Library Progress International
Vol.44 No. 3, Jul-Dec 2024: P.685-694

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article

Available online at www.bpasjournals.com

Maximizing efficiency with a Cloud Connected ECG Devices in Remote Cardiac Diagnosis

Sanjay Tanaji Sanamdikar[1*], Sheetal Vijay Kulkarni[2], Ravindra K Moje[3], Ashwini Vinayakrao Kulkarni [4]

[1*]Department of Instrumentation Engineering, PDEA's College of Engineering Manjari, Pune. Maharashtra, India 411028.email:sanamdikar123@gmail.com
[2]Department of Instrumentation Engineering, AISSMS Institute of Information Technology, Pune 411001, Maharashtra, India, email: sheetal.kulkarni@aissmsioit.org
[3]Department of E&Tc Engineering, PDEA's College of Engineering Manjari ,Pune. Maharashtra, India 411028. email: ravindra.moje@gmail.com
[4] Department of Instrumentation, Government College of engineering and research Avasari kh, Pune , Maharashtra, India, email: avkulkarni.instru@gcoeara.ac.in
Correspondence to: *Sanjay Tanaji Sanamdikar*[1*]sanamdikar123@gmail.com

How to cite this article: Sanjay Tanaji Sanamdikar, Sheetal Vijay Kulkarni, Ravindra K Moje, Ashwini Vinayakrao Kulkarni (2024) Maximizing efficiency with a Cloud Connected ECG Devices in Remote Cardiac Diagnosis, 44(3), 685-694.

ABSTRACT

The major cause of death worldwide are cardiovascular diseases with a disproportionate impact on various underserved populations. This research paper helps to improve remote cardiac diagnosis analysis and monetary with the help of cloud connected ECG devices especially in the population where the resources are limited. There are many recent advancements in iot based ECG monitoring devices which help for real time data collection data transmission analysis and monitoring, which have been studied in this research paper. The potential components which make the systems very support you are variable ECG sensors mobile applications and cloud-based platforms for processing and storage of the data. The cloud connected ECG devices are very popular and the increased use of them is because of applications like accessibility to continuous monitoring potential for early detection of diseases like arrhythmias. The upcoming research challenges as reviewed in this paper are the quality of the signal patient compliance and the data security. The automation of ECG interpretation and risk stratification can be done by using the latest AI and ML algorithms. To summarise this cloud connected ECG devices are helpful in representing a positive approach and extending cardiac care beyond the expected traditional health care and environment. The work done in this paper can be taken further explore research ideas to optimise the clinical utility and also to address the various implementation barriers.
Keywords: CVD, ECG, AI, cloud, real-time monitoring, hearth diseases

INTRODUCTION

It is very difficult to enhance healthcare services for the inhabitants of a developing nation. World Health Organisation (WHO) studies [1] indicate that 17.5 million people died in 2012 from cardiovascular diseases (CVDs), accounting for 31% of all fatalities globally. The figure has continued to rise since then, reaching a staggering 17.7 million fatalities in 2015 [2]. A stroke or heart attack account for 85% of the 75% of cardiovascular disease mortality in poor and medium income nations. The National Family Health Survey (NHFS) found that cardiovascular diseases (CVDs) are more common in villages in India compared to metropolitan regions. Nearly three billion people call rural areas home, and providing universal healthcare there is a major challenge for the government [3]. There is a severe shortage of basic facilities, highly trained medical professionals, and healthcare facilities in this area. Because many doctors are hesitant to work in outlying areas, rural healthcare facilities are struggling to meet patient needs. Hospital visits are infrequent among low-income people in rural areas that rely on daily salaries [4]. The commute to the nearest metropolitan healthcare facility is also somewhat lengthy.

Unfortunately, by the moment a patient gets to the healthcare facility, physicians are usually too busy with other patients to spend much time talking to them. To allow distant, immediate tracking of the individual's heart condition, among the most potential solutions for technology is an IoT-based CVDs tracking system. An Internet of Things (IoT)-based cardiovascular disease (CVD) monitoring system may collect electrocardiogram (ECG) data and analyse it in real-time from a distance. Simultaneous wireless transmission to the cloud is used to transfer the gathered data. With this information, the carer may conduct clinical investigations and further analyses to build a system to support decisions that may aid in early identification and treatment. As things are, CVDs and associated problems disproportionately affect the elderly [5]. The need for methods and instruments that can identify CVDs quickly and reliably using a low-cost technology is thus growing in popularity. For the purpose of detecting and diagnosing CVDs, ECG tracking and analysis have gained widespread acceptance. The conventional method of collecting electrocardiogram (ECG) data involves using twelve electrodes, which results in a cumbersome, expensive, and immobile apparatus. As a result, people end up spending more money on healthcare and putting more strain on the hospital. The Internet of Things (IoT) [6], wireless sensor networks (WSNs) [7], mobile applications [8], and wearable electrocardiogram (ECG) electrodes are all quickly developing innovations. The system uses three-lead electrocardiogram electrodes to determine the ECG signal, which makes it transportable [9]. The Internet of Things (IoT) enables non-invasive electrocardiogram (ECG) signal extraction and transmission to a mobile app via an internet-connected module, such as Bluetooth. Modern 3 or 5 electrode ECG systems are able to get more accurate ECG signals than the old technology. There are a number of devices that have been developed and introduced to the market for the purpose of monitoring and analysing CVDs. Furthermore, other approaches to peak identification have been put forward, including the Hidden Markov model and Pan Tompkin's. The main issue with ECG signal evaluation is the lack of standard of ECG characteristics and the fact that each individual's ECG data is unique. There are a number of problems, including a real-time electrocardiogram tracking device that is not medically acceptable and a lack of resilience and mobility. Analysing the ECG signal does not have a long-term answer. Accordingly, an immediate need exists for electrocardiogram (ECG) monitoring in the form of a cheap, movable, and real-time device [10]. The different types of CVD are shown in Table 1 which is inspired from [9-10].

Table 1: CVD types [9-10]

CVD Type	Symptoms
Heart Attack	Abnormal beating hearts, nausea, vomiting, acid reflux, diarrhoea, and pain.
Coronary Heart Disease	Discomfort, Heavy feeling in the chest
Ischemic stroke	Headache, paralysis, or facial numbness, leg and arm, trouble with talking
Arrhythmia	Feeling weak, fainting, experiencing palpitations, and fatigued.
Heart valve Disease	Symptoms include fast gaining weight, difficulties with breathing, and swelling of the legs, ankles, or stomach.
Enlarged Heart	Chest pain, oedema, lethargy, and difficulty breathing
Heart Murmurs	Anaemia and Hypertension
Cardiac Arrest	Fast Heart Rate, Light-headedness

1. Real-time Monitoring:

With the ability to remotely monitor and make decisions about the heart, cardiac implanted electronic devices (CIEDs) have the potential to improve patient outcomes across a variety of age groups and reasons. having an ever-increasing mean age, the amount of people having a device put in is also on the rise, according to the higher median lifespan. The COVID-19 pandemic and subsequent recommendations for its broad usage as a means to prevent or decrease visits by patients have made remote monitoring (RM) an increasingly significant tool for meeting the need for frequent examinations of these many systems. Current RM technology is widely available, but not everyone uses them. This is especially true for the elderly, who may gain the most from them. Indeed, elderly illnesses greatly limit individuals' autonomy and mobility, both physically and mentally; hence, electronic health records might aid in the care of this group. Randomised studies often fail to adequately represent this population of patients, and there is a lack of reliable information about the therapeutic usefulness of these gadgets and the RM that follows in older persons. In addition, RM encounters unique obstacles in this expanding patient population, but it also has the potential to provide substantial advantages [11]. Multiple crucial parts must work together for RM to be successful. In RM, patients play a pivotal role; the accompanying therapeutic advantages can only be achieved with their active participation and strict commitment to the treatment plan. A multi-specialty group of nursing staff, technologists, electrophysiologists, and heart failure (HF) experts work in the distant technology clinic. The last piece of equipment is home monitoring and RM systems, which allow the newly hired RM workers to retrieve information. After taking into account all of RM's activities and organisation, there are a number of additional challenges which every patient face, with the aged facing them more acutely (Figure 1). Because the elderly are notoriously resistant to change, it is important to first think about how a new technology can affect their mental health. Fear of inadequate clinical monitoring is a common concern among patients who have fewer encounters with healthcare professionals. Older adults still prefer in-person visits to a healthcare provider for a number of reasons, according to a survey: the opportunity to ask questions and build rapport with the doctor, the peace of mind that comes from seeing a cardiologist rather than dependent on a RM structure, the ease of being close to the medical facility, as well as the realisation that some have had bad experiences with RPMs [11]. Additionally, a few of them might be interested in visiting the hospital more often than once a year. While a few patients were agnostic about the option, those who were vocal about the benefits of RM also stressed the need of physical trips to the clinic. Furthermore, not completely comprehending the advantages and operation of RM occurred due to an alleged absence of knowledge during recruiting. Older participants, who often have hypoacusis, memory loss, or dementia, may also find transmitter management to be difficult. Transmission problems in the elderly have been reported on event, and these common circumstances might potentially affect RM management.

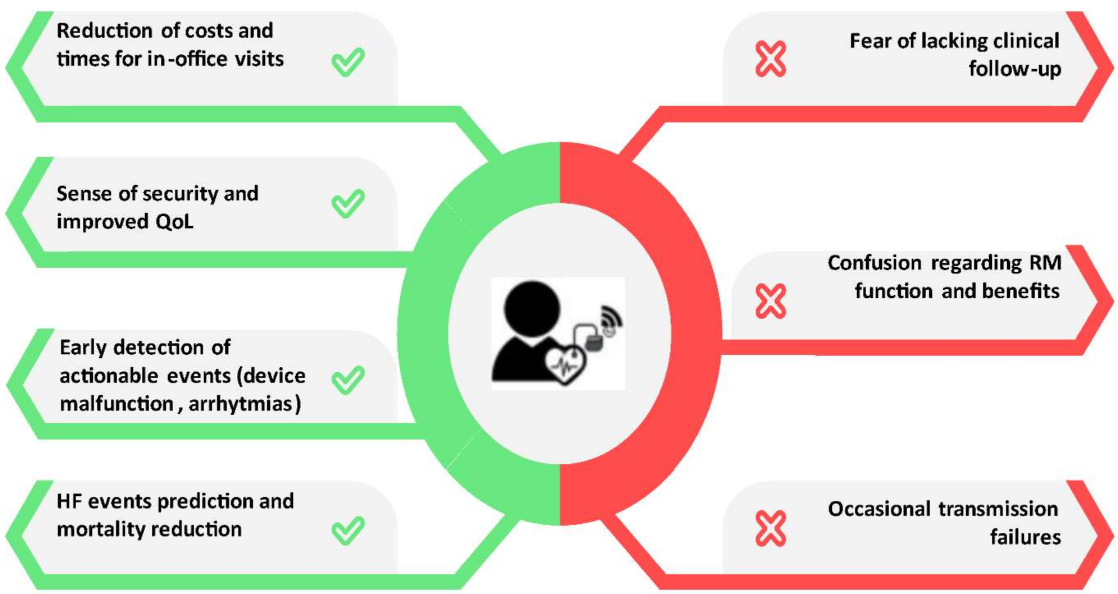

Figure 1: The pros and cons of RM for patients who are extremely old [11].

By connecting everyday IoT devices, IoT is revolutionising e-Health by enabling distant and ongoing treatment. Both patients as well as doctors stand to gain from these creative ideas, in which devices are increasingly serving as points of care (PoCs) that extend beyond medical centre walls [3]. Patients enjoy the advantages of faster, more individualised treatment, while experts rely on a comprehensive information system to back up their diagnostic procedures. To achieve ongoing surveillance, trackers are the best approach to seamlessly evaluate patients as they go about their everyday lives, supplementing the data collected by standard pressure tests—which only encompass a certain period in time—with data collected in real-time. IoT systems for e-health oversee wearables and other IoT devices that collect data in near-real-time and may be used to draw conclusions that might aid in digital early illness diagnosis from a distance. Worldwide, CVDs account for the vast majority of fatalities. CVDs include arrhythmias, which are irregular cardiac rhythms that, if unchecked, may endanger people's lives. The periodic nature of arrhythmias makes them easy to ignore, especially if they don't create any noticeable symptoms like nervousness, vision impairment, chest discomfort, or exhaustion. Conventional methods for detecting arrhythmias include 24-hour Holter monitoring, stress tests, and rest ECGs. But such tests only track a small number of the heartbeat (around 2000 in a stress test), which isn't enough data for a thorough study. Also, patients have to wait around for a physician's appointment, go to a medical centre, then wait even longer for test outcomes (around 1 to 4 months in Spain). Clearly, these conventional methods need an in-person visit to the doctor and more time for a diagnosis, both of which might have negative effects on the wellness of the individual due to the reduced likelihood of an early diagnosis. IoT stands up as a promising approach in this case for addressing the need to reduce both distance and time in order to predict the arrhythmia diagnostic. These days, non-invasive distant or even continuous cardiac monitoring is possible with smart medical gadgets. Size, electrode location, lead count, monitoring length, battery life, ease of use, healthcare professional setup required, open software development kit (SDK) for third-party integration, and quality of signal are some of the ways in which these devices differ. A common feature for these wearables is the Bluetooth connection protocol, which allows them to link up with a smartphone app that acts as a gateway and sends the data they gather to other offerings, like a cloud-based platform for medical experts, to be used in real-time. In any event, these entryways can't take the place of a doctor's diagnosis, but they may receive warnings on the heart's state. So, in this study, we establish a BMP taking into account the requirements of the IoT as well as the assistance of the medical practitioners' duties in providing a definitive diagnosis.

2. Cloud Connected ECG Devices in Remote Cardiac Diagnosis

The Figure 2 compares the traditional ECG method with the noncontact ECG method. The traditional method of clinical electrocardiogram monitoring involves the attachment of 12 or 15 electrodes made of silver chloride (wet ECG) to various areas of the body, including the chest, arms, palms, and legs. Traditional electrocardiogram (ECG) methods provide greater signal quality and more comprehensive data about the circulatory system, but they need the use of electrodes coated with electrolytic paste, which must be kept in a steady ohmic proximity to the skin at all times to facilitate the transfer of charges. This ECG method yields high-quality signals, but it's cumbersome, and the toxicity concerns with the gels mean that treatments that last longer run the risk of contact with the skin and allergies. Hence, it's possible that a wet ECG electrodes setup isn't the best choice for ECG monitoring over a period of time**.** Chair bio signal monitoring is the goal of a noncontact electrocardiogram (ECG) measuring technology. This method may be used on various chairs in various places to continually monitor a patient's health. This is crucial since people spend a significant amount of time on chairs each day. It might be a chair used at an office while the user is working there, or it could be a seat used when driving a car.

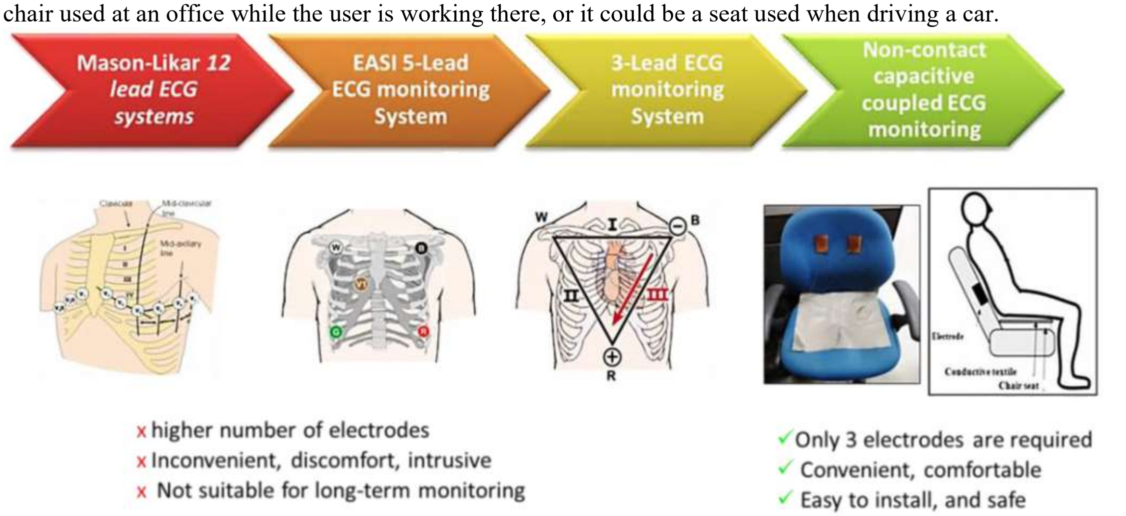

Figure 2: Evaluation of traditional and noncontact capacitive-coupled ECG techniques [12].

Most people's idea of a perfect day is lounging about the house, either watching TV with the old or getting some work done in the comfort of their own study chair. Mobile healthcare systems and cloud-based services are the primary applications of the suggested system for electrocardiogram (ECG) tracking. The suggested system for mobile medical status assessment and real-time electrocardiogram tracking is shown in Figure 3. All the while, the user's smart phone is helping them with their treatment. A web server is used in a clinical data centre system for the aim of communicating health status in order to continually and smoothly examine the Bio Signal.

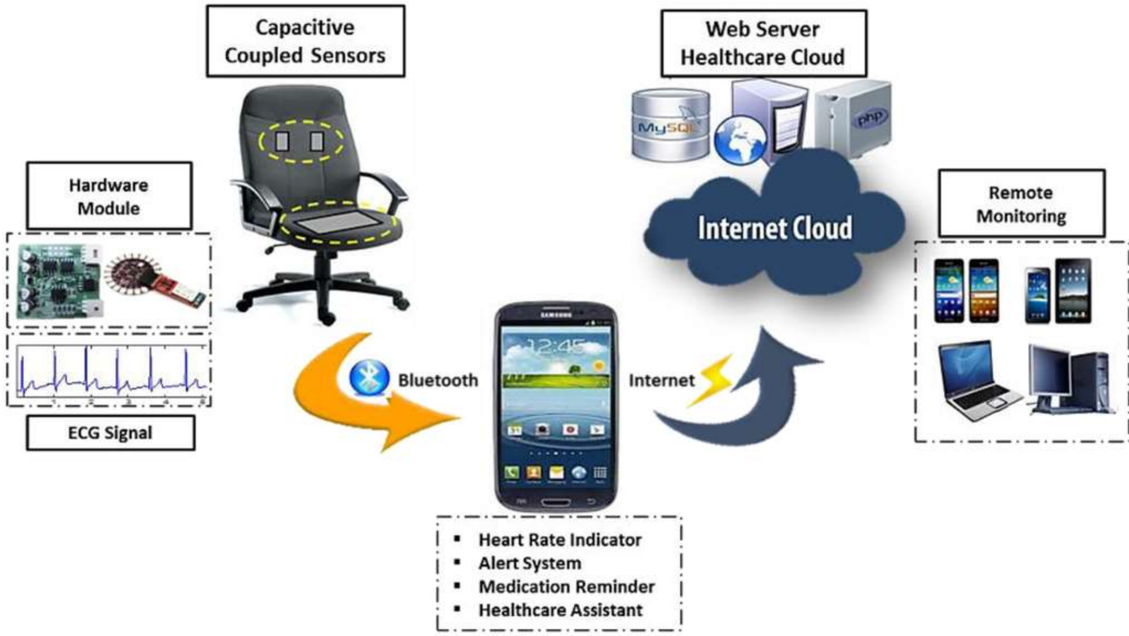

Figure 3: A noncontact electrocardiogram (ECG) monitoring system that incorporates cloud computing, a mobile device, and a data gathering module is designed for use in healthcare settings that prioritise mobility and accessibility [12].

A work in [13] has a real-time wearing peripheral ECG monitoring relies on the IoT and has a single channel. An ECG device that is worn is the heart of the system. The user's phone receives data streams sent by the wearable gadget using Bluetooth Low Energy (BLE). After that, the user's ECG data is shown as a single lead tracing along with their heart rate, and if there are any irregular rhythms in their heart rate, an associated Android app on their phone will alert them. A doctor's smartphone and an interactive cloud database allow for the sharing of identical information to the user's doctor. The physician's smartphone may also detect and label arrhythmias (bradycardia or tachycardia) based on the user's heart rate and live electrocardiogram trace [13]. To mitigate disturbance from 50 Hz power lines, an AFE uses an RLD circuit to get a CMRR of up to 121 dB. The noise from 50 Hz power lines is entirely removed by an additional notch filter that is digitally applied. Incorporating a PSoC microprocessor into the suggested gadget not only decreases its size and price but also increases its versatility via scalable alternatives. As the software can handle data sent to the cloud by various users and patient information accessed by different physicians at the same time, it is very expandable. In addition, there are no restrictions on the users' whereabouts throughout the 25 hours of ongoing surveillance. According to the findings of the experiments, the device can effectively remove 50 Hz noise from ECG readings while still generating clean signals with all the necessary properties. The device's outstanding accuracy and absence of false negatives proved that the integrated QRS detection method was of excellent quality. Also demonstrated was the gadget's precision in detecting cardiac problems, which is on par with that of a commercially available heart rate app. The trial findings clearly show that the system provides minimal latency and rapid responsiveness. Because of their dependability and low prices, Android smartphones keep a steady lead over Apple's. For users in remote areas and in the case of a COVID-19 pandemic, the suggested system becomes an appealing option for real-time electrocardiogram surveillance because to its minimal latency, excellent performance, scalability, and cheap cost. In Figure 4, one can see the suggested system's design in [13].

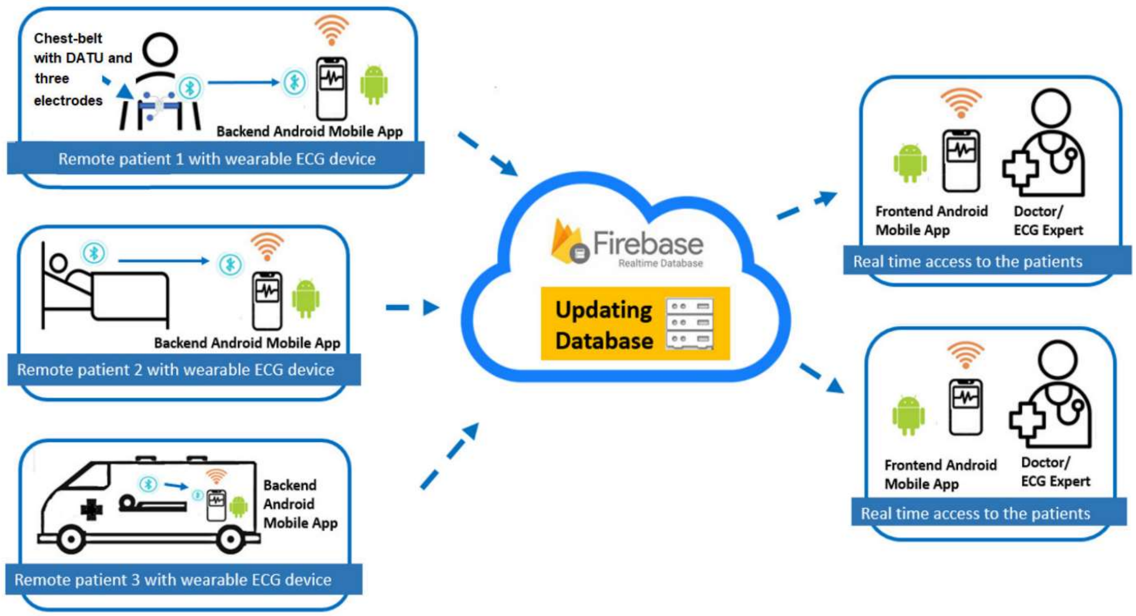

Figure 4: System in [13]

This module instantly sends to the user's phone the recorded ECG data over the Bluetooth connection. In the background, an Android app shows the user's pulse and the returned ECG tracing in real time. The app also sends the user's details and the ECG data to a cloud service so they may be shared and stored. The Google Firebase cloud database allows for effective real-time data exchange of the electrocardiogram data. An autonomous system for evaluating electrocardiogram (ECG) data was created by combining handheld devices with cloud computing in the study reported in [13]. The collected information pertaining to individuals' health is saved to a cloud-based database via this autonomous cloud-based setting. The data that is saved is then examined by means of cloud-based software applications. Multiple users may access the system from various places. The smartphone's application also includes setup choices that let users choose how often data are delivered for distant examination. An electrocardiogram (ECG) is the gold standard for detecting and diagnosing arrhythmias. When diagnosing irregular cardiac rhythms, two criteria are considered. First, in the event that tissue injury occurs during electrocardiographic transmission. Finally, if a deficit in electrolytes causes a shift in the heart rhythm. It helps pinpoint the exact location of an infarction of the heart while making a diagnosis of the condition. According to the research's categorisation findings in [14], four different illness types may be identified from electrocardiogram (ECG) pictures using the suggested DNN model. As an indication of anaesthesia risk, the findings of classifying ECGs as normal or abnormal may be used. In order to facilitate real-time IoT monitoring, the researchers built a prototype equipment as shown in Figure 5. Doctors will be able to use the data to detect heart problems in electrocardiograms. A patient whose resting heart rate falls between 60 and 100 beats per minute might benefit from the used gadget. A potential arrhythmia surveillance method and concept gadget. So, more precise conclusions and general conceptions will be generated by further diverse examples. In the meantime, further research will investigate arrhythmia in a variety of heart rates and geometries in order to evaluate the offered gadget. Last but not least, this machine concept has the potential to enable remote tracking in real-time and automated identification of the various rhythm classes. For both routine and emergency patient care, it could be useful for doctors. Maybe more research needs to be done on this.

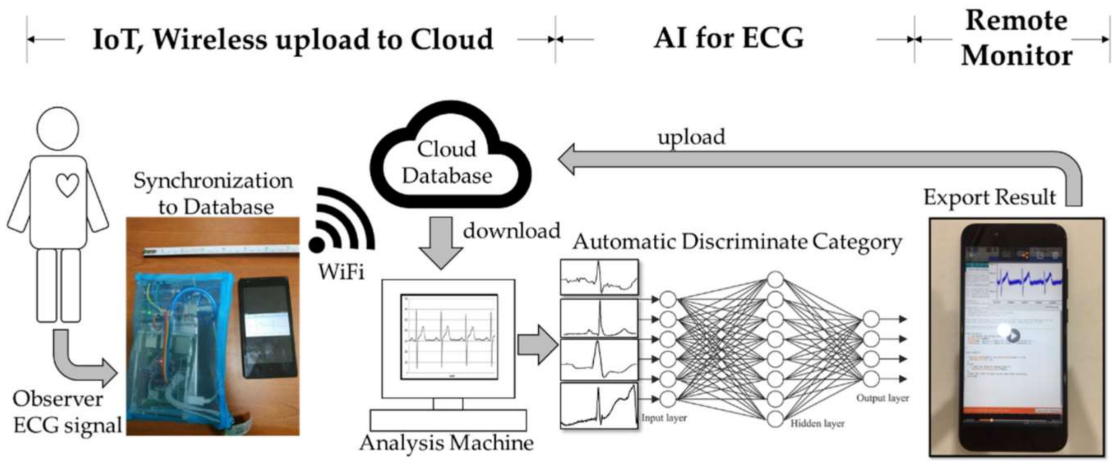

Figure 5 : The process that uses a mix of AI and IoT [14]

The Hybrid Cloud Performance Management Process (HCPMP) is the recommended architecture [15]. It consists of three main components. Figure 6 shows the device's health monitoring element and the Max30100 sensor in action during the control stage. The patient or person is then introduced to these components.

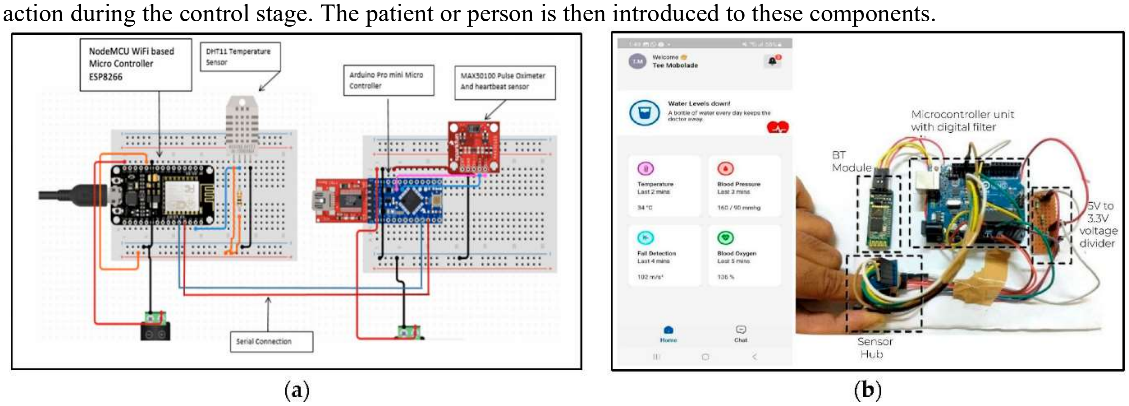

Figure 6: Feature of the created gadget that detects health issues. a) Components electronics for health detection. (b) Electronic gadgets to be worn and software [15].

As demonstrated in Figure 7, the individual's information is recognised after the IoT Health Tracking System detects their finger placed on the Max30100 sensor during the identification phase. After the IoT Patient Monitoring System has discovered it, the data capture step entails populating the patient's data into a SQL database.

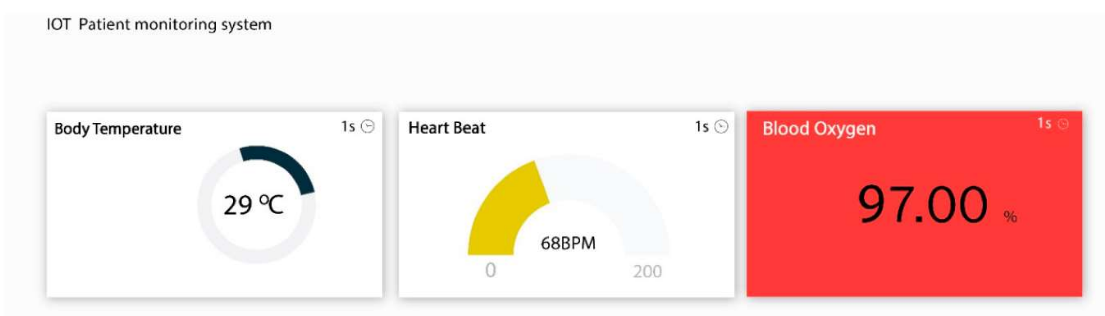

Figure 7: Phase of detection [15]

3. Challenges:

Patients may engage in behaviours such as jogging and physical activity under continuous surveillance, despite the fact that these activities sometimes cause signal noise, degradation, and movement artefacts. In their study, the work in [16] emphasises the significance of integrating effective filtering techniques for real-time monitoring systems with the elimination of motion artefacts during exercising or jogging. They suggested using an accelerometer to measure background noise. Continuous intensive care unit surveillance relies heavily on accuracy. The requirement for effective filtering and amplification methods is further highlighted by the fact that the ECG signal is millivolts in measurement and is chaotic [17]. As a general rule, real-time screening takes more time than conventional screening (days or months) to complete. This results in a huge, often overwhelming, quantity of ECG signal data being produced. Consequently, analysing and interpreting signals becomes a very difficult job. This highlights the importance of these monitoring sets' ability to automatically analyse and interpret signals information in addition to provide helpful alerts for patients as well as medical professionals. Issues with electrodes design, lead count, and conductor type are among those that arise with issues with ECG signal information quality and size. The number and kind of electrodes used to capture an electrocardiogram (ECG) signal may have an effect on the quality of that signal, as pointed out in [18]. Thus, more investigation into the viability of this record technique for illness diagnostics is required. The chosen electrode should be able to accommodate the various recording kinds needed for various disorders. The ease with which patients may wear adhesive electrodes presents yet another obstacle to design. There was some discussion in [19] about potential negative effects of electrodes on humans. In addition, the research in [20] brought attention to the fact that 7.3% of those who took part had mild irritations of the skin which were connected to the sticky gel electrodes. On the other hand, instead of using disposable gel electrodes that irritate the skin, the contributors of [21-22] suggested a chemical formulation that would work well when dipped into a variety of textiles, such as cotton [23], polyamide [24], and polyester [25], to create washable, adaptable electrodes for continual monitoring [26]. The problem of poor signal quality as electrodes dry up is a prevalent one with gel electrodes, but our textile washing electrodes also address it [27]. However, further investigation is needed to address the difficulties associated with the design of portable devices. Beyond the previously listed issues, ECG monitoring systems face new ones, such as collecting energy [28], patient/user reluctance to participate in their own monitoring via the use of diverse technology and sensors, and complicated computing needs. Due to their inherent limitations, cell phones are not well suited for processing computationally heavy data due to their use in ongoing ECG monitoring [29]. While the mobile gadget does make monitoring a little more versatile, issues with battery life and computing power have not been fully addressed. In order to create an accurate, fully connected, effective, and cost-effective ECG monitoring system, recent advancements have made use of new technologies like deep learning, AI, Big Data, and the Internet of Things. Electronic cardiac monitoring systems have a lot of room to grow because to enabling technology. The Internet of Things (IoT) enables ubiquitous, unfettered connection with applications that make smarter, more informed choices about our lives in real time by using data [30]. In addition, the combination of fog and cloud computing opens up new possibilities for streamlining operations and meeting the needs of a wide range of flexible applications. In addition, the use of blockchain technology allows for autonomous security for numerous actions across the various levels of the ECG tracking system framework [31-32].

4. Discussion and Future Scope:

In this work, we conducted a comprehensive literature analysis of electrocardiogram (ECG) monitoring equipment, examining several factors such as their design, lifetime, categorisation, problems, application, and technologies employed. The electrocardiogram (ECG) is a goldmine of useful data. The use of wearable devices that capture electrocardiogram (ECG) data and continually analyse it in real-time using artificial intelligence algorithms is enabling the diagnosis and prediction of certain medical diseases, such as arrhythmias, CVD, sleep apnoea, psychological wellness, and seizures. We reviewed the present state of ECG-AI on wearable devices for illness diagnosis and prediction, highlighting its uses, efficiency, and limits. Multiple writers have noted that in order to create and validate different AI methods, it is necessary to continuously build big, curated datasets addressing certain clinical situations. The most successful procedures for one clinical condition may not be applicable to others since ECG-AI is customised for particular medical purposes. Progress in this area requires a blend of several areas of expertise. Personalised medicine is undergoing a paradigm change because to this technology, which is simplifying, improving, and decreasing the cost of diagnosing a wide range of medical disorders. In order to provide healthcare surveillance around the clock, we are motivated to build a medical cloud that makes use of these sensors. Many medical products and services have been designed to take use of cloud computing, particularly in light of recent advancements in mobile devices and real-time surveillance systems. With the cloud technology, medical professionals may access patient records instantly regardless of their location, and patients can provide feedback via a network.

Research into robotics and health automation might revolutionise electrocardiogram (ECG) devices for monitoring in the future, making them easier to use during robotic-assisted surgeries, for elderly people, and for both in-and out-of-hospital ongoing surveillance of patients. Future breakthrough healthcare will be possible with surgical robotics that is more precise, easier to regulate, and has better eyesight. The rapid expansion of the Internet of Things (IoT) and other smart linked devices presents exciting new opportunities for wellness prevention and the early diagnosis of patients' abnormal health conditions or changes in behaviour. A greater quality of life for users may be achieved via the further development of personalised surveillance equipment, which are highly customisable according to their requirements and active to enable particular setups and modifications. Lastly, more study might focus on making patients' environments smarter. This could include installing sensor in the carpet, for instance, to better track patients' activity. The goal would be to identify trends in their behaviour and identify any irregularities.

References:

1. Sahu, M. L. et al. (2021) "IoT-enabled cloud-based real-time remote ECG monitoring system," Journal of medical engineering & technology, 45(6), pp. 473–485. doi: 10.1080/03091902.2021.1921870.
2. Ardeti, Venkata Anuhya, et al. "Development of real time ECG monitoring and unsupervised learning classification framework for cardiovascular diagnosis." Biomedical Signal Processing and Control 88 (2024): 105553.
3. Putra, Karisma Trinanda, et al. "A Review on the Application of Internet of Medical Things in Wearable Personal Health Monitoring: A Cloud-Edge Artificial Intelligence Approach." IEEE Access (2024).
4. Raheja, Nisha, and Amit Kumar Manocha. "An IoT enabled secured clinical health care framework for diagnosis of heart diseases." *Biomedical Signal Processing and Control* 80 (2023): 104368.
5. Gómez-Valiente, Patricia, et al. "Smart-IoT business process management: a case study on remote digital early cardiac arrhythmia detection and diagnosis." IEEE Internet of Things Journal 10.19 (2023): 16744-16757.
6. Kapoor, Bhaskar, Bharti Nagpal, and Meshal Alharbi. "Secured healthcare monitoring for remote patient using energy-efficient IoT sensors." Computers and Electrical Engineering 106 (2023): 108585.
7. Rajagopal, Shinu M., M. Supriya, and Rajkumar Buyya. "FedSDM: Federated learning based smart decision-making module for ECG data in IoT integrated Edge–Fog–Cloud computing environments." Internet of Things 22 (2023): 100784.
8. Adeolu, Olawuni, and Babalola Abayomi. "Design and Development of an Android-based Remote Cardiac Monitoring Device for Continuous Real-time ECG Signal Acquisition, Transmission, and Analysis." Journal of Engineering Research and Reports 26.4 (2024): 42-58.
9. Sanamdikar ST,Hamde ST,Asutkar VG(2021)ClassificationandanalysisofECGsignalbased onıncrementalsupportvectorregressiononIOTplatform.BiomedSignalProcessControl1–9. https://doi.org/10.1016/j.bspc.2020.102324
10. Husain, K.; Mohd Zahid, M.S.; Ul Hassan, S.; Hasbullah, S.; Mandala, S. Advances of ECG Sensors from Hardware, Software and Format Interoperability Perspectives. *Electronics* **2021**, *10*, 105. https://doi.org/10.3390/electronics10020105
11. Scacciavillani, R.; Koliastasis, L.; Doundoulakis, I.; Chiotis, S.; Kordalis, A.; Narducci, M.L.; Kotoulas, S.; Pinnacchio, G.; Bencardino, G.; Perna, F.; et al. Remote Monitoring of Cardiac Implantable Electronic Devices in Very Elderly Patients: Advantages and Specific Problems. J. Cardiovasc. Dev. Dis. 2024, 11, 209. https://doi.org/10.3390/jcdd11070209
12. Fong, E.-M.; Chung, W.-Y. Mobile Cloud-Computing-Based Healthcare Service by Noncontact ECG Monitoring. Sensors 2013, 13, 16451-16473. https://doi.org/10.3390/s131216451
13. Ali, H.; Naing, H.H.; Yaqub, R. An IoT Assisted Real-Time High CMRR Wireless Ambulatory ECG Monitoring System with Arrhythmia Detection. Electronics 2021, 10, 1871. https://doi.org/10.3390/electronics10161871
14. Yeh, L.-R.; Chen, W.-C.; Chan, H.-Y.; Lu, N.-H.; Wang, C.-Y.; Twan, W.-H.; Du, W.-C.; Huang, Y.-H.; Hsu, S.-Y.; Chen, T.-B. Integrating ECG Monitoring and Classification via IoT and Deep Neural Networks. Biosensors 2021, 11, 188. https://doi.org/10.3390/bios11060188
15. Ebadinezhad, S.; Mobolade, T.E. A Novel Cloud-Based IoT Framework for Secure Health Monitoring. Sustainability 2024, 16, 1349. https://doi.org/10.3390/su16031349
16. Preejith, S.P.; Dhinesh, R.; Joseph, J.; Sivaprakasam, M. Wearable ECG platform for continuous cardiac monitoring. In Proceedings of the 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Lake Buena Vista, FL, USA, 16–20 August 2016; pp. 623–626.
17. Serhani, M.A.; T. El Kassabi, H.; Ismail, H.; Nujum Navaz, A. ECG Monitoring Systems: Review, Architecture, Processes, and Key Challenges. Sensors 2020, 20, 1796. https://doi.org/10.3390/s20061796
18. Fensli, R.; Gunnarson, E.; Gundersen, T. A wearable ECG-recording system for continuous arrhythmia monitoring in a wireless tele-home-care situation. In Proceedings of the IEEE Symposium on Computer-Based Medical Systems, Dublin, Ireland, 23–24 June 2005; pp. 407–412.
19. El-Saadawy, H.; Tantawi, M.; Shedeed, H.A.; Tolba, M.F. Electrocardiogram (ECG) classification based on dynamic beats segmentation. ACM Int. Conf. Proc. Ser. 2016, 09-11-May-, 75–80.

20. Sanamdikar ST, Hamde ST, Asutkar VG (2020) Analysis and classification of cardiac arrhythmia based on general sparsed neural network of ECG signal. SN Appl Sci 2(7):1–9. https://doi.org/10.1007/s42452-020-3058-8.
21. Tao, X.; Huang, T.; Shen, C.; Ko, Y.; Jou, G.; Koncar, V. Bluetooth low energy-based washable wearable activity motion and electrocardiogram textronic monitoring and communicating system. Adv. Mater. Technol. 2018, 3, 1700309.
22. Ankhili, A.; Tao, X.; Cochrane, C.; Coulon, D.; Koncar, V. Washable and reliable textile electrodes embedded into underwear fabric for electrocardiography (ECG) monitoring. Materials 2018, 11, E256.
23. J. Aditya Khatokar et al., “Carbon nanodots: Chemiluminescence, fluorescence and photoluminescence properties,” Mater. Today, vol. 43, pp. 3928–3931, 2021
24. Sudhir A. ., Dhumale, R. B. ., Beri, N. ., Lourens, M. ., Varma, R. A. ., Kumar, V. . ., Sanamdikar, S. ., & Savadatti, M. B. . (2023). The Impact of Generative Content on Individuals Privacy and Ethical Concerns. International Journal of Intelligent Systems and Applications in Engineering, 12(1s), 697–703. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/3503
25. Bale, A. S., Aditya Khatokar, J., Singh, S., Bharath, G., Kiran Mohan, M. S., Reddy, S. V.,Huddar, S. A. (2021). Nanosciences fostering cross domain engineering applications. Materials Today: Proceedings, 43, 3428–3431. doi:10.1016/j.matpr.2020.09.076
26. A. S. B et al., "Mobile Cloud Computing - Enabling Technologies and Applications," 2021 6th International Conference on Signal Processing, Computing and Control (ISPCC), Solan, India, 2021, pp. 491-496, doi: 10.1109/ISPCC53510.2021.9609344.
27. S. Joy, R. et al., "A Comparative Study on Recent Trends in Iris Recognition Techniques," 2022 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2022, pp. 1521-1525, doi: 10.1109/ICEARS53579.2022.9752355.
28. S. S. Kumar, et al., "Conceptual Study of Artificial Intelligence in Smart Cities with Industry 4.0," 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), Greater Noida, India, 2021, pp. 575-577, doi: 10.1109/ICACITE51222.2021.9404607.
29. Bale, A. S. ., Tiwari, S. ., Khatokar, A. ., N, V. ., & Mohan M S, K. . (2021). Bio-Inspired Computing-A Dive into Critical Problems, Potential Architecture and Techniques. Trends in Sciences, 18(23), 703. https://doi.org/10.48048/tis.2021.703
30. Gholamhosseini, Leila, et al. "Cloud-based Internet of Things in healthcare applications: A systematic literature review." Frontiers in Health Informatics 12 (2023).
31. Sharma, Pawan, et al. "Real Time Remote Cardiac Health Monitoring Using IoT Wearable Sensors-A Review." Proceedings of the Second International Conference on Innovations in Computing Research (ICR’23). Cham: Springer Nature Switzerland, 2023.
32. Moshawrab, Mohammad, et al. "Smart wearables for the detection of cardiovascular diseases: a systematic literature review." Sensors 23.2 (2023): 828.