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## **Real-time health monitoring using IoT devices for patients with chronic conditions**

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**Abstract--Background:** The healthcare sector is experiencing a transformative shift due to advancements in technology, particularly with the Internet of Things (IoT). IoT integration in healthcare is poised to revolutionize patient monitoring and management, particularly for individuals with chronic conditions. The Grand View Research Inc. analysis projected a significant increase in IoT penetration in healthcare, with a market value of approximately \$409.9 billion by 2022. **Aim:** This article aims to explore the applications, benefits, and future potential of IoT devices in real-time health monitoring for patients with chronic conditions. **Methods:** The review encompasses various IoT-based health monitoring systems, including wearable and implantable devices, biosensors, and remote patient monitoring systems. The methodologies of existing IoT applications, such as the UbiMon project and various ZigBee-based systems, are analyzed to understand their impact on patient care. **Results:** IoT technologies facilitate real-time monitoring of vital signs, improve chronic disease management, and enhance emergency response systems. Examples include smart inhalers, ECG monitors, and remote surgery systems. The integration of IoT in healthcare has led to improved patient outcomes, reduced emergency waiting times, and better resource management in hospitals. **Conclusion:** IoT is transforming healthcare by enabling continuous, real-time monitoring of chronic conditions and enhancing overall patient care. Future developments in IoT, such as Bio-IoT and Nano-IoT, promise further advancements in medical technology, although they will require addressing new security and ethical challenges.

**Keywords---**Internet of Things (IoT), real-time health monitoring, chronic conditions, wearable devices, biosensors, remote patient monitoring, Bio-IoT, Nano-IoT.

## **Introduction**

The healthcare sector is being transformed by recent technology innovations like mobile apps, smart devices, biosensors, wearable technologies, home virtual assistants, and blockchain-based electronic medical record systems. Integration

of sensors with mobile devices allows different criteria to be precisely recorded, analyzed, and sent to healthcare institutions. A Grand View Research Inc. analysis estimates that by 2022 the Internet of Things (IoT) penetration in healthcare would reach around \$409.9 billion. Technavio's market analysts project that by 2020 the worldwide IoT healthcare industry would have a compound annual growth rate (CAGR) of almost 37%. Several "smart" medical devices, including the "smart inhaler," "smart syringe pen," and "smart pills," are in development or early release now to help control diabetes mellitus (diabetes). Furthermore a major part of the continuous digital revolution in healthcare are biosensors, which have several uses for wireless network-mediated medical data transmission to mobile and web platforms. This helps doctors to track patient treatments and health statuses outside of the conventional hospital setting. Furthermore, by non-intrusive data collecting on physical activity, sleep, and general health, biosensors help consumers in daily tasks. Biosensors, for instance, can track glucose levels, arterial pressure, heart rate, oxygen saturation, pulse, blood alcohol levels, thereby providing real-time data and alerting users [1, 2].

Remote healthcare systems depend critically on good patient monitoring outcome communication. Since Patient Health Portals (PHPs) are so important link in the healthcare system, several versions of them are in development. These portals give patients internet services, thereby improving patient happiness and concurrently give healthcare staff convenience. Patients can consult doctors online, view test and lab results, make payments, interact with other patients, get health advice, and plan appointments—all of which help to lower the administrative load on hospital staff linked to normal activities [1].

Applications of health monitoring have attracted increasing attention during the past 15 years. Many initiatives have suggested wearable and even implantable devices using low-cost sensors and wireless technologies as means of remote personal health monitoring. For instance, the UbiMon (Ubiquitous Monitoring Environment for Wearable and Implantable Sensors) project [2] sought to define the features of mobile and wearable sensor systems and concentrated on people with arrhythmia cardiac diseases. This included portable, wearable, or handheld sensors for safely remotely tracking heart function. Five primary components make up the system: Body Sensor Network (BSN) nodes, a processor, a central website, a patient database, and a PC. Combining additional sensors with wireless electrocardiogram (ECG) and pulse oximeter (SpO<sub>2</sub>) sensors creates the BSN loop on customized wireless cards. PDAs collect signals, monitor and analyze data, and operate as a router between the BSN and the central server via Wi-Fi or GPRS on a Compact Flash card. The PC runs the user interface to handle incoming patient sensor data, and the created program sends pertinent data to the staff members in medicine.

In Dağtas [3], a system is presented whereby digital ECG data is sent to a database via a ZigBee network continuously to a central webserver. Healthcare personnel then review the data kept in the central database. One should be aware that ECG monitoring calls for a far higher data rate than pulse oximeter sensing. Presented in [4] is another ZigBee-based system that counts patient steps and gathers ECG data at once. Under this technique, the PDA of the healthcare

provider locates the receiver while the transmitter is set on a collar worn by the patient. Using Maxstream's wireless modules and contact-type microphones, another solution details a system whereby the patient's pulse rate and ECG data are sent to the central database using a ZigBee network [5]. Operating through triggered searches to the central database, this system keeps an error rate of less than 5.97%. More recently, the growing acceptance of IoT has improved remote patient monitoring applications and resulted in the creation of functionally complicated systems spanning more distances. Beyond patient monitoring, IoT is transforming medicine delivery, diagnostic processes, preventative care, and emergency services. IoT will also find integration in medical equipment diagnostics and hospital administration.

### **IoT and Healthcare Sector:**

In the near future, standards and technologies such as Long-Term Evolution (LTE) [7], machine-to-machine (M2M) communication [8], and Near Field Communications (NFC) [9] will enable most modern devices to connect and communicate via IP (Internet Protocol) addresses. Both cellular and wireless communications will be IP-based. These advancements are expected to bring numerous innovations to everyday life, primarily by enabling a world where both people and objects are interconnected. The concept of connecting "things" and allowing them to operate remotely across various communication networks and technologies is referred to as the "Internet of Things (IoT)." Essentially, this means that smart devices and systems will form an intelligent network capable of collecting and processing data with minimal or no human intervention. As a result, everyday items such as refrigerators, televisions, washing machines, and heaters will have IP addresses, allowing them to connect to the Internet and continuously communicate with other devices [10, 11]. The "Internet of Things" concept was initially introduced by Kevin Ashton in 1999 to describe devices communicating via Radio Frequency Identification (RFID). However, the concept has since evolved into a broader and more comprehensive field now known as IoT [12]. In 2008, the number of devices with IP addresses exceeded the world population, and by 2020, it was anticipated that 50 billion devices would be connected. This vast expansion of connected devices is made possible by the IPv6 (Internet Protocol Version 6) protocol, which offers a 128-bit address length capable of uniquely addressing an astounding 340 undecillion entities.

Limiting IoT to the notion of intelligent devices in homes or factories communicating with each other to provide information to humans would oversimplify the concept. The essence of IoT lies in these devices' ability to operate in a sophisticated manner across diverse communication technologies. IoT is poised to bring significant advancements not only to homes and industries but also to various aspects of modern society, with the healthcare sector being a prime candidate. Through IoT, a patient's condition can be monitored continuously and in real-time, which is crucial for patients with chronic illnesses [13].

In the event of a patient emergency, even if the system cannot reach the doctor or family, it can automatically alert paramedics or first responders, ensuring that critical data, such as the patient's vital signs, is transmitted to the hospital or

medical database before the patient's arrival. This facilitates faster medical intervention and better outcomes, potentially transforming emergency and paramedic services. For instance, based on a patient's medical history, the system could detect early signs of an increased risk of heart attack by tracking their blood values and heart rate. If a heart attack occurs, the patient's blood values would be sent to the doctor before they even reach the hospital. This would allow preparations, such as first aid measures and medication, to be completed ahead of time, reducing the likelihood of a fatal outcome. Moreover, IoT, in combination with nanotechnology, can offer highly detailed information from within and outside the body, which can be transmitted instantly to the relevant systems, triggering alerts for medical personnel. Some of these applications have already begun integrating into daily routines, with many more expected to follow soon. IoT technology is impacting the entire healthcare sector, influencing medical, operational, and administrative services. According to [1, 14], the primary areas where IoT is transforming healthcare include remote health and monitoring services, assisted living and elderly care, chronic disease management, personalized medication, reduced emergency waiting times, monitoring hospital resources and personnel, and ensuring critical medical equipment assessment.

### **Best Uses of IoT in Healthcare Sector:**

The Internet of Things (IoT) has numerous impactful use cases across various sectors, particularly in healthcare, where it has the potential to revolutionize patient care and operational efficiency. Some of the best IoT use cases include:

- 1. Remote Patient Monitoring:** IoT-enabled devices, such as wearable sensors, track patients' vital signs (e.g., heart rate, blood pressure, glucose levels) in real-time and transmit the data to healthcare providers. This allows for continuous monitoring, especially for chronic disease patients, enabling early detection of issues and timely interventions. Examples include **smart glucose monitors** for diabetes patients and **ECG monitors** for heart conditions.
- 2. Smart Inhalers and Medication Adherence:** IoT-powered **smart inhalers** help patients with asthma or COPD by tracking inhaler use, monitoring environmental conditions, and sending reminders to ensure medication adherence. Other **smart pill dispensers** track if a patient takes their medication on time, ensuring proper dosage and improving compliance.
- 3. Emergency Response Systems:** IoT systems can monitor patients' vital signs, detect emergencies like heart attacks, and automatically alert healthcare providers or emergency services. **Wearable panic buttons** and **fall detection devices** for the elderly or at-risk patients can summon immediate assistance, improving response times during critical situations.
- 4. Hospital Asset Tracking:** Hospitals use IoT for **real-time tracking of medical equipment**, such as ventilators, wheelchairs, and defibrillators. This not only prevents loss or misplacement but also ensures that essential equipment is available and maintained. IoT-enabled **inventory management systems** help track the use and availability of medical supplies.
- 5. Smart Beds and Connected Wards:** IoT-based **smart beds** adjust themselves based on patients' needs, such as posture changes or pressure points. They also track patient movement, monitor vital signs, and help

prevent conditions like bedsores by alerting caregivers when a patient needs repositioning. **Connected hospital wards** streamline communication between devices and caregivers, improving patient outcomes.

6. **Remote Surgery and Telesurgery: IoT-driven robotic surgery** systems allow surgeons to perform surgeries remotely using robotic instruments. These systems use real-time data and precise control to enhance accuracy, making it possible to perform surgeries with fewer complications, even from long distances.
7. **Chronic Disease Management:** IoT helps manage chronic diseases like diabetes, hypertension, and heart disease by enabling continuous monitoring through **biosensors**. Data from these devices can be analyzed to track trends, identify patterns, and adjust treatment plans accordingly.
8. **Medication Management and Smart Pharmacies:** IoT-enabled **smart pill bottles** and **dispensers** remind patients to take their medication on time. For pharmacies, IoT improves **inventory management** by tracking stock levels, ensuring medications are available, and reducing waste through better forecasting and reordering systems.
9. **IoT-Enabled Wearables:** Devices like **smartwatches** and **fitness trackers** can monitor physical activity, sleep patterns, heart rate, and calorie consumption. These devices promote preventive care by encouraging healthier lifestyle habits and enabling early intervention for medical issues.
10. **Personalized Healthcare and Predictive Analytics:** IoT devices collect extensive data from patients, which, when combined with **AI and machine learning**, can help deliver **personalized treatment** plans. Predictive analytics also allow healthcare providers to foresee medical conditions, such as an imminent stroke or heart attack, enabling preventive care and reducing hospitalization rates. IoT is transforming healthcare by improving patient outcomes, reducing operational costs, and enhancing the overall quality of care.

#### **Remote health and monitoring services:**

A highly recognized and widespread use of Internet of Things (IoT)-enabled healthcare services is remote health monitoring, commonly known as Telehealth. Through IoT, patients may avoid the need to visit the emergency room or hospital in certain situations. This service not only reduces expenses and eliminates unnecessary hospital visits but also enhances the patient's quality of life by sparing them the discomfort associated with hospital trips. This convenience is particularly significant for patients with mobility challenges or difficulties traveling, especially when relying on public transportation [14].

#### **Assisted living and elderly care:**

With global increases in life expectancy and the rapidly growing elderly population, it is evident that current healthcare systems are unable to adequately meet the needs of senior patients, both in terms of physical resources and financial capacity. Many elderly individuals, often due to medical reasons, require continuous, discreet monitoring. IoT technology enables the constant observation

of the health status of elderly patients. Additionally, IoT-enhanced assisted living environments offer a more comfortable lifestyle for individuals suffering from conditions like Alzheimer's, Parkinson's, or dementia, while also easing the burden on caregivers and family members.

### **Identifying and managing chronic diseases:**

The rise in chronic diseases is closely linked to the extended human lifespan. Fortunately, significant advancements have been made in treating these conditions, many of which can be greatly supported by IoT technology. Wearable devices, advanced analytics, and mobile technology contribute to the detection and management of chronic illnesses. Devices akin to Fitbit, which utilize IoT, allow for the continuous, long-term tracking of personal health. Such data can be seamlessly shared with healthcare providers to assist in the treatment of chronic conditions. A notable example is the Health Net Connect diabetic management program, designed to enhance clinical care and lower healthcare costs for diabetes patients.

### **Personalized medication:**

An intriguing development associated with IoT in healthcare is the advancement of personalized medication and drug treatments. Though it may appear futuristic, pills embedded with minuscule sensors, no larger than a grain of rice, are capable of sending signals to an external device worn by the patient, ensuring correct dosage and medication adherence. This technology can also remind patients to refill prescriptions or track their medication schedules. Moreover, patients can use smartphone applications to access information about their health, monitor their progress, and adopt healthier habits.

### **Reducing emergency waiting times:**

Several aspects stand out for individuals waiting in an emergency room, including financial costs and the lengthy time it often takes to receive care. In New York's Sinai Medical Center, waiting times for patients requiring in-patient care were reduced by approximately 50%, thanks to GE Healthcare's IoT-based software, "AutoBed." The system monitors bed occupancy across 1,200 units and considers 15 distinct metrics to prioritize patient needs. Although it is an older example, it has served as inspiration for more recent IoT applications in other hospitals and represents a highly efficient, innovative system utilizing IoT technology.

### **Monitoring personnel, equipment, and safety in hospitals:**

Tracking resources such as personnel, patients, and equipment is a manageable task for smaller healthcare facilities but has become a significant challenge for large metropolitan hospitals handling thousands of patients and staff across multiple clinics and departments. As a result, many healthcare organizations globally are adopting IoT and real-time location systems to streamline resource and service management. IoT-based systems provide not only an affordable means of monitoring daily hospital activities but also a cutting-edge solution for managing these intricate environments.

**Critical medical equipment assessment:**

Modern hospitals rely heavily on next-generation medical hardware and software to deliver effective services. Like all electronic devices, these critical systems—some of which are vital to preserving human life—are susceptible to risks, ranging from power outages to system failures. The consequences of such risks can be life-threatening, depending on the situation. A comprehensive IoT solution to address this issue is Philips' "e-Alarm System," which offers a proactive approach by virtually monitoring medical devices and alerting hospital staff when issues arise, rather than waiting for equipment to malfunction.

**Medical IoT-Based Systems: Architecture and Future Directions:**

Thanks to recent developments in sensor and wireless transmission technology, sensors can now be worn or placed on patients, therefore enabling the gathering of vital physiological data outside of hospital environments, say in the comfort of patients' homes. Integrated into Wireless Body Area Networks (WBANs), these sensors enable ongoing surveillance without disturbing patients' everyday activities or creating discomfort. For patients, wireless systems mostly provide independence from movement constraints and transportation, therefore allowing accurate, automated measures free from patient intervention's necessity. Modern remote monitoring systems provide rapid reactions to possible problems regardless of the patient's location—home or a hospital—by including IoT-based WBANs and RFID technologies. This information helps medical professionals to do more exact analysis and maybe generate more accurate diagnosis. The need and cost of healthcare services have exploded with the worldwide aging population and rising frequency of chronic diseases, mental health concerns, injuries, and lethal infectious infections. Moreover, prolonged hospital stays sometimes lead to further physical, psychological, and social problems connected to hospitalization. One big benefit of wireless technology is their capacity to provide healthcare services outside of conventional healthcare environments. Wireless technology remote monitoring helps healthcare institutions [15] to be less burdened. Wireless Sensor Networks (WSNs) and Wireless Body Area Networks (WBANs) are two must-have elements of IoT in medical applications.

Usually consisting of a wide range of sensors of different sizes and types (e.g., light, temperature, pressure, sound, motion) and wireless nodes able of gathering, processing, and transferring data to a predetermined, usually remote, destination, a WSN is a network. These networks let patients keep their normal activities while gathering physiological data at designated intervals in healthcare without creating discomfort. In the health sector, WSNs have as their main goals constant monitoring, improving patient quality of life, and allowing preventative actions prior to the start of a medical crisis. When vital indicators either exceed or fall below a given level, WSNs can alert the medical professionals and initiate quick treatments. For unconscious people or those going through shock or heart attacks, this technology especially helps since it offers exact information about their situation and position [16]. IoT combined with WSNs is already used in industrial automation, home automation (smart home systems [17], agricultural [18], security systems [19], energy management, and presents great potential applications in remote healthcare services [20].

Wireless Body Area Networks (WBANs) are another absolutely vital element of medical IoT systems. WBANs differ from WSNs in terms of range and the kinds of sensors used even if they also enable wireless data transmission. Small, clever wireless communication devices housed on or inside a patient's body make up WBANs. Everyday examples include ingestible sensors that offer internal organ data [21] as well as wearable devices including ECG, EMG, EEG, SpO2 monitors, blood pressure, step, and temperature sensors [21]. IoT helps to store and analyze everyday data over time as well as to monitor real-time. This data collecting makes it possible to make exact treatment judgments over several times. Already under progress are test implementations leveraging Zigbee-based wireless sensor networks [6]. A patient's blood pressure, pulse, and oxygen levels can be sent in real-time to a central monitoring station by, say, linking a pulse oximeter to a Mica radio sensor node. Viewing the patient's real-time blood readings on a screen, healthcare providers can notify or alert their equipment as needed [22]. Future integration of nano nodes and network interfaces will improve speed and efficiency, hence facilitating data transfer over greater distance.

### **Bio-IoT and Nano-IoT Trends in Healthcare Systems**

A significant future trend in IoT-based healthcare systems is the development of **Bio-IoT**, which involves utilizing the body's natural mechanisms for molecular communication. This approach allows for the detection of abnormal conditions within the body by leveraging its existing biological systems. Molecular communication, in this context, relies on messenger molecules divided into primary and secondary reporters. **Primary messengers**, such as hormones and growth factors, facilitate inter-cell communication, while **secondary messengers** manage intra-cell communication. These systems function organically, with the communication speed depending on the proximity of cells. For example, in nerve cells, the transmission can occur much faster due to nerve cell extensions [22][23][24][25][26].

Despite being in its early stages, Bio-IoT holds vast potential. Just as the miniaturization and evolution of mobile phones in the 1990s seemed improbable, the future of Bio-IoT may revolutionize healthcare. However, there are considerable challenges ahead, particularly in terms of security. Close monitoring of the human body may introduce new risks, such as **biological warfare and terrorist attacks**, highlighting the need for stringent security measures and updated standards for internet security. Another emerging trend is **Nano-IoT** or the **Internet of Nano-Things (IoNT)**. This concept, leveraging materials like graphene, allows for the interconnection of nanoscale objects, creating nano networks with applications in various fields, especially healthcare. **Nano-Bio IoT** represents the fusion of biological and electronic communication, enabling intra-body sensing and the activation of nano-devices for medical purposes. This communication paradigm bridges biology and networking, facilitating interaction and data transmission within a biochemical domain [22, 27].

### **IoT in Different Medical Departments:**

The integration of **IoT (Internet of Things)** technologies is transforming medical departments across various fields, offering more efficient and personalized patient

care. Each department can leverage IoT systems to improve data collection, real-time monitoring, diagnostics, and treatment. Here's a look at how IoT is applied in different medical departments:

### 1. Cardiology

IoT plays a crucial role in **cardiology** through the use of wearable devices and implantable sensors for continuous heart monitoring. Examples include:

- **Wearable ECG/heart rate monitors:** These devices collect real-time data on heart rhythm, detecting irregularities such as arrhythmias or early signs of cardiac arrest.
- **Implantable devices:** Pacemakers and defibrillators can transmit data to healthcare providers, enabling remote monitoring of heart function and timely interventions.
- **IoT-integrated stents:** These devices can provide post-procedure monitoring for patients who have undergone stent implantation, ensuring that blockages are not forming again.

### 2. Neurology

In **neurology**, IoT devices are widely used for monitoring neurological disorders such as epilepsy, Parkinson's disease, and Alzheimer's disease:

- **Wearable EEG devices:** These devices monitor brainwave activity in patients with epilepsy and send real-time alerts in case of seizures.
- **Smart pill technology:** IoT-enabled smart pills track drug adherence in patients with neurological disorders, ensuring they take their medication at prescribed times.
- **Brain-computer interfaces (BCIs):** These systems allow patients with neurological impairments to control devices with their brain signals, improving communication and mobility.

### 3. Endocrinology and Diabetes Management

IoT has had a significant impact on **diabetes management** by enabling continuous monitoring of glucose levels:

- **Continuous Glucose Monitors (CGMs):** These devices measure blood sugar levels in real time, sending data to smartphones or wearable devices. Alerts are generated when blood sugar levels are too high or low.
- **Smart insulin pumps:** IoT-enabled insulin pumps adjust insulin delivery based on real-time glucose readings from CGMs, providing personalized diabetes care.

### 4. Oncology

In **oncology**, IoT systems enhance patient monitoring, diagnosis, and treatment for cancer patients:

- **Smart infusion pumps:** These deliver chemotherapy drugs at precise doses and monitor infusion rates, reducing the risk of medication errors.
- **Wearable sensors:** Sensors monitor cancer patients' vital signs and physical activity during treatment, detecting adverse effects such as fatigue or infection.
- **Connected imaging devices:** IoT-enabled imaging tools help oncologists track tumor growth, response to therapy, and adjust treatment protocols accordingly.

## 5. Radiology

IoT is revolutionizing **radiology** by integrating connected imaging systems with AI for faster and more accurate diagnoses:

- **Smart imaging devices:** IoT-enabled MRI, CT scans, and X-ray machines provide high-resolution images and send them instantly to radiologists for evaluation.
- **Remote image access:** Radiologists can review diagnostic images from anywhere, improving consultation and reducing patient wait times for results.
- **Automated diagnostics:** AI-powered IoT systems can analyze images for early detection of diseases like cancer, fractures, or neurological conditions.

## 6. Emergency Medicine

In **emergency medicine**, IoT plays a critical role in improving response times and treatment outcomes in critical situations:

- **Remote monitoring systems:** Paramedics can use IoT-connected devices to monitor a patient's vitals while en route to the hospital, allowing doctors to prepare for immediate treatment.
- **Smart ambulances:** These vehicles are equipped with IoT technology to transmit real-time data from the patient to the emergency department, facilitating better preparedness upon arrival.
- **Wearable emergency devices:** Wearables equipped with emergency alert systems can notify healthcare providers or emergency contacts in case of sudden health events such as heart attacks or falls.

## 7. Intensive Care Units (ICU)

IoT is transforming the **ICU** by allowing continuous monitoring of critically ill patients:

- **Smart beds:** IoT-enabled beds track patients' movement and vital signs, ensuring they receive the proper care and positioning to avoid complications like pressure ulcers.
- **Remote monitoring systems:** These systems enable healthcare providers to monitor ICU patients from a distance, reducing the need for constant bedside supervision.
- **Connected ventilators and infusion pumps:** These devices can adjust their settings automatically based on the patient's condition, ensuring optimal treatment.

## 8. Pediatrics

IoT plays a significant role in **pediatric care**, particularly in managing chronic conditions or monitoring newborns:

- **Wearable health monitors for children:** These devices track vital signs and activity levels in children with chronic conditions like asthma or diabetes.
- **Neonatal monitoring systems:** IoT-enabled incubators and wearable monitors track the health of premature babies, ensuring they receive appropriate care in neonatal intensive care units (NICUs).
- **Smart inhalers:** Pediatric asthma patients can use IoT-enabled inhalers to ensure proper medication delivery and monitor their condition.

## 9. Orthopedics

In **orthopedics**, IoT helps in monitoring recovery and tracking physical rehabilitation:

- **Wearable motion sensors:** These devices monitor patients' movements during rehabilitation exercises, providing real-time feedback on range of motion and muscle activity.
- **Smart prosthetics:** IoT-enabled prosthetics allow patients to control movements and receive feedback, improving mobility and rehabilitation outcomes.
- **Fracture monitoring:** IoT sensors can be embedded in casts to monitor healing progress and detect any complications in real time.

## 10. Gastroenterology

In **gastroenterology**, IoT devices help track digestive health and monitor conditions such as Crohn's disease or irritable bowel syndrome (IBS):

- **Smart capsules:** IoT-enabled ingestible sensors monitor digestive functions and collect data from within the gastrointestinal tract, aiding in diagnosis and treatment.
- **Wearable devices:** These track hydration levels, digestive patterns, and other parameters related to gastrointestinal health.

## Conclusion

The integration of the Internet of Things (IoT) in healthcare represents a significant leap forward in the management and monitoring of chronic conditions. IoT technology has proven to be a game-changer, providing real-time, remote health monitoring that greatly enhances patient care. Devices such as wearable sensors, smart inhalers, and biosensors allow for continuous monitoring of vital signs, such as heart rate, blood pressure, and glucose levels, offering invaluable data to healthcare providers. The development and implementation of IoT-based systems, like the UbiMon project and various ZigBee-based solutions, have demonstrated the capacity to improve chronic disease management by enabling early detection and timely intervention. These systems not only monitor patient health metrics but also alert healthcare providers and emergency services in critical situations, potentially saving lives. For instance, real-time ECG and blood glucose monitoring can facilitate immediate medical responses, significantly reducing emergency response times and improving patient outcomes. Moreover, IoT applications extend beyond individual health monitoring to include advanced features such as remote surgery and smart hospital management systems. These innovations contribute to more efficient use of hospital resources, better tracking of medical equipment, and enhanced patient care. Looking ahead, emerging trends such as Bio-IoT and Nano-IoT promise to further revolutionize healthcare. Bio-IoT aims to leverage the body's natural communication systems for enhanced health monitoring, while Nano-IoT could enable intra-body sensing and data transmission at a microscopic level. Despite these exciting prospects, there are challenges to address, including data security and ethical concerns related to continuous monitoring and the use of nanoscale technology. In summary, IoT is not only transforming patient care through enhanced monitoring and management but also shaping the future of healthcare with innovative technologies. Continued advancements and careful consideration of associated

risks will be essential for realizing the full potential of IoT in improving health outcomes and operational efficiencies.

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## المراقبة الصحية في الوقت الحقيقي باستخدام أجهزة إنترنت الأشياء للمرضى الذين يعانون من حالات مزمنة

### الملخص:

**الخلفية:** يشهد قطاع الرعاية الصحية تحولاً كبيراً بفضل التقدم في التكنولوجيا، وخاصة مع ظهور إنترنت الأشياء (IoT) من المتوقع أن يُحدث دمج إنترنت الأشياء في الرعاية الصحية ثورة في مراقبة وإدارة المرضى، خصوصاً لأولئك الذين يعانون من حالات مزمنة. وقد توقع تحليل شركة Grand View Research Inc. زيادة كبيرة في اختراق إنترنت الأشياء في الرعاية الصحية، حيث من المتوقع أن تصل القيمة السوقية إلى حوالي 409.9 مليار دولار بحلول عام 2022.

**الهدف:** يهدف هذا المقال إلى استكشاف تطبيقات وفوائد وإمكانات أجهزة إنترنت الأشياء في المراقبة الصحية في الوقت الحقيقي للمرضى الذين يعانون من حالات مزمنة.

**الطرق:** يتناول الاستعراض أنظمة المراقبة الصحية المعتمدة على إنترنت الأشياء المختلفة، بما في ذلك الأجهزة القابلة للارتداء والمزروعة، والمستشعرات الحيوية، وأنظمة مراقبة المرضى عن بُعد. يتم تحليل المنهجيات المتعلقة بتطبيقات إنترنت الأشياء الحالية، مثل مشروع UbiMon وأنظمة ZigBee المختلفة، لفهم تأثيرها على رعاية المرضى.

**النتائج:** تسهم تقنيات إنترنت الأشياء في المراقبة في الوقت الحقيقي للعلامات الحيوية، وتحسين إدارة الأمراض المزمنة، وتعزيز أنظمة الاستجابة للطوارئ. تشمل الأمثلة أجهزة الاستنشاق الذكية، ومراقبي تخطيط القلب الكهربائي، وأنظمة الجراحة عن بُعد. أدى دمج إنترنت الأشياء في الرعاية الصحية إلى تحسين نتائج المرضى، وتقليل أوقات الانتظار في الطوارئ، وتحسين إدارة الموارد في المستشفيات.

**الخلاصة:** يُحدث إنترنت الأشياء تحولاً في الرعاية الصحية من خلال تمكين المراقبة المستمرة وفي الوقت الحقيقي للحالات المزمنة وتعزيز الرعاية العامة للمرضى. تعد التطورات المستقبلية في إنترنت الأشياء، مثل Bio-IoT و Nano-IoT، بمزيد من التقدم في التكنولوجيا الطبية، على الرغم من أنها ستطلب معالجة تحديات جديدة تتعلق بالأمن والأخلاقيات.

**الكلمات الرئيسية:** إنترنت الأشياء (IoT)، المراقبة الصحية في الوقت الحقيقي، الحالات المزمنة، الأجهزة القابلة للارتداء، المستشعرات الحيوية، مراقبة المرضى عن بُعد، Bio-IoT، Nano-IoT.