

Original Article

IoT in Healthcare and Wearable Devices

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Abstract

Recently, many apps now use the Internet of Things (IoT) in their functionality. As with other industries, IoT has changed many areas of medicine. IoT connects a variety of medical devices to one another and also to the internet using sensors, so data about patients can be transmitted and recorded so that it can be monitored in real-time. For example, patient wearables like smartwatches, fitness trackers, and smart ECG monitors enable healthcare professionals to monitor patients and provide feedback on how their health is changing continuously. The smart devices based on IoT improve healthcare service delivery by enabling remote patient monitoring, providing remote access to healthcare professionals so that early detection of disease takes place and allowing for better treatment and management of patients by providing comprehensive information about their health. The purpose of this research paper is to describe how IoT has impacted the healthcare industry; it will describe the architecture and applications of IoT; the advantages of using IoT in healthcare; the challenges that have developed because of IoT; and the future development of IoT in healthcare, specifically with respect to wearable technology.

Keywords: IoT, IoMT, Wearable Devices, Remote Monitoring, Healthcare, smart hospitals.

Introduction

There are many things that can connect to the internet wirelessly and talk to each other. An IoT is a collection of objects that are all linked via the internet. Therefore, when you have multiple devices able to communicate with each other that qualifies as IoT. Medical devices with IoT capabilities are part of an emerging industry known as the Internet of Medical Things (IoMT). It includes medical devices and systems that collect, store, and share health information. IoT in health care makes regular medical devices smart by letting them connect to the internet and letting medical devices work with hospital information systems. Wearable technology (like heart-rate monitors) and device sensors (like bed sensors) are connected to the internet so that doctors can get real-time data. This can help doctors make more accurate diagnoses, better treatment plans, and even therapy delivered remotely, all of which will help them make healthcare decisions for each patient.

IoMT is already being used in healthcare settings in a number of ways, such as keeping an eye on patients' health from a distance, managing their chronic medical conditions, keeping track of medical equipment, and automatically giving patients their medications. Hospitals that use IoMT are seeing a lot of benefits, such as shorter patient stays and fewer readmissions after being discharged. They are also seeing more engaged patients and lower overall patient care costs.

Objective:

The goals of this report include:

- Learn about how the Internet of Things (IoT) works with regard to health care and what this looks like in the real world.
- Investigate the use of wearable devices for tracking and managing patient wellness.
- Look for ways IoT and wearable technology can help improve patient care.
- Determine the future of wearable technology for use in the Internet of Medical Things (IoMT).
- To evaluate the effectiveness of wearable devices in the early detection of various diseases.

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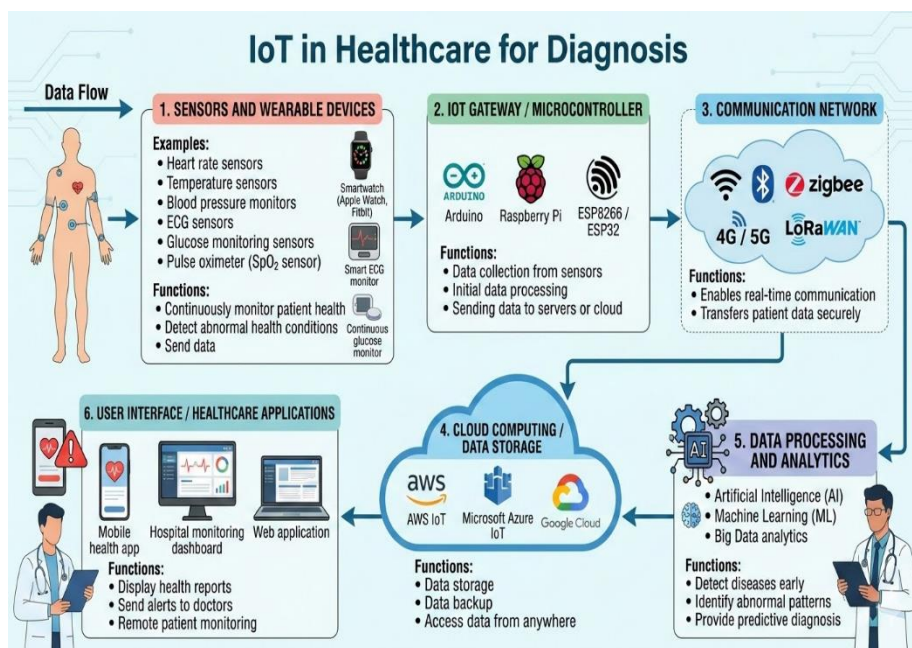
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A) Literature Review:

Wearable technology like Smart Watches, Smart Bands, and other wearable devices helps consumers track their health. These wearable devices can provide information about an individual's heart rate, physical activity level, and sleep patterns. Research indicates that the Internet of Things (IoT) has greatly improved healthcare services by providing real-time patient monitoring through the use of interconnected devices. According to researchers, such as Gubbi et al. (2013), the IoT combines sensor technology with networks and cloud computing to collect and analyze health information in an efficient manner. Researchers are developing solutions to the existing challenges of data security, privacy, and device compatibility that have emerged through the use of IoT and wearable devices; therefore, the use of IoT and wearable devices is affecting how contemporary healthcare systems function.

B) IoT architecture in Healthcare:



As per my research I have designed above diagram with the help of Gemini that visually represents the six key components of IoT used in Healthcare for Diagnosis

- Wearable devices and sensors:** are basically things that people wear to keep track of their health stuff in real time. They pick up information about patients all the time, like heart rate or whatever else is going on. It seems like they are always on, monitoring everything without stopping. That way, if something weird happens, like an unexpected change in condition, they can alert the doctors right away. I mean, that sounds useful, but I'm not totally sure how reliable they are in every situation. Then there's the part where they send all that data over to other connected gadgets or systems. So the info doesn't just sit there, it gets shared quickly. Some of the common sensors you see on the market, well, they're listed in this chart here. Like fitness trackers or smartwatches with health features, stuff like that. It gets a bit messy trying to explain all the types, but the chart shows some typical ones anyway.

Sensor Type	Measurement	Clinical Application(s)
Electrocardiogram	Electrical activity of the heart	Detecting arrhythmias, heart disease
Pulse Oximeter	Oxygen saturation (\$SpO_2\$) & HR	Surgery monitoring, COPD, asthma
Blood Pressure	Arterial blood pressure	Hypertension and hypotension
Glucose	Glucose (blood/interstitial)	Diabetes management
Temperature	Body temperature	Detecting fevers or hypothermia
Respiratory	Respiratory rate and rhythm	Sleep apnoea, breathing disorders

2. **Microcontroller / IoT Gateway** - How it works: - Gathers information from multiple sensors - Formulates and arranges gathered data in preparation for transfer - Sends collected data to the cloud/server
3. **Network for Communication** - To share patient's health related data among healthcare technicians using wireless communication - How it works: - Provides real time health data transfer - Provides secure transport of health related data
4. **Cloud Computing/ Data Storage** - Due to vast data storage capacity offered by cloud computing platforms, cloud computing offers health providers the capability to store, back-up, and access their patients' health data from any remote location. - How it works: - Backup data; - Access data remotely.
5. **Analytical and Data Processing** - The use of artificial intelligence and machine learning for analysing patient's collected health data - How they work: - Identify illness during the early stages, - Identify abnormalities - Provide a forecast diagnosis.
6. **User Interface / Healthcare Applications**

Healthcare IoT app provides patients the means to manage their own health information as well as physician access to those same records. It gives users the option to review patient health records, receive alerts, and remotely monitor medical records available to them, and it increases timely medical treatment for patients by improving the communication between patients and healthcare providers.

Operations:

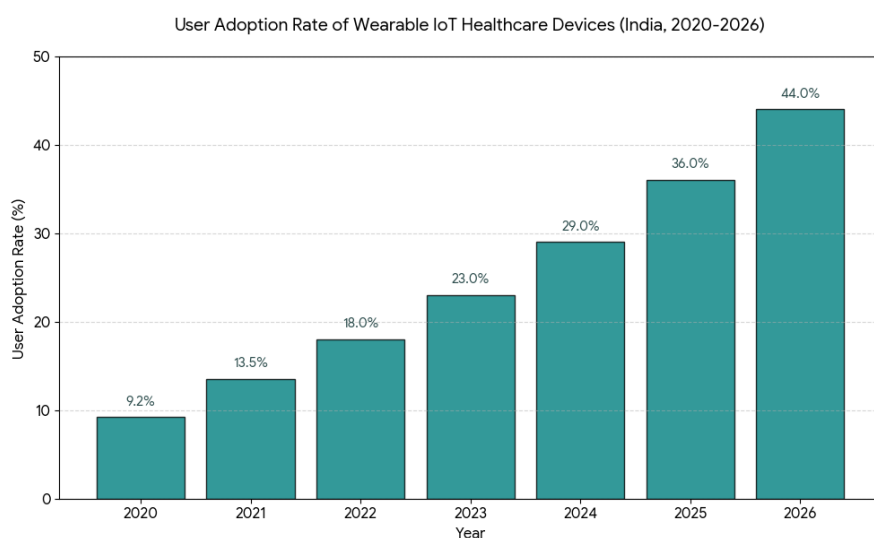
1. **Access to Patient Health Records:** enables physicians and patients access to stored or live health information on their patients (blood pressure, heart rate, blood sugar levels, etc.).
2. **Alerts to Physician:** With this tool, the physician can receive alerts of any areas of concern based on abnormal health situations identified through the patient's data, allowing for quick medical intervention.
3. **Remote Patient Monitoring:** The use of wearable devices connected through the Internet of Things allows for physicians to monitor their patient's health remotely and reduce the number of times patients need to visit the hospital.

C) Wearable Healthcare Devices:

Wearable healthcare devices are those smart gadgets you wear on your body to track health stuff and send it over the internet to doctors or apps on your phone. They keep an eye on things all the time, which helps catch problems early and makes care for patients better overall.

In India, people are starting to use these more and more. The adoption rate went up from about 9.2 percent in 2020, and it's supposed to hit 44 percent by 2026. I think the COVID pandemic really kicked it off back in 2020 and 2021. Everyone got way more worried about their health, so demand shot up for things like pulse oximeters and monitors for heart rate that let you check remotely.

That trend has not slowed down since. Companies are making cheaper versions right here in India, and they are adding better medical features to the popular ones. It feels like this market is just picking up speed, with more options coming out. The growth in user numbers seems steady, even if it's hard to say exactly how fast. Some products are getting improved, which probably helps keep people interested.



The above chart analysis from Google Gemini displays the usage of wearable IoT devices in the Indian market between 2020 & 2026.

Examples of Wearable IoT Healthcare Devices

The following are some popular healthcare wearables available on today's market

1. **Smartwatch:** Smartwatches, which are the most commonplace and widely used wearable device on today's wearable health technology market, serve many purposes such as; tracking an individual's heart rate; tracking how much physical activity is being performed by an individual; tracking how well an individual sleeps at night; tracking the amount of oxygen in an individual's bloodstream; and many smartwatches now have intelligent tracking capabilities that track how far out-of-sync an

individual's heart is from their ECG as an example. All of these features make them very popular. Notable examples of smartwatches include the Apple Watch, Fitbit and the Samsung Galaxy watch.

2. Fitness-tracking devices (like Fitbits): are worn daily by millions of people (to help them track their steps, calories burned, heart rate and physical conditioning). There are fitness trackers on the market today that offer multitudes of features beyond those already listed (health records that can be uploaded to your doctors or insurance companies).
3. Smart clothing: (also known as "smart apparel") is fabrics that are embedded with sensors, conductive threads, and microcontrollers, enabling them to do things like monitor your heart rate, and improve your performances. Some examples of smart clothing being used today are Hexoskin Smart Shirt and Athos Smart Apparel. Smart shirts and smart pants utilize embedded sensors that provide real-time feedback about heart rate, respiration (breathing) and muscle activity on the wearer to monitor their condition; this provides excellent data for improved healthcare delivery as well as sports medicine.
4. Continuous Glucose Monitoring (CGM) Devices:
A Continuous Glucose Monitor, or CGM, is a device that is worn on someone's body which keeps track of blood sugars continuously. The device typically has a sensor that is inserted just under the skin, allowing for continuous, real-time and automatic readings of glucose levels and trends without needing to perform finger pokes every day. This type of monitoring device allows for someone managing diabetes to stay in control of their blood sugars (low or high) and to help improve their glycaemic control due to the ability to continuously measure blood glucose levels and transmit this information to a smartphone or physician.

Examples of CGM devices would be Dexcom G6 and Free Style Libre.

5. Wearable ECG Monitors:
Consumer health devices are used for tracking the electrical activity of the heart to help identify behaviors that indicate a problem such as AFib (Atrial Fibrillation). Wearable ECG monitors can be as simple as a wristwatch providing periodic "spot checks", or more complex as to include a continuous recording of the ECG over a 24-hour period. These devices measure electrocardiogram (ECG) signals in order to help identify abnormalities such as arrhythmias and allow physicians to monitor patients remotely.
Two examples of ECG devices are Kardia Mobile and Zio Patch.
6. Smart Patches:
Wearable tech for smart patches includes adhesive devices with sensors and microelectronics that can monitor, collect, and send data from the body. Smart patches are small, sticky things that you put on your skin. They keep an eye on blood pressure, heart rate, temperature, and hydration levels.
For example, the Vital Connect Health Patch.
7. **Advanced hearing aids:** that are connected to a smartphone via IoT technology and have the ability to automatically adjust their sound processing.
8. **Smart Rings:** Small electronic devices with sensor(s) connected via Bluetooth to your cell phone enable figure out how healthy you are with respect to various activities. Smart rings can measure other activities as well i.e. hours of sleep, heart rate, level of activity and temperature. Two smart rings in the marketplace are the Oura ring and the Circular ring.
9. **The smart devices with IOT technology (wearable) to track blood pressure:** They provide real-time data and continuing blood pressure measurements by using wrist-mounted or arm-mounted sensors to measure blood pressure. Patients can use these devices at home or at work without visiting a hospital or doctor's office to manage their hypertension. An example of a smart device to monitor blood pressure is the Omron Heart Guide.
10. **Wearable pulse oximeters:** are small electronic devices that can be worn on your body, such as a finger, wrist, or around your wrist, and measure both your blood's oxygen content (SpO₂) and how fast your heart is beating by using optical sensors. They can determine how much oxygen is in your blood by calculating how much is purified by the lungs. Many people use this device to monitor how well they are doing and how well their lungs are working (for example, people with chronic respiratory disorders like asthma or COPD).

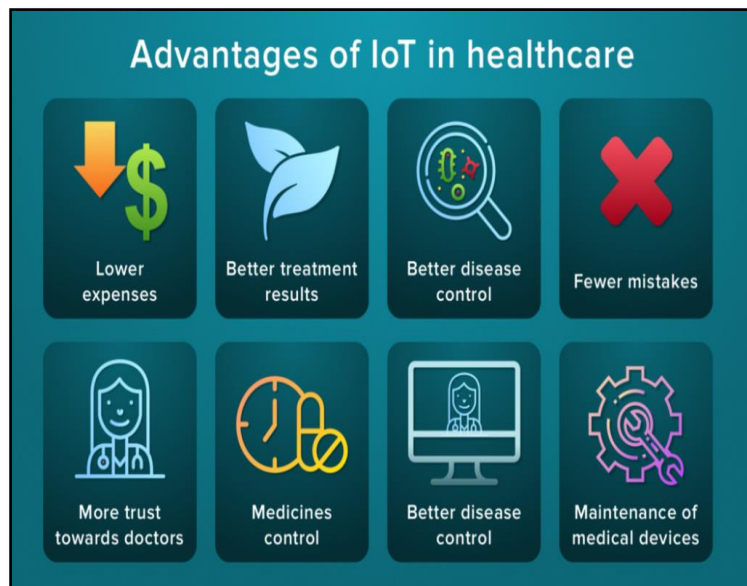
D) Benefits of Wearable Device IoT technology in healthcare:

Using this technology allows healthcare workers to monitor people from afar or track them without needing a physical visit with them. With the use of IoT technology such as smart devices (worn) and sensors, healthcare professionals can collect extensive data on a variety of health variables, including but not limited to heart rate (HR), blood oxygen saturation (SpO₂), blood glucose level (BG) and the sending/receiving of secure data through a central cloud based service. Healthcare professionals will be able to evaluate a person's health situation when they are being treated, and remote patient care will allow healthcare professionals to provide care, allowing the patient to remain at home rather than have to go to a healthcare facility, so that healthcare can be achieved remotely (using this IoT technology). Some benefits of IoT technology helping healthcare include:

1. **Cost Savings:** The IoMT allows for immediate (real-time) patient care, and can save healthcare providers billions of dollars annually by eliminating unnecessary doctor visits, unnecessary hospital admissions, and unnecessary readmissions.
2. **Improved Quality of Care:** The ability to utilize data, providers will be able to facilitate evidence-based decision making, enabling them to diagnose patients earlier than before, or even before symptoms appear, thus aiding the physicians in providing their own personal health preventative care.
3. **Medications and Capital Equipment Management:** The management of medical supplies and capital medical equipment is a challenge in the healthcare sector, IoT can provide improvements to that process and reduce costs. The use of connected

IoT devices will enable both patients and physicians to assist in the effective delivery of medications and also will enable both patient and physician to identify when a capital equipment needs to be serviced.

4. **Hospital Management:** The overall management of daily hospital activities can be enhanced with IoT to help decrease time and cost. For example, the use of an RFID or Bluetooth sensor attached to a piece of medical equipment can determine the physical location of that device.



Reference: <https://evolveetfs.com/2020/01/the-future-of-healthcare-digital-healthcare-and-iot-in-healthcare/>

E) Challenges of IoT in Healthcare:

The main challenges associated with integrating Internet of Things devices into healthcare include:

1. **Patient Data and Privacy:** Information on an individual patient's health such as blood pressure, heartbeat rates, or past history are collected through IoT devices and presented to physicians. Protecting this type of sensitive information from hackers and other unauthorized individuals poses one of the biggest barriers to securing patient data using IoT.
2. **Compatibility of Devices (Interoperability):** Most healthcare devices and systems have been developed by many different companies, leading to problems associated with using different devices when they are unable to communicate effectively with one another.
3. **High Cost of Implementation:** There are many costs (e.g. infrastructure, tech wearables, cloud storage, network systems, etc.) associated with implementing IoT in hospitals and health care companies.
4. **Management of Power and Battery Life:** Wearable devices need to be powered constantly to track a patient's physical activity. The functionality and reliability of these devices can be adversely affected by a short battery life.
5. **Accuracy and Reliability of Data:** Wearable devices can produce inaccurate or inconsistent data due to sensor malfunction or environmental influences, which can impact medical interventions.
6. **Networking Issues:** IoT devices require internet connectivity for operation. Poor network connectivity can interrupt real-time monitoring and data transmission.
7. **Managing and Storing Data:** IoT medical devices generate enormous volumes of data, therefore effectively managing, storing, and analyzing that information is a significant challenge.
8. **Legal Concerns and Regulatory Issues:** IoT deployment and development will be complicated by strict regulations governing medical devices and healthcare technology.

F) Future Scope:

The future scope of IoT in healthcare will include moving from tracking to predicting, which will allow smart rings and patches to not only record data, but also identify potential health crises (i.e., a heart attack) before they occur. 5G and artificial intelligence will facilitate the development and implementation of "hospital-at-home" models by offering continuous monitoring of patients' health status and eliminating the need for hospital trips. Wearable technology will be completely integrated into our clothing through the manufacturing of smart fabric or embedded as small sensors that don't require batteries. "Smart Pills" are also being developed to help monitor organs internally and relay this information automatically to a doctor through a text message on their mobile device. The increasing acceptance in India and worldwide will create affordability and security for this type of technology, providing for universal access to high quality medical diagnoses.

Conclusion:

The combined use of wearable devices with the Internet of Things (IoT) will be one of the greatest changes to modern medicine, moving healthcare from hospitals and institutions to a patient-first model where care is provided daily and continuously.

For example, the ability of the integrated Internet of Medical Things (IoMT)—with its sensors, smart gateways, and cloud analysis—to now allow for real-time monitoring of a patients' health is revolutionary. As a result, this connectedness of the IoMT gives patients the tools they need to maintain their own wellness and provides clinicians with accurate data to detect disease early and personalize treatment plans.

Countries like India are experiencing a surge in the adoption of wearable devices and are forecasted to achieve a 44% penetration in the user base by 2026. This indicates a growing consumer desire for accessible and affordable health technology. This evidences a developing interest from consumers about health technology that is easy to access and can provide good value for money. For example, continuous glucose monitors, smart patches, and wearable ECGs have all been successful in managing chronic diseases and have decreased the stress or strain placed on traditional healthcare facilities. IoT provides hospitals with efficient management, reducing the rate of re-admissions, IoT can answer many challenges related to the continual rising costs of healthcare globally.

For IoMT to be fully realized, the industry will need to overcome many challenges including data privacy, interoperability and battery life. We can expect to see artificial intelligence and IoT data merge to advance the future of predictive diagnostics.

Even though there are still technical and regulatory hurdles to overcome, wearable IoT technology is evolving and fundamentally changing the "smart hospital" concept, and is a critical enabler for the future of digital health around the world.

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Conflicts of interest

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

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