American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBB
ISSN: 2997-9331

Internet of Things for Remote Patient Monitoring Using Cloud Computing

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Received: 2025 19, Mar
Accepted: 2025 28, Apr
Published: 2025 20, May

Annotation: One way to reduce hospitalizations and improve healthcare is to move from constant monitoring in health facilities to remote patient monitoring. The internet of things (IoT) is emerging as a relevant choice for remote monitoring and sensing. In general, modern IoT systems find massive use in lives, cities, environments, industries, and health. Particularly in the health sector, IoT is also finding ample use in the monitoring and treatment of chronic diseases (like diabetes and blood pressure control) using custom fitness programs and care of elderly persons (eHealth). Moreover, the IoT-supported patient monitoring and remote telemetry using sensor-embedded watches, textiles, or vitals-measuring appliances aim to improve the healthcare system and reduce its associated costs.

This paper proposes a scalable cloud-based model for the remote monitoring of patients. The model consists of three welldefined and interrelated modules: sensing, network, and application. The sensing module uses a variety of IoT devices to collect the patient's data (like GPS location, temperature, heart rate, and blood pressure). The data are continuously transferred to the cloud using API gateways. The network module uses cloud services and consists of several subsystems (like data processing, alert generation, patient management, and display management). The application module provides an interface for the end users using desktop, web, and mobile applications and supports the end user in visualizing the data and performing remote interactions (like warnings on emergency conditions, display of patient vitals, interaction with health providers, and video call with health providers) . The proposed model is designed to handle large-scale data collected from IoT devices. The results show that the model can support four times more patients by reducing the data burden through edge processing techniques. Besides supporting the increased number of patients, the gains are realized at the network layer by reducing pressure on the cloud services and network bandwidth.

1. Introduction to Remote Patient Monitoring

Remote Patient Monitoring (RPM) using Internet of Things (IoT) is an emerging technology in the field of healthcare, and it can collect various vital signs such as Pulse Rate, Electrocardiography (ECG), Body Temperature, Respiratory Rate, Galvanic Skin Response (GSR), and more with IoT-based sensors. The collected data will be utilized for later processing and consulting purposes of the patients. It can send alerts about falls, pulses above a threshold, temperature, ECG abnormalities, etc., in real-time cases. Vital signs knowing when a patient considered in critical health issues can be a great initiative. RPM using IoT is a new, innovative technology, and for the first time, the Arduino development board, along with off-the-shelf, available commercial components, has been adapted to healthcare monitoring. In a healthcare monitoring system, these data are fed to a cloud server, where data will be managed. The cloud server can be either free or paid, depending on the implementation priority. The data will be displayed on the associated android application, whereas other options for personal computers and laptops are available. This system can alert patients in cases of respiratory rate monitoring thresholds such as Suspend Game SMS or emergency alarm SMS or a calling signal [1].

Remote health monitoring is a promising approach to extend reactive and proactive healthcare solutions for populations at-risk beyond traditional clinical settings [2]. Such a service allows continuous monitoring of patients in their daily routines, enabling early intervention services in case of health deterioration. Moreover, it has the potential to alleviate medical costs and hospital visits for patients, improving their quality of life as well as independent living. IoT as an advance network of objects, consisting of environmental, stationary or mobile, and user-centric things, can be advantageously applied in such applications. IoT-based systems leverage a variety of sensors, communication infrastructures and computing resources to deliver monitoring solutions. In the context of remote health monitoring in everyday settings, these systems demand continuous data acquisition with high-level quality attributes, where various vital signs, such as seizures, heartbeats, oxygen saturation (SpO2) level, body temperature and falls, should be collected seamlessly while end-users are involved in daily routines.

2. Overview of Internet of Things (IoT)

A recent research study overviewed how patients report and communicate their health conditions to healthcare providers. Due to the growing demand for remote patient monitoring (RPM), telemedicine, smarter healthcare devices, and applications have emerged rapidly. Major companies in the telemedicine market are focusing their investments on expanding their services.

Smart health is an up-and-coming research topic based on the rapid growth of the Internet of Things (IoT), ubiquitous computing, and emerging information communication technology (ICT). Advanced smart health technologies can enhance the quality of life among the elderly and people with chronic diseases by enabling affordable and ubiquitous health monitoring and promotion. Although significant contributions have been made in smart health research, the current state of the art is limited in adoption and awareness among patients and care providers. For RPM services to be effective, efficient, and usable, health monitoring devices should be engineered to permit automatic operation and minimize the burden of usage on patients and caregivers while obtaining accurate and complete health data [3].

The use of IoT technology and wearable and embedded smart devices helps auto, automate the entire patient care workflow, assisting patients in monitoring their health status. Along with a smart health monitoring device, a workflow-based IoT-enabled health monitoring and diagnosis service is proposed to obtain accurate treatment services and strategies by healthcare providers. Currently available developed health monitoring devices are surveyed, and reviews and suggestions for innovative devices using new materials and technologies are provided. In addition, other devices beyond vital sign measurement, such as emotion or mental health monitoring devices, are discussed. Patients can use these devices anywhere and immediately transmit their health conditions and test results via IoT-enabled devices and integrated apps.

3. Cloud Computing Fundamentals

Cloud computing is a general term for the delivery of networked services that include computing power, data storage, and applications without direct active management from users. Cloud computing provides information-access services over the internet. The delivered resources and services include network-based data storage services, servers, processing, and software. Generally, users are charged for cloud services based on either a monthly or yearly payment plan or according to resource consumption. Currently, a number of the major companies provide cloud computing, including Microsoft, Google, IBM, and Amazon. Cloud computing use enables organizations to harness computer power, store and share data across multiple locations, and consult these datasets to achieve results. This technology is rapidly infiltrating various sectors such as education, finance, commerce, entertainment, and healthcare [1].

Cloud computing can be divided into three service models based on usage methods, namely Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Cloud computing deployment methods can also be differentiated as public cloud, private cloud, hybrid cloud, or community cloud depending upon organizational, regulatory, or governmental constraints. Scalability, heterogeneity of resources, and multi-tenancy nature of cloud make security and privacy concerns even more heightened.

Another novel and innovative cloud computing environment that can support IoT-based remote patient monitoring is fog computing. Fog computing can bring cloud-based services closer than before by bringing them to the local environment, which is the first hop of the network. Fog computing inherits important properties of the cloud environment and is able to provide storage, computing, communication, and security services [2].

Fog computing also distributes cloud services to edge devices, enabling local real-time operations such as computing, communication, storage, content, and security to the edge of the

IoT. Fog computing is based on the idea that an enormous amount of data generated at edge IoT devices should not all be sent to an infinitely resourceful cloud for storage and analysis. Instead, it should first be filtered at the edge of the network and only information that passes certain metrics should then be sent to the cloud for better visualization and understanding.

4. Integration of IoT and Cloud Computing

Telemonitoring of asymptomatic patients has gained attention due to the surge in online resources necessary to store, retrieve, and process data. With the fall in the price of components and the rise of the internet of things (IoT), health monitoring devices have been created that are very user-friendly and allow for easy intervention with users. In addition to IoT, data mining tools are being developed that allow for knowledge extraction from huge data. Today, with the emergence of cloud computing, the cost of maintaining databases has been drastically decreased. Embedded technology is an application generated by a combination of science and technology. Simply stated, it refers to putting an artificial intelligence program in a microchip and placing it inside a structure or device to make it clever. With increases in technology, distributed, modular, and low-cost embedded systems are developed, allowing for easy installation of one or more sensors. Sensors can monitor methods on a low-cost single board computer. The application then accesses the database for future predictions based on its own rules. If it finds high deviation in future results with respect to a threshold, it will raise alerts. Covered in this section are details on the IoT hardware and sensors, data handling on the cloud, and software on web platform. The monitoring hardware consists of low-cost systems that are easily available and even cheaper on bulk orders. Humidity and temperature sensors, discrete temperature sensors, and evaluated pulse wave sensors are interfaced with IO board, known as a mini computer. With ports specifications like GPIO, I2C, SPI, using a combination of algorithms, desired data reads are obtained. To reduce data transfer to the cloud, only relevant changes are communicated, as in the absence of a significant increase in humidity and temperature, chances of critical alerts are very low. This hardware has been tested with adult volunteers and has performed accurately in all tests. It has successfully diagnosed fever by detecting maximum surface temperature. The health monitoring model is developed, tested, and demonstrated on this hardware system for five different diseases. [4][5][6]

5. Key Technologies in IoT for Healthcare

IoT-based Remote Patient Monitoring Devices. The majority of recently developed IoT-enabled smart devices for monitoring personal health take the form of wearables or patches that can monitor a variety of health information channels. Wearable devices are simple to wear and measure multiple variables, including heart rate, accelerometer outputs, blood oxygen concentration, and skin temperature. While using a wearable device, monitoring takes little effort from users, and the collected health information can be easily converted into application program interfaces for the development of applications. Patches are skin-mounted devices equipped with sensors and peripherals to monitor different cardiovascular or skin health conditions. Commercial technologies have been developed for heart or skin health management, including a bioelectric patch, which monitors the electrocardiogram/heart rate, accelerometer temperature, skin temperature, and ambient temperature in one device. The integration of low-power chips and a wide variety of sensors enables the device to monitor health signals at low power consumption while reporting collected health information to smart devices through Bluetooth Low Energy or has long-distance communication with a cloud server. For real-time telemetry of health signals, from IoT-based health monitoring devices, application-specific data mining techniques could be implemented and used for the refinement of physiological feature extractions. Recently, smartphones have become multi-purpose smart devices that enable the transmission of patient health signals, run intelligent algorithms to analyze patient health signals, and visualize the results to patients and their physicians. Many patients and physicians are installing the smartphone chatbot application for on-time management of chronic diseases, including diabetes and heart disease. Several vendor-independent health monitoring health management platforms having daily health monitoring devices in addition to the smartphones have been reported recently [3].

Cloud Health Data Integration and Management. In the healthcare field, the number of health data transmitting smart devices is increasing by a large margin on an almost daily basis, opening the next generation health data integration and management platforms. Cloud computing serves as an open network for the equipment of portable health monitoring devices, where the collected patient health information can be stored, exchanged, and analyzed with reduced grant-on and time costs. The development of cloud integration and management platforms has enabled the formation of smart health data ecosystems where patients, healthcare providers, device manufacturers, and third-party developers can efficiently transact data and services [7]. As user-friendly cloud health data integration platforms are developed, the number of cloud health data consulting services is rapidly increasing.

5.1. Wearable Devices

Wearable devices have gained immense attention from researchers and the general public through their low cost, portability, and ease of handling. Many researchers have proposed wearable health monitoring systems employing various types of sensors. Since 2008, an NFC-enabled mobile phone has been used as a health monitoring device. The layout and composition of mobile phones are extremely versatile. This enables low-cost health monitoring devices within limited size and weight and limits the increase in health monitoring devices' size and weight. A basic architecture of the health monitoring system is constructed via a health monitoring and NFC reader. User’s preference has a big impact on health monitoring.

A RFID IC-based NFC sensor tag is employed as the transmitter of the health monitoring system. The well-designed analog frontend for the receiver and holder unit simplifies the integration of the health monitoring system, reducing the power consumption and size of the device. Moreover, the analog frontend includes the operation-driven carrier generator and demodulator with sampling frequency lower than sub-Hz. This makes it appropriate for various energy harvesting systems driving automatic health monitoring equipment like smartphones.

The collection and processing of the huge amount of data generated by patients with chronic diseases are major challenges in telemedicine. A system of energy-efficient and cost-effective wearable devices powered by energy harvesting and smart fog-assisted resource management. Three wearable devices, including ECG, GSR, and PPG sensors were designed and built on tiny and lightweight platforms to monitor the physiological signs of patients with CVD. An energy-efficient on-device charging circuit converts the output voltage of the energy harvester to match the supply voltage of the devices while allowing them to be powered directly for more energy and cost-effective monitoring in standalone mode. A fog-assisted architecture was proposed to cost-effectively manage the resources in wearable devices. [8][9]

5.2. Smart Sensors

Smart sensors capable of sensing various environments can be used in a range of electronic devices including mobile, wearable, and miniaturized devices. Under the framework of the Internet of Things (IoT), they are being developed for applications in smart homes, smart cities, and smart factories. These sensors will provide a variety of services including detection of various environments (light, sound, tactile, gas, temperature, etc.), conversion of analog signals to digital signals, and outputting of information after processing embedded applications. They will process information using embedded applications after sensing it with embedded sensor devices. Especially in cloud-based applications, the processing of information as a high-level service will enhance value. The data may need to be shared and processed among different IoT service application providers requiring interoperability among them. The incoming data stream is in various formats and protocols and may not match the format the processing service expects. While the need for streams with normalized formats and protocols has been addressed by existing research, there is still a need for a general approach to adapt the normalized streams into a format and protocol expected by a processor capable of efficiently elaborating the intended processing service. Several processing approaches for IoT stream filtering and service composition are presented, with focus on efficient processing schemes using presentations on high-level query languages [1]. Monitoring of patients' health status by analyzing their health data is vitally important to provide effective healthcare services, prevent disease outbreaks, or reduce hospitalization costs. As technology advances, a variety of wireless, portable, and garment-type health monitoring devices are becoming available. They can measure various health data such as body temperature, blood pressure, pulse, electrocardiograms, and blood sugar levels. These devices can continuously monitor patients' health status in real time and precisely measure health data by using advanced methods such as image processing and machine learning. Patients can use IoT-enabled devices and integrated apps to transmit their health conditions and test results instantly and easily to medical experts, making it easier to fit testing into daily life [3]. Patients can stay up-to-date and in contact with patients without needing to visit doctors in person by monitoring their health conditions remotely. These smart devices can disrupt target wearables and by directly providing user well-being data, will undoubtedly redefine the user diagnosis landscape for the better. This paper aims to review the current state-of-the-art patient health monitoring devices integrating services spanning checking, monitoring, and analysis of health conditions. A variety of approaches to collection and analysis are discussed. The performance metrics (access range, battery life, weight, price, detection modality) of tested devices are reviewed and compared. Practical usability aspects ensuring more robust ubiquitous monitoring such as cost, form factor, availability of data sharing, legal regulations, and privacy concerns are also provided. Potential directions for future research including opportunities for the integration of cloud computing and blockchain into the reviewed devices are offered, which will provide unprecedented breakthroughs in on-demand health services.

5.3. Mobile Applications

Many diseases do not show external symptoms for long periods, leading to late presentation, poorer conditions, and high mortality rates. Many emerging technologies and applications promise to address problems faced by patients' health conditions with relatively high accuracy and to help save lives in high-risk situations. In the modern world, wearable devices and sensors have found applications in monitoring human body conditions. An application could consist of wearable sensors to observe the body condition and a mobile device to collect data from the wearable sensor or sensors. A mobile application was developed for Android-based phones. This mobile application contacts cloud computing and can retrieve information from anywhere and at any time. The scalability of wearable wireless sensors is built on cloud-based infrastructures. On top of cloud computing, crowd sensing, and big data management techniques, more reliable and advanced healthcare analytics can be provided for the mobile-phone-connected sensors. The primary aim was to develop different mobile applications for monitoring one or more medical parameters. A mobile healthcare application was developed to receive patient health information through a serial port connection. To easily determine the human body condition, wearable sensors need to be interfaced with a mobile phone application. One of the health parameters was obtained using a wearable sensor wirelessly interfaced with a mobile phone. To offer more comprehensive body condition monitoring, some mobile applications focused on developing various wearable and miniature sensors that collected other blood measures, including blood oxygen saturation, blood pH, and skin relative temperature. A mobile application displayed blood condition values on the phone and recorded values for future review. A mobile tele-monitoring application for a Body Area Network is proposed to support multi-parametric asynchronous monitoring tasks. The application also organized the gathered data using a modular and configurable algorithm and served it with simple and continuous online visualizations. Various mobile phone sensor applications could help improve patient health conditions through the rapid development of mobile phones and sensors. [10][11]

6. Data Collection and Transmission

Recent technological advancements in mobile health result in a significant increase in the use of biosensors as wearable devices to monitor a patients health remotely. These biosensors can be implanted on target parts of the body like the wrist, neck, fingers and many more locations. Different biosensors have different applications. For example, using an electromyography (EMG) sensor worn on the arms can calculate the electrical signal generated by muscles and can subsequently understand the movement of the arm. Similarly, a heart beat sensor encased as a smart watch can be used to identify the heart beat count, saturation percentage level, body temperature, EKG, etc. These wearable biosensors acquire constant data from a patient and process that data using a mobile aggregator, which can be a laptop or mobile phone. The aggregated data is transmitted to a server to be stored.

The server for data storage can be cloud computing. The cloud computing server does not permanently store the fresh data that comes in from the patient. Instead, after a certain passage of time, this fresh data is overwritten by new data from the patient. This sort of processing of the data can create a data loss issue. Moreover, the patient is not in direct connection with the server and the application. Depending on the layout of the health care center, the patient may be too far from the mobile aggregator causing data transmission crashes. Thus, there is a need for a time-efficient and accurate IoT system that can remotely collect data and store it on cloud computing without any data loss or gap and also consider fundamental challenges, such as effective real time transmission, storage, availability, and managing edge devices. The health care part of the system can be both for the patient and health care professional. The patient can monitor the health of the patient outside the hospital premises with instant notifications of any abnormality in the health parameters, and the health care provider can monitor the patients health once they are back at the hospital [2].

6.1. Data Acquisition Techniques

The data acquisition process involves gathering, storing, and managing data from patients by employing various techniques to obtain raw signals for further processing. Medical sensors attached to patients capture various physiological signals, such as heart rate (HR), temperature, SpO2, and blood pressure (BP), which are generally analog over time. These signals must be converted into a binary format to enable compression and storage for future analysis [1]. Usually, an analog-to-digital converter (ADC) converts electrical signals into a binary format to process in a system. Compressing routine health monitoring signals takes place by discrete cosine transform (DCT), discrete wavelet transform (DWT), or filter banks transform (FBT) [2]. Due to bandwidth limitations of wireless channels, the transmission of data takes place daily by 6 Mb and can be compressed with DCT on the personal computer or centralized server. Concatenation of patient signals is carried out to reduce overhead while transmitting data into subbands. The reconstructed signal is approximately equal to the original signal with errors introduced at low bitrate.

6.2. Communication Protocols

As the number of remote monitor systems grows, so does the demand for a wired or wireless connection between the patient side and the monitoring server [1]. Today, several communication protocols are widely used in patient remote monitoring and telemonitoring systems to conduct clinical tests and measure patient physiological parameters remotely. The patient-side devices, using various sensors, collect clinical data and send it to the monitoring server via the previously mentioned protocols over a wired or wireless network.

Bluetooth is a well-established short-range wireless communication technology with low power consumption. It connects small, portable, and hand-held devices, allowing devices to communicate with each other. Bluetooth uses a master/slave configuration, where a master can communicate with multiple slaves. Bluetooth is useful for low-cost personal devices where high throughput is not necessary. Several Bluetooth-enabled devices, such as glucose sensors and cardiac devices, record health information from patients. These devices send the collected data to Bluetooth-enabled Smartphones, which then relay the information to a healthcare center. The main disadvantage of Bluetooth is that its range is limited to 100 meters. High-frequency bands are susceptible to electronic noise, leading to reliability issues.

Wi-Fi technology is widely used due to its low cost, mobility, and data transmission rate. Using a Wi-Fi-enabled device requires an ISP network connection to a router. Wi-Fi is a good option for patients with stationary or less mobile portable devices. Using portable PC devices such as Bluetooth-enabled devices is commonly used in telemonitoring systems. The main disadvantage of Wi-Fi is energy consumption, as 90% of its consumption goes to power its radio. The average consumption of health monitoring units varies from 0.007948819 to 0.679 W, where the power required for standby mode is less than that for active mode. This leads to substantial energy consumption when portable monitors that continuously transmit data are used, as it is not straightforward to replace batteries in such devices.

7. Data Storage Solutions in the Cloud

This section discusses the solutions proposed for efficient data storage in the cloud provided by cloud computing environments. These approaches can in fact be considered as cloud-specific data storage approaches.

[1] proposed a spatiotemporal compression based approach to efficiently store stream of very high rate logs generated by patient's health monitoring devices into cloud databases. The proposed query processing approach allows health auditing over such huge-data stream with very little latency using cloud resources. It builds on dimensionality reduction for spatiotemporal compression of health logs that combines CPU-intensive linear predicated weighting model with I/O-intensive sampling and market-share based temporal imputation on the top of parallelization. The query planning and execution also fully utilize cost-effective heterogeneous cloud computing resources and active replication. These techniques make the approach as efficient as necessary to support real-time data processing on cloud with hardly noticeable overhead. Experiments on both synthetic data and real-world health dataset demonstrate the practical feasibility and scalability of the proposed approach.

More efficient storage of monitored health data instead of observing its behavior by sending it to the cloud router device is proposed by [12]. The data is to be sent to the cloud router device only after it is compressed to make sure that cloud database storage does not exceed its prescribed limits.

7.1. Database Management

With the rise of smart connected health and fitness devices, an alarmingly increasing amount of medical datasets collected from remote sensors and smart devices is made available. Thanks to enormous efforts made by the scientific community in the field of Internet of Things, ubiquitous patient remote monitoring via Web Services and Cloud Computing has now become a reality. However, the dawn of unforeseen opportunities comes with the challenges of big data volume and complexity that might inhibit the envisioned advancement. Special techniques and tools to seize the hidden, actionable insights from the noise and chaos of the data are required, alongside the storage and management capabilities provided by the cloud paradigm.

Aside from the sheer amount of medical information generated by huge population numbers, the complexity of this information makes it more difficult to manage it efficiently and extract meaningful information out of it. The information is often in non-traditional formats like time-series readings captured from motion sensors or wearable medical devices, images or raw data recorded by cameras or photoplethysmograms, and many more types. Such data is heterogeneous in nature, coming from many different vendors with different dimensions, meaning and representations. Variability in data storage, nomenclature and semantics standards renders it bewildering for the end-user. In conjunction with that complexity, massive patient numbers currently monitored remotely will ultimately bring the total volume of all this information to unprecedented scales. Hence the hype of Big data has been spawned. In short, with volumes on the Tb level, velocities on the minute to hour level, variety and complexity present at different dimensions and levels of abstraction, and veracity in terms of uncertainty and imprecision of numbers, the understanding obtained through cloud eventually rolling in and monitoring different data types, patterns and volumes grows very difficult.

Data explosion has led researchers from every field to pursue knowledge mining techniques. Responsibility for research in data management and data mining techniques in the clinical remote monitoring domain falls on both data management and bioinformatics communities. Complex time-series data clustering and other basic building blocks of high level knowledge discovery automatism need to be designed before the time and space-consume big data analysis framework is put in place. The aim of this paper is identifying methods and tools used to address the challenges faced down the road in dealing with big data. One of the key features of this aim is to take into account the full data life cycle ranging from data generation phase to discovery and sharing in data execution phase. [13][14][15]

7.2. Data Security and Privacy

The monitoring of chronic diseases is a social imperative realized through Continuous Patient Monitoring (CPM). The lack of surveillance means medical care cannot begin until symptoms have reached the patient. It is particularly important for long-term chronic diseases such as those requiring 24-hour monitoring. The solution is not problematic since it appears to be feasible with remote surveillance systems that include cameras and microphones in homes and transfer this information to cloud infrastructures for analysis. Nevertheless, cost constraints must be addressed. In most cases, even with sophisticated camera systems, the privacy of relatives and physicians cannot be guaranteed. A modular system for Immersive CPM (ICPM) focuses on minimizing the system price through better use of existing resources in hospitals and homes. These resources may include health over-the-counter monitoring systems, smartphones for videoconferencing, or tablets for weather information and games that can also be adapted for medical purposes. The best human intelligence is shown at the beginning of human life, especially in infancy. The invasiveness of medical systems is painfully clear in this case. With large-spacetime data, the use of automated filers based on Machine Learning and the cognitive ability to define rules, the best human intelligence can help human interpreters seek insights from these data over creative visualization.

Wireless Patient Monitoring Systems (WPMSs) allow the real-time sharing of patient data among medical professionals. This paradigm guarantees patients' safety and allows for the early detection of unpredictable events. As a result, a growing interest has surrounded the design, implementation, and deployment of WPMSs. However, in developing countries, most recent commercial WPMSs are very costly. Proposing high-quality yet inexpensive wireless systems for patient vital signs monitoring is essential. Therefore, the budget should be realistic and feasible for developing countries to establish health monitoring systems by maximizing the profit of mass production [1]. The goal is to provide a complete WPMS for early detection and notification of patients' temperature, heart rate, and electrocardiograms that uses proprietary critical technologies for product exploits and health sensor integration. Security and privacy are fundamental to developing WPMSs as systems connected to the Internet. The Internet of Things extends the traditional concept of the Internet by connecting any device with an identifier and offering data exchange capabilities to this device. Consequently, tens of billions of devices will be connected to the Internet in a matter of years.

8. Data Analytics in Remote Patient Monitoring

A contemporary challenge in telehealth is the dissemination of vast amounts of information from IoT devices to clinical information systems. A standard medical examination with ICD-12 diagnoses and LOINC observations entails processing up to 4319 bytes of data. Another challenge is that in addition to high bandwidth, diverse processing capabilities should be available for real-time analysis of signals from wearable sensors. Platform-based cloud systems currently have a limited capacity owing to physical constraints of nodes, which necessitates constant distribution of processing. Algorithms for machine learning on procedural empirical observations are another big issue. For real time estimation of parameters for a complex dynamical model, the time overhead is a couple of seconds if input arrives at intervals less than several seconds. A thorough investigation and testing of intelligent adaptive methodologies is another challenge.

Wearable medical sensors and IoT signal acquisition systems autonomously transfer packets of samples to a cloud via the 5G and subsequent telecommunication systems. Limitations of this subscription service and cloud visualization of the signals create challenges in the realization of medical knowledge and their usage in decision making [2]. Cloud archives in a forensic analysis of signals which are important for a retrospective clinical evaluation of patients. Once the knowledge is required the online analysis is connected to a cloud and a choice of its big data is retrieved. Such architecture is costly and tedious. Real time telemedicine with online questions and immediate answers is still unreachable. A high capacity universal platform based information technology system is needed which will have enough network, storage systems, control and analytical power, the proper medical knowledge and autonomously solve medical problems in real time for hundreds of millions of patients. Technologies of such a system should be based on all opportunities of hardware and software implementation.

Real time variation of patient clinical status, breaches in medication intake, abrupt deviations of sensors and apparatuses should constitute the basis of vast implementations of telehealth and remote patient monitoring [1]. Such immediate and real time events are expected to be processed within milliseconds in the patients' edge. For such analysis of habitude changes during the connection to a telemedicine system and intelligent infrastructure of processing processes is needed. A low level decision control with choice of precise adaptive methodologies for each patients' control or subparts of his network of control systems is needed before a higher level decision making can be adopted. Such intelligent processing platforms should have the one and multiple training learning and nonlinear parameter estimation opportunities.

8.1. Real-time Monitoring

There is an increasing obligation for patients to be continuously monitored in medical centers. Quality of service (QoS) monitoring of the computation and communication subsystems is crucial to provide personal health monitoring. These subsystems are referred to as Internet of Things (IoT) systems, and they are spread out across multiple interconnected levels ranging from sensors to data centers. Each level offers its resources, is defined by its own frameworks and protocols, and can use its own types of interfaces and performance measures, among other factors. In this manifold environment, IoT solutions can provide an adequate data acquisition service relied on health monitoring [1]. Likely, the IoT system becomes inoperative if a proper QoS monitoring mechanism is not provided to these solutions. QoS is a set of measures of the performances achieved by the solution in providing a service. It covers a variety of measures at any level of the worn thin architecture, relying on metric identifiers that describe them. QoS monitoring aims to organize in time and space the complex measurements on the IoT system regarding QoS. Indeed, the solution-specific monitoring mechanisms deployed in the IoT system monitor independently any observable QoS attribute based on the respective metric identifiers. On the other hand, in real-life applications, there is a high probability that the IoT solution is composed of components and services based on different metric identifiers. The monitoring results from this wide variety of monitoring mechanisms should be synchronously organized in time and space to allow coherent and efficient maintenance actions.

A two-fold abstraction is implemented on the monitoring mechanisms and monitoring data in order to monitor the QoS of various IoT architectures in real life. On the one hand, an abstraction with types is imposed on the monitoring mechanism, which is fully flexible regarding performance measures and monitoring policies. On the other hand, a blackboard architecture is applied to the monitoring data, allowing the whole QoS monitoring mechanism to be scalable and extensible via service composition. Cloud computing (CC) is a promising technology for realizing the remote health monitoring of patients with chronic diseases living in remote areas. The proposed architecture for remote health monitoring consists of three modules, namely, the sensing module, the networking module, and the application module [2]. The specially designed system for remote health monitoring with the help of the proposed architecture in this paper is believed to be very useful for the health safety of people living in remote areas.

8.2. Predictive Analytics

One of the significant shortcomings of a plethora of IoT devices used in remote patient monitoring (RPM) is that the unprocessed raw data they produce is transmitted to the server, also known as the cloud, mostly at fixed intervals. This leads to a block of transmitted data that is directly proportional to the sampling rate of the sensors. Hence, for high-bandwidth sensors, it is possible that they can inundate the server by transmitting a huge data block and entirely block it from utilization for a determined amount of time. So, it is essential that predictions of patients' future health states should be performed on the edge, as far as possible from the cloud server. Such a processing paradigm reduces the bandwidth consumption between the edge and the cloud and offers the possibility of low-latency communication. Edge computing and fog computing are two closely related paradigms that make use of either physical or virtualized resources to offer storage and processing power at the edge of the network, where data is generated, contrary to the cloud model.

With the assumption of taking preliminary measurements at a high resolution, fog-assisted processing should be performed at the gateway for a remote patient monitoring system. In such a system, every patient wears a wearable device containing inertial and physiological sensors. The wearable device is responsible for recording data according to an initial configuration. To save energy, smart communications are necessary so that only the events of interest are sent back to the server. It includes shared state estimation and a switched model. The shared state estimation is passed between the sensors and the server for a reboot display. The remaining computational predictions are performed by the gate. Learning agents allow building a sparse matrix to reflect the storage consumption of the sensors. It is finished after a few steps of Batch-Sequential (BS) processing. The sensors are calibrated and diagnosis is performed through mean-hitting time probability and recurrence rate matrix. The goal is to optimize the learning agents' feedback to the wearable devices, which in turn are responsible for reconfiguring the next recording periods [2].

It illustrates the structure of the proposed system for remote patient monitoring. It consists of wearable sensors and a gateway running the fog-assisted algorithms while a central cloud-based server performs machine learning algorithms, and finally, end-users are provided with visualization tools.

9. Challenges in Implementing IoT for Healthcare

One way to reduce hospitalizations and improve healthcare is to move from constant monitoring in health facilities to remote patient monitoring. The Internet of Things (IoT) is emerging as a relevant choice for remote monitoring and sensing. IoT is finding ample use in the monitoring and treatment of chronic diseases and care of elderly persons. The IoT-supported patient monitoring aims to improve the healthcare system and reduce its associated costs. An end-to-end solution is vital, requiring a scalable model at the sensing, network, and cloud levels and their well-defined integration. This paper proposes a scalable cloud-based model for the remote monitoring of patients consisting of three well-defined modules: Sensing, Network, and Application. The Sensing module uses IoT devices to collect the patient's data, which are continuously transferred to the cloud using API gateways. The Network module uses cloud services and consists of several subsystems, storing data for services such as AI, machine learning, and decision-making. The Application module provides an interface for end users to visualize data and perform remote interactions. The proposed model can support four times more patients by reducing the data burden through edge processing techniques, reducing pressure on the cloud services and network bandwidth [1]. The other challenge in the PPG signal acquisition is the amount of noise in the signal. Ambient light diffuses to the exposed body tissues close to the sensor spot and causes a level of noise to the recorded signal. Although increasing the brightness of LEDs in the PPG sensor reduces the effect of ambient light noise, it increases also the power consumption in the sensor node. The last PPG-related challenge is that the most parts of signal processing are not possible to carry out with low power microcontrollers of wearable sensor nodes. The sensor node should send the raw signal to a gateway or cloud server for further processing. This, in turn, requires more power for radio transmission [2].

9.1. Technical Challenges

The Internet of Things (IoT) and Cloud Computing presents new challenges and opportunities for the healthcare sector. There are several major challenges relevant to the development of a system for the automated identification and alerting of medical events indicating patient deterioration. Handling irregular and large scale data streams represents one major challenge. Other challenges include the proper design of the monitoring coordination service and the optimization of its operational parameters, as well as functional testing of the application in hospices with proper technical equipment and human resources. Monitoring and understanding the emotional status of heart failure patients is expected to offer significant benefits for earlier detection of deteriorating heart ailments and for the improvement of the overall long-term care of patients that may often live on their own, providing better prevention of unwanted states and higher wellbeing. Emotional status may be categorized as events (high level semantics) – e.g., speech changes indicating outbursts of anger or screaming (sad), or state detection (lower level). A system framework with HoToC and the HL query language is provided by the system in relation to the HoTL framework.

Multi-dimensional Smart City Monitoring Systems, employing low-cost devices and sensors, are being deployed to continuously monitor various activities and phenomena in urban environments. In addition to processing continuous data using Hadoop, various considerations are required such as feature extraction, model derivation, model deployment and management, and benchmarking. They have proposed a cloud-fog orchestration architecture that includes edge device awareness and service dispatching and matching to facilitate cloud-fog orchestration, addressing technical aspects of the cloud-fog architecture. However, to appropriately place the Fog-Services, video monitoring application models must consider the data traffic generated by cameras and their availability. [16][17][18]

9.2. Regulatory and Compliance Issues

Regulations and policies must be clear in laying the groundwork for platform developers. There are several attempts in defining global and local guidelines on IoT applicability in healthcare in the academic and industry worlds. However, most of them still need to be explicitly addressed because IoT devices determine savings for users and patients, and the right security approaches can make the difference [1]. The general regulations are on cloud services (homogeneous), but the devices are heterogeneous, operating on many architectures and protocols introduced for specific purposes. The regulatory compliance matching process is based on a pre-evaluation of the legislation and is built to ease the definition of the project's regulatory capabilities. After reading the regulatory text, CONTENT is parsed according to a predefined schema using extended rules that identify the irrelevant sections. Here are some examples of the rules: 1) Title, paragraph, and footnote must be discarded. 2) Sections and subsections must be renamed as regulation's title, and their content must be set as regulation's content. 3) Consider sentences as

CONTEXT and board contents, where lettering must be discarded, as footnotes. The second phase creates a set of concepts used, for example, to define the country or type of technology area from this catalog of metadata. Per country, there is a collection of additional well-known labels given the possibility to advance regulations' matching on a simple keyword basis. The BIG_DATA taxonomy covers some sample taxonomy layers, where the information is stored either at the general level or mapped on the more specific lower levels as an array of strings. The procedure for matching regulations needs one or more examples of their application to explorers or try it first [19]. The matching procedure uses for each selected data subset the classification and filtering algorithm described. It is based on reasoning engines capable of answering selection questions and searching for similar concepts by providing a hint on desired keywords for the search. The OWL real model uses the Semantic Graph, where information is stored. A specific model that can be used to integrate additional information is the Linked Open Data model.

10. Case Studies of IoT in Remote Patient Monitoring

To reduce hospitalizations and decrease risks to patients and their families from constant monitoring in health facilities, healthcare must transition from this care model to one in which the patients remain in their usual environments, but the monitoring is performed remotely. The WSN is a subdivision of IoT in which networks of inexpensive, power-limited, wireless sensor nodes measure environmental conditions and collect activity information. The IoT is interconnected computing devices that may transfer data over the network without human interactions. A critical context is that IoT holds relevance as a choice for remote monitoring and sensing by unlocking insights in the healthcare field such as telemedicine, telemonitoring, and remote monitoring of vital signs. Telemedicine is a healthcare service based on telecommunication technologies that include video conference systems and telephone to connect doctors to their patients, increasing the accessibility of healthcare information. Telemonitoring is a health-care service field that uses remote health-care equipment on architectures such as WSN in which patients are measured with devices then measured information are sent for health analysis. It encompasses systems for the remote monitoring of patients and remote telemetry for monitoring operations of UHFs with bands below 50 Hz. Health Care is providing healthcare services to routine health examination and procedures, such as a normal heart rhythm examination, checking blood pressure, blood glucose test, and cholesterol examination in a health center or hospital. Moreover, the harsh reality is that, as the elderly population rises, the average age of the population increases all over the world, and chronic diseases will remain for a long time. The IoT can be thought of as an extensible multi-sensor system that gathers continuous signals from a variety of patient biosensors and smart devices. The sensed signals are aggregated and transmitted via different network connections such as cable and WiFi to a remote cloud center for archiving and processing. This architecture is known as Internet of Things base patient monitoring [1]. IoT health monitoring systems also offer ample IoT use cases in healthcare. Modern IoT systems find a vast number of uses; they have extensive use in building management and automation, smart cities, transportation management, health care, industrial monitoring and control, and greater automobile communication [2]. There is a growing concern in IoT that smart health IoT-based systems gather, store, and process more data regarding patients' health conditions, routine activities, and other associated tactics. Electronic health record is replacing paper records for health, and data monitoring and alerting systems are being deployed that automate observations and analyses. This IoT-based patient monitoring and remote telemetry attract researchers and engineers to ease patients' lives and minimize resources in the health care system. Moreover, large data of different types come from vast and diverse deployments of IoT-related devices for patient monitoring at different health institutions or even in homes. It is difficult to transfer them due to higher-volume network bandwidth; moreover, the patient's health data should be treated sensitive and private. The patient monitoring system has a three-module architecture composed of a sensing module, a network module, and an application module. The sensing module collects the patient's signals with IoT devices and transmits them to the network module. The network module securely stores the IoT devices' monitoring signals and processes them to derive insights. The application module interacts with the end users and provides them with access to interact with the services offered by the network module. An integrated routine monitoring system makes the neglected interaction among several patients' IoT devices sense and network models. A worrying number of studies designed for only a subset of factors in isolation and did not incorporate and consider simultaneous variables. Several considerations are behind a model choice; one should choose a model that corresponds appropriately to the type of data collected, or it could worsen instead of fixing a problem.

10.1. Successful Implementations

During the recent COVID-19 pandemic, telemedicine services (ehealth) saw a surge in adoption around the globe. Intensive care units turned into remote wards, and freelance healthcare workers multiplied. Out-of-hospital service requests increased three times. So did the need for off-the-shelf wearable and portable medical devices. Hospitals built out-of-hospital services starting with teleconsultation and virtual examinations. The basic goal was to minimize patient load and the risk of infection for in-house staff. The anticipated advancement is the supply of real-time readouts of metrics and investigation results for acute patients as well. It is a fundamental change of the consumer regulations for wearables which previously required only customary telemetry. Sharing raw data from commercial multi-parameter devices is bringing a new risk of backing closed-loop algorithms and classification services. Consumer confidentiality, anonymization, or data and model sharing provisions in national legislation or device purchase agreements cannot easily eradicate this risk [1]. However, it is difficult to theorize this great business opportunity in risk management. The objective of this section is to take lessons learned from real-life deployment challenges of these out-of-hospital services. A particular focus lies on designing systems meeting users' needs and expectations, molding legacy systems and vendor-neutral interfaces, ensuring data compatibility and sustainability, data confidentiality, quality, and ownership, as well as device verification and maintenance, and model performance assurance, or conformance checking [2]. It is shown how these requirements are addressed in a real life deployment of the out-of-hospital COVID-19 telemedicine care for 360 patients with great success. The ehealth service providers are Mediq, an EU pharmaceutical wholesaler, and a hospital network providing the medical supervision. A teleconsultation and virtual examination thing covered at first was <1 MIN walking and <4 HOURS time-adjusted van rides. Deteriorating patients can be connected to real-time telemetry monitoring with wearables and portable vitals. Moves from consumer confidentiality to management of remote processing are anticipated. During a COVID-19 pandemic surging worldwide demand for off-the-shelf monitoring devices typically measuring a patient's pulse, SpO2, temperature, and ECG. Devices are most often available from consumer electronics stores without a prescription. Products are not validated for medical diligence, and supply chains are not traceable either foreseen shall the data owners decide so. Products are widely multifarious in data formats and transmission protocols, and conceivably create a void for interoperability in great video conferencing. They gain little if unreliably interpreted. But the patients find difficulty in deciphering secretive coding, distorted recordings, or excessive surfeit.

10.2. Lessons Learned

The Internet of Things (IoT) concept refers to the massive interconnection of smart devices such as sensors, actuators, and cameras spread over different sites that work together to enable various real-world applications. While the conventional routing process is more suited for static and peer-to-peer networks, it is not efficient in IoT networks where the nodes are mobile. Thus, it is imperative that routing protocols for networks with the IoT paradigm are designed with mobility in mind. Moreover, while some devices may possess connection capabilities with other networks, an essential part of this family of devices is cheap low-bandwidth devices as a new path in the Internet access that is mainly based on an ad hoc paradigm such as sensor networks. This can usually be achieved by connecting these ad hoc devices to an intermediary device or a special network camera that peers another network in a peer-to-peer manner. However, the complex topology, and the mobility of nodes, as well as a high degree of link instability, pose several challenges for routing protocols in such networks.

The emergence of real-time health monitoring systems as the forefront of IoT applications is motivated by the needs of end-users such as citizens and patients. Remotely monitoring basic vital signals such as temperature, pressure, activity level, and others is mostly straightforward due to the off-the-shelf availability of low-cost sensors. Various operation scenarios foresee the analysis of a continuous stream of data beyond basic telemetry to enable real-time event detection and alerts. A challenge associated with the increasing ubiquity of health monitoring devices and applications is the containment of subsequent IT and data management infrastructures. It is expected that significantly more users are going to engage in an active event detection health monitoring process and have access to increasingly more varied monitoring devices and applications with huge associated health decisions thereafter to minimize uncertainties. These devices should overcome challenging wide-area mobile computing deployment scenarios in terms of energy efficiency, performance, and communication ability. For video-based health monitoring, a desired and challenging aim is to offer effective and timely long-term video analysis of resource-constrained client devices such as smart health cameras that continuously monitor large areas without providing any prior object location information.

Careful consideration should be given to the design of more sophisticated cloud computing infrastructures with much more powerful CPUs and wide-area video communication abilities offering a much richer fusion solution accelerating queries as an event detection service. Supporting ad hoc signatures of the same type at different available angles can be more guaranteed by remote mobile infrastructure, less important monitoring devices should be prepared to enhance overall flexibility and service ability in an event capturing context, and appropriate processing capabilities to identify the video feeds with more or no resources devoted to an event detection service should be offered and maintained by mobile remote infrastructures. [20][21][22]

11. Future Trends in IoT and Cloud Computing for Healthcare

The number of connected health devices is predicted to grow from 9 billion in early 2021 to 10.6 billion in 2023. The development of the internet of things (IoT) technologies is providing significant cost savings for healthcare organizations through more sophisticated care delivery models. Remote patient monitoring (RPM) uses IoT and cloud computing technologies to create a safer, more efficient, more proactive healthcare environment through innovative patient monitoring devices that generate actionable mobile data in real-time. Health practitioners can use this technology to enable real-time and remote monitoring of conditions such as heart disease, diabetes, and chronic obstructive pulmonary disease. Patients can engage with care providers remotely, improving preventive health behaviors.

The advent of the cloud computing model for health monitoring and through the continuous integration of recent web services has provided seamless data transmission from the wearable sensor node to the cloud. These developments are enabling the wearable sensor to analyze sensor data in a batch mode while the health data is being processed in the cloud in real-time. The use of small but powerful sensor nodes with bio sensing capabilities can detect health abnormalities, such as when a person's heart rate deviates from the allowable upper/lower range. To avoid redundant transmission of non-invasive health data and battery drainage, less serious abnormalities are mitigated in the layer placed below this cloud [1].

The demand for patient-health-sensing systems with low latency and high accessibility has risen dramatically recently. With the economic growth and increasing awareness of health by shared jewelry or wearables, the market associated with personal health sensing is anticipated to rise nearly 25% from 2017 to 2022. In personal health monitoring, both smart wearables and the mobile or home-centered Internet of Things (IoT) devices are at the forefront of innovation.

Recent advances in nanoscale circuitry, miniaturization of chem-bio sensors with new nanomaterials, new forms of imaging, lab-ons-a-chip devices, enhancement of spectrum bands, and deep learning-based pattern-recognition methods have enabled the enhancement of wearable device capabilities. AI image analysis algorithms have been more focused on the cloud side, and the offloading of image processing to the cloud is expected to be essential due to wearable devices' stringent power limitations. [23][24][25]

11.1. Emerging Technologies

Recent development strategies in the healthcare sector have introduced patient health monitoring platforms that utilize intelligent patient monitoring and actively collect patient vital signs to prevent health deterioration before specialized treatments [3]. Prior to the spread of smart devices, patients underwent health testing and physician-monitored health checks at clinical hospitals on a scheduled basis. However, for many patients, these provisions for health checks are inconvenient and therefore difficult to keep up with. As a result, patient self-monitored health tests have attracted attention. Over-the-counter (OTC) IoT-enabled devices are now commercially available, which enable patients to transmit their health condition in a more accurate and easier manner and to monitor their test results. The progress of telemedicine, which is the remote communication between patients and hospital professionals, has sought to lessen the inconvenience of the existing provision of medical services.

To perform the information collection process where critical information is extracted from the raw data generated from smart medical sensor devices and represented in an understandable format, the development of intelligent patient health monitoring has been needed. The development of the Internet of Things (IoT) has enabled the remote monitoring of patients with coordinate, cost-effective, and creative health monitoring services through the utilization of smart sensor devices. The introduction of state-of-the-art security mechanisms for patient information transmission also makes the secure provision of the monitored patient health information. With these advancements, concerns have been raised about the provision of health information monitoring without physical visits in various healthcare domains.

These patient monitoring platforms therefore grant easy access to the safe and secure monitoring of patients' health information in real-time. However, they usually do not permit on-demand patient health testing services so that some patients could switch regularly from routine testing to on-demand testing. Recently, attention has been given to the improvement of skillful and rational provision for the active testing of health seekers using commercially available inexpensive smart devices. [26][27][28]

11.2. Potential Impact on Healthcare Delivery

For the past two decades, the Internet of Things (IoT) has provided an effective management system for health care professionals as well as patients. By using wireless sensors such as a blood pressure monitor, glucose meter, or other sensors that measure ECG or temperature, various medical parameters can be monitored remotely by health care providers. IoT helps deliver more vigilant monitoring and a prompt response to a possible medical emergency. A smart medical system ensures the delivery of medical information about the patient's condition so decisions can be made faster. After consulting with a doctor, patients can go home, and from that time on, the doctor will monitor them through the monitoring system. Patients can use these devices anywhere and immediately transmit their health conditions and test results using IoT-enabled devices. IoT-enabled devices are an alternative approach for patients to better fit testing into their busy lives rather than going to laboratories or hospitals for testing. It is often a more convenient option, for example, blood glucose meters can easily monitor blood glucose levels at home.

Patient monitoring is a state-of-the-art service that makes it easier to stay up-to-date and in contact with patients, without in-person visits. Hospitals can handle more patients while consuming fewer resources. Wearable sensors scheduled to measure vital signs can keep track of vital parameters when the patient is not in clinic or hospital; the patient can receive periodic notifications on medication intake; clinicians can notify their patients in advance about the tests to avoid a waste of resources and time. IoT-enabled smart devices including smartphones have advanced tremendously in terms of performance and pricing, allowing for increased health data capture, provisioning, and processing. The incorporation of the cloud in the service provisioning of health monitoring platforms has created revolutionary breakthroughs in the provision of health services [3].

Data analyzed and aggregated in the cloud empower health providers and patients with unprecedented insights regarding health conditions. However, the volatile nature of the cloud leverages ongoing concerns amongst various stakeholders that prohibit them from fully harnessing the potential of the paradigmatic shift brought about by these technologies [1]. Thus, efforts to develop more rigid, secure, and efficient architectures have been a pivotal concern in this space. Blockchain technology provides a decentralized and tamper-proof mechanism to store health data, and guarantees user empowerment and privacy in the exchange of health information among multiple stakeholders, such as hospitals, patients, pharmacies, and health insurance companies.

12. Patient Engagement and Empowerment

Health-monitoring devices have developed with advances in consumer electronics. Patients can use these devices anywhere and immediately transmit their health conditions and test results using IoT-enabled devices and integrated apps. Embedded physiological-sensing systems in portable devices extend the traditional hospital-dominated health monitoring beyond the boundaries of healthcare facilities, making it easier to fit testing into daily life. Hardware vendors have developed cloud-connected smart health devices, and research teams have proposed a variety of health technologies based on the Internet of Things. The sensors integrated in commercial devices and custom-built sensor systems measure various health-related data, including electrocardiogram, blood pressure, temperature, blood glucose, dehydration status, and physical activities. The acquired data are sent to cloud servers via a combination of smartphones and the Internet to allow doctors to monitor patients remotely and to extract health monitoring information from data using big data technologies. Thus, through patient monitoring, it is easy to stay up-to-date and in contact with patients without in-person visits. Remote patient monitoring allows a continuous relationship between patients and healthcare providers with the ultimate objective of determining optimal health outcomes [3]. Because of the combination of smart wearable sensors for continuous autonomous monitoring of patient state and smartphones for on-the-go management of chronic diseases, new IoT-based systems promise to transform healthcare services with the potential to make monitoring practical, cost-effective, and comprehensive.

As one of the most problematic diseases of our time, cardiac arrhythmia is responsible for a high percentage of mortality rates. An innovative intelligent cardiac arrhythmia monitoring system differentiates physiological data acquisition from real-time signal processing and annotation. The device's intelligent component is capable of inferring rhythm abnormalities from aggregated data of multiple sensors over time regardless of the employed sensors. Moreover, in light of the continuously growing market for mobile health devices, DL-based automatic recognition of sleep apneas was proposed to ensure the construction of medical-grade devices. The effects of age and gender on automatic classification were discussed, and a program for development and evaluation of graphic-based studying aids was presented. The concept of sharing and monetizing take-home sleep study was analyzed, with emphasis on its places and applications [1].

13. Conclusion

The Internet of Things (IoT) has redefined the way healthcare is delivered and managed today. The advancements in IoT technologies, along with the rapid growth of internet penetration, have made it possible to continuously monitor an incurred patient’s vitals even after they are released from the hospital. Various kinds of wearables and other electronic devices are being developed that continuously monitor a patient's vitals, using small and low-cost sensors. The challenges and issues faced in achieving a remote patient monitoring system using this technology have been covered.

Finding a solution for worldwide pandemic diseases has been extremely challenging. However, devising a constant improvement technique towards healthcare management is one way of paving the way ahead. In this regard, countries all over the world can focus on the healthcare management of their citizens, with motivating ideas for IoT. Healthcare comes first when it comes to everyone's needs. An efficient healthcare management system represents the developing nation's eco-friendliness and prosperity, which will, in turn, motivate citizens to contribute in the same manner. A patient's health status is generally monitored continuously in a hospital. However, upon release, there is no system to monitor them and inform their physicians of any inconvenience. The idea of monitoring patients continuously even after they are released from the hospital has been proposed. This is accomplished by wearing a few small devices on the body that grasp the vitals of the human body.

The system comprises wearables to record the vitals and a mobile app that displays them to the patient. This information is sent to the cloud via the internet, where the physician can see the readings and be informed in the event of any abnormality. The proposed system would help a patient feel cared for and loved by their physician, even from a distance. Furthermore, the concept of patients owning their records has been introduced, which the physician could access with the patient's approval.

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