologies and 5G networks, it will be possible to send health information in real-time with little delay. This is possible because it leads to quicker medical response and safety of the patient.

D. Data Characteristics and Transmission Requirements in Wearable Healthcare

The wearable health surveillance systems produce various forms of physiological information based on the sensors used. The data rate of simple parameters like the heart rate and body temperature can be low, whereas data rates of more intricate signals like electrocardiogram (ECG) and continuous oxygen saturation can be relatively large. As an example, a standard ECG signal with 250 to 500 Hz sampling and 1012 bit resolution can to need a data rate between 250 and 500 kbps. Conversely, those values that are transmitted at a frequency of a few seconds, such as heart-rate and SpO 2, need a few kilobits per second.

Latency is another key requirement in the medical monitoring system other than the data rate. Even a few seconds delay in an emergency situation

involving sudden cardiac abnormalities or fall cases can have severe results. As such, an effective wearable healthcare system should be able to meet the requirements of low-volume transmission to accommodate regular check-ups and the short latency to transmit emergency situations.

The traditional wireless communication technologies, like Bluetooth and Wi-Fi, are not specifically tailored to such mixed-traffic environment. Bluetooth is low power consuming, but has a short range and unpredictable latency. Wi-Fi has increased throughput but is not reliable when used on mobile. Such constraints also explain why more advanced wireless technologies like 5G should be employed in the next generation healthcare monitoring system.

III. LITERATURE REVIEW

This paragraph reviews five research papers that are most relevant to the real-time health monitoring and wearable technology.

A. Paper 1: IoT-Based Wearable Health Monitoring System

The initial article reports a wearable health monitoring system based on IoT designed to measure vital signs, including heart rate and body temperature. The design involves microcontroller and biomedical sensors that are connected to the architecture and transmit the combined data to a cloud server using Wi-Fi.

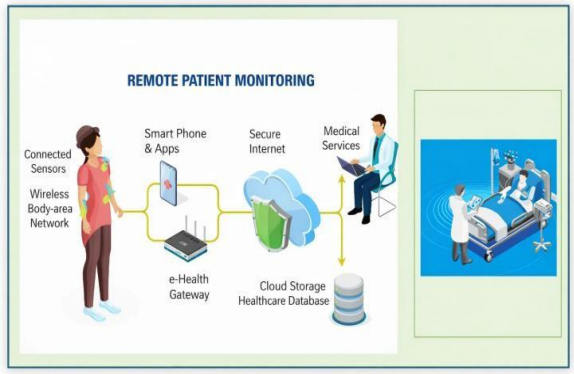
The main benefit of this system is that it is simple to design and cheap. It allows constant monitoring of key health indicators and allows access to patient data remotely using a web-based dashboard, which facilitates monitoring at home and overall fitness tracking.

On the other hand, its greatest weakness lies in the fact that it uses Wi-Fi to transmit the data, which makes it ineffective in an emergency situation when the patient is outside or where a steady Wi-Fi connection is not available. Besides, the system does not have fall-detection facilities and real time alerting systems.

B. Paper 2: Smart Wearable Device for Remote Patient Monitoring

The second paper suggests a small, power-efficient wearable apparatus to perform remote monitoring of a patient, which makes use of Bluetooth and a smartphone as a gateway. The device measures the heart rate and SpO 2 and transmits the information to a mobile application, which in turn sends the information to a cloud server.

The system is made portable and easy to implement by use of the smartphone as a gateway. The mobile application that comes with it provides a convenient interface in which health data can be viewed.



The method, however, highly depends on having a smartphone and a stable Internet connection. The transmission of data is not truly real-time and there could be any delays when uploading to a cloud. Moreover, the design fails to include such advanced wireless technologies as 5G.

C. Paper 3: 5G-Enabled Healthcare Monitoring Framework

The third paper presents a 5G-driven healthcare monitoring system that targets the provision of medical information with low-latency. The design includes 5G communication module, wearable sensors and edge computing nodes.

Another significant contribution of the study is the ability to show the capabilities of 5G to transmit medical data in real-time with low latency and high

reliability; the latter is important due to the urgency of medical services being provided.

However, the study focuses more on network structure and a simulated result. It is not an actual wearable hardware prototype and the high cost and complexity of 5G modules is practically a barrier

D. Paper 4: Wearable ECG Monitoring Using Edge Computing

The fourth article describes a wearable ECG-based monitoring system which uses edge computing as a means of real-time data processing. The ECG signals are sent to an adjacent edge server to be processed.

The great advantage of this arrangement is that it reduces processing delay and improves real-time performance and has a reduced computational burden on the wearable gadget.

Although it has all these strengths, the system remains reliant on traditional wireless network and fails to utilize 5G communication; therefore, this increases the latency of the system compared to 5G-based solutions.

E. Paper 5: Remote Patient Monitoring Using IoT and Cloud

The fifth paper explains the use of an IoT based remote patient monitoring system that transmits vital information to a cloud server where it is stored and visualized.

The scalability of the system and easy access to patient information are some of the strengths because a clinician can review health metrics remotely using a web interface.

It has a weakness though in that it lacks real-time emergency response and relies on continuous Internet connectivity.

F. General Observations from Existing Wearable Healthcare Systems

One of the themes identified in the analyzed wearable healthcare systems is a strong emphasis on data gathering instead of being responsive in real-time. Numerous designs are constantly accumulating physiological data but sending it in batches or at a fixed rate, so that it can be useful in large-scale analysis of health trends, but not in giving immediate clinical clarity.

The absence of responsive data-transmission strategies is another weakness that is pervasive. Many devices have a fixed data-rate, independent of the patient status, an effective design would reduce the transmission rates under normal conditions and increase them in case of critical events, but intelligent bandwidth control is not commonly done.

These observations underscore the fact that future wearable healthcare systems should not only accommodate better communication technologies but they should also include advanced data processing and adaptive transmission policies.

IV. COMPARATIVE ANALYSIS

The comparative analysis of the studies reviewed can clarify the advances made in the sphere of wearable health monitoring and reveal the still existing practical limitations.

The initial article, an IoT enabled wearable system based on the use of WiWireless technology, focuses on the use of simple and low cost hardware to measure basic physiological parameters. The fact that it can only support persistent real-time data transfer in settings where Wi-Fi is not available makes it inappropriate in emergency care where immediate action is required.

The second article presents a wearable based on Bluetooth technology with an attachment to a smartphone gateway. Although this design makes it more portable and user friendly, given that the ubiquitous nature of smartphones is used, reliance on a smartphone as well as active Internet connectivity creates delays that affect real-time critical monitoring.

The third article reports a 5G-focused framework that features an exceptionally low latency and extreme reliability. The article successfully demonstrates the technical benefits of 5G in healthcare; however, it is a conceptual, simulation-oriented endeavor lacking a tangible, wearable hardware implementation, and 5G modules are too expensive and complex to be implemented widely.

To conclude, the previous systems are simple and more affordable but have no real-time performance, whereas the solutions based on 5G network provision can achieve higher communication performance values but cannot match the hardware usage wearable by users.

IV. Parametric Comparative Analysis

Paper	Sensors Used	Communication	Latency	Power Use	Mobility	Cost	Limitations
Paper 1	HR, Temp	Wi-Fi	High	Medium	Low	Low	Not real-time
Paper 2	HR, SpO2	Bluetooth + Internet	Medium	Low	Medium	Low	Phone dependent
Paper 3	Multiple sensors	5G	Very Low	High	High	High	Expensive
Paper 4	ECG	Edge + Wi-Fi	Medium	Medium	Medium	Medium	No 5G
Paper 5	HR, SpO2	IoT + Cloud	Medium	Medium	Medium	Medium	Delay

V. SYSTEM ARCHITECTURE TRENDS IN WEARABLE HEALTHCARE

A. General Architecture of Wearable Health Monitoring System

Modern wearable health supervision systems are often designed on a layered design. The first layer consists of biomedical sensor and a microcontroller. The next layer will include a wireless communication module. Cloud or edge servers which store and process data form the third layer. The terminal layer makes clinician and caregiver user interfaces easy.

B. Communication Flow in a 5G-Enabled Wearable Monitoring System

In a 5G-enabled wearable health monitoring system (canonical), physiological data are first obtained via on-body sensors, such as those capturing heart rate, peripheral oxygen saturation (SpO 2) and temperature. The actual sensor data are preprocessed by a microcontroller which carries out the denoising and feature extraction functionality. This processed information is then relayed to a 5G module of communication built into the wearable device.

The 5G interface transmits the data to the next base station which transmits it to an edge server or a cloud server. In latency-sensitive applications, e.g. electrocardiographic monitoring or fall detection, edge servers are preferred due to their ability to do local data analysis and generate alerts in minimalLatency. The processed data and notification that results is then sent to clinicians, caregivers, or relatives either through mobile or web application.

This multitiered communication channel highlights the importance of 5G in creating a direct point-to-point, low-latency communication channel between the wearable device and the rest of the medical monitoring network.

VI. RESEARCH GAPS AND MOTIVATION

A. According to the literature review, the research gaps that are identified are as follows:

- Most of the existing health wearable devices use either Wi-Fi or Bluetooth technology that is typically not compatible with real-time emergency cases.
- Limited use of 5G technology in practical wearable hardware systems.
- Lack of integrated emergency alert and fall detection features.
- High latency and unreliable connectivity in existing systems.

Such shortcomings demonstrate the necessity of a small and convenient wearable item capable of relaying health information on the fly with the 5G connection.

B. Practical Challenges in Implementing 5G Wearable Devices

Most of the existing wearable health monitoring devices are dependent on Wi-fi or Bluetooth which cannot be used in real-life emergency cases.

Most of the existing wearable health monitoring devices use Wi-Fi or Bluetooth technology which is not well suited to real time emergency applications.

A size issue of hardware is another practical challenge. Most 5G modules being commercially available are still too large in comparison to Bluetooth modules. Such modules need to be carefully designed and integrated into small wearable devices, e.g. smart bands or smartwatches.

Other limiting factors include cost. 5G devices are still costly and this means that the total price of the wearable device will go up as well as make large-scale implementation a challenging task, especially in developing nations.

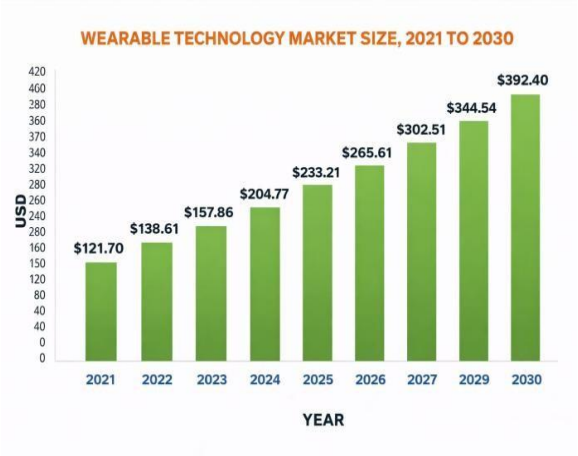
Such difficulties mean that 5G is not yet ready to become widely available in the consumer-grade wearable healthcare device market, though more studies and engineering optimization is needed.

VII. CONCLUSION AND FUTURE SCOPE

A. Recent Research Work

This review paper discussed recent research work related to wearable health monitoring systems and real-time data transmission. Five closely related research papers were analyzed and compared. Although existing systems provide basic health monitoring features, most of them are limited by high latency, unreliable connectivity and lack of real-time performance.

In future work, a 5G-enabled wearable device can be developed to monitor vital signs such as heart rate, SpO2 and body temperature. The system can also include fall detection and emergency alert features. Such a device can be highly useful for elderly care, remote patient monitoring and critical healthcare applications.



B. Application Scenarios of 5G-Enabled Wearable Healthcare Systems

Wearable healthcare systems based on 5G can find application in multiple scenarios in the real world. These devices can also be used in the caring of the elderly to continuously measure vital signs and alert the care giver with an abnormal situation or fall. Patients are also in a position to leave hospitals at an earlier time and undertake post-surgery monitoring remotely instead of incurring higher healthcare expenses.

Real-time measurements of sports physiological parameters may facilitate the application of the training intensity in athletes and help to avoid excessive workloads. Wearable health technology with connection to 5G can be used in rural and remote regions to provide rudimentary medical monitoring services in areas lacking easy access to hospitals.

Those use cases in which real-time wearable healthcare systems are utilized prove to be very wide-ranging in terms of their practical applicability.

REFERENCES

[1] S. Morale, S. Sakharkar, A. Thombre, and A. Unawane, “IoT Based Wearable Health Monitoring System,” IJIRT, 2021.

[2] U. Hariharan et al., “Smart Wearable Devices for Remote Patient Monitoring,” Springer, 2021.

[3] N. Spicher et al., “Edge computing in 5G cellular networks for real-time analysis of ECG,” arXiv, 2021.

[4] D. H. Devi et al., “5G Technology in Healthcare and Wearable Devices,” Sensors, 2023.

[5] I. Batool, "Real-Time Health Monitoring Using 5G Networks," JMIRx Med, 2025.
[6] M. Chen et al., "Wearable 2.0: Enabling Human–Cloud Integration," IEEE Commun. Mag., 2015.
[7] P. Patel et al., "Mobile Health Monitoring Systems," IEEE Commun. Mag., 2012.
[8] R. Varshney, "5G Wireless Systems for Healthcare," IEEE Wireless Commun., 2020.
[9] A. Pantelopoulos, N. Bourbakis, "A Survey on Wearable Sensor-Based Systems," IEEE Trans. Syst., 2010.
[10] M. Haghi et al., "Wearable Devices in Medical Internet of Things," IEEE Access, 2017.
[11] S. Ullah et al., "A Comprehensive Survey of Wireless Body Area Networks," J. Med. Syst., 2012.
[12] Y. Cao et al., "Edge Computing in Smart Healthcare," IEEE IoT J., 2020.