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DEVELOPING AN AFFORDABLE IOT BASED ECG MONITORING SYSTEM USING AN ESP32 AND UBIDOTS PLATFORM

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ABSTRACT :

An Electrocardiographic (ECG) equipment plays a vital role for diagnosis of cardiac diseases. However, the cost of this equipment is huge and the operation is too much complex which cannot offer better services to a large population and also low income area's. we have designed and implemented a low cost portable ECG monitoring system using ubidot platform. Our designed system is low cost, battery powered, portable and travel friendly. It's easy to handle nature makes it useful and more comfortable for handicaps and unconscious people. Device can be either used with desktop computer or laptop and output of the electrical pulse is shown and displayed on the monitor.

KEYWORDS : : Electrocardiogram, Ubidot platform, Portable, Cost effective..

INTRODUCTION[1,15] :

The Electrocardiogram (ECG) is a vital medical test that assesses the heart's electrical activity, aiding in the detection of abnormalities and evaluating its overall function. As technology progresses, continuous heart monitoring has become feasible through portable and wearable ECG devices. Our team has developed an innovative IoT-based, low-cost ECG monitoring device, offering early detection and intervention for heart-related conditions. Utilizing the ESP32 microcontroller, we designed a heart monitoring system capable of continuously observing the ECG signal. The gathered data is seamlessly transmitted to the Ubidots platform for real-time visualization and analysis. The ESP32's cost-effectiveness and low-power consumption, coupled with its built-in Wi-Fi and Bluetooth capabilities, made it the ideal choice for this IoT application. Ubidots, a cloud-based data visualization and analysis platform, enables efficient storage, visualization, and examination of data from diverse IoT devices. Its user-friendly dashboard empowers healthcare professionals and individuals to monitor ECG data, set alerts, and trigger actions based on specific conditions. The resulting heart monitoring system is both portable and user-friendly, catering to healthcare professionals and individuals alike. It facilitates monitoring of vital signs, heart rate, and rhythm, enabling early identification of heart-related issues and timely intervention. Moreover, the low-cost nature of the system enhances accessibility, ensuring that users from various backgrounds, including low-income and rural areas, can benefit from this valuable technology. Ultimately, our IoT-based ECG monitoring device holds the potential to improve heart health management and contribute to better healthcare outcomes.

AIM & OBJECTIVE[4] :

AIM - The aim of this project is to create a cost-effective and portable ECG monitoring system using ESP32 and Ubidots platform. The system is designed to continuously monitor and analyze the electrical activity of the heart in real-time. Its user-friendly nature makes it suitable for use in hospitals, clinics, and even at home, providing timely detection of any irregularities in heart rhythm.

OBJECTIVE :

1) **Real-Time ECG Signal Monitoring:** Develop a system capable of real-time monitoring of the ECG signal and displaying it on a screen, ensuring immediate access to heart activity data.

2) **Accurate Heart Rate Measurement:** Implement accurate heart rate measurement capabilities in the system, enabling precise heart rate readings to be displayed on the screen.

3) **Detection of Abnormal Heart Rhythms:** Incorporate algorithms to detect abnormal heart rhythms, including atrial fibrillation, ventricular fibrillation, and other arrhythmias, providing timely alerts for potential health issues.

4) **Data Storage and Analysis:**Create a mechanism for the ECG data storage and analysis, allowing healthcare professionals to gain valuable insights into the patient's heart health and historical trends.

5) **Cloud Integration with Ubidots:** Integrate the ECG monitoring system with the Ubidots cloud platform to enable remote monitoring and analysis of the patient's ECG data. This will enhance accessibility and facilitate healthcare professionals to remotely monitor multiple patients.

6) **Cost-Effectiveness:** Ensure that the developed device is cost-effective by utilizing affordable components and materials. The aim is to make the system accessible to individuals in rural or low-income areas.

7) **Portability:** Design the ECG monitoring system to be highly portable, lightweight, and easy to carry, making it suitable for use both indoors and outdoors.

8) **Abnormality Detection:** Incorporate algorithms to identify various abnormalities and health issues related to heart activity, assisting in early diagnosis and timely intervention.

ELECTROCARDIOGRAM (ECG)[7] :

The ECG (electrocardiogram) is a diagnostic test used to assess the electrical activity of the heart, give valuable information about its rhythm and function. This non-invasive procedure helps identify irregularities in the heart's electrical patterns. The ECG graph displays the heart's electrical activity in the form of waveforms. Time is represented on the x-axis, while the y-axis shows the voltage of the electrical signals. Typically, 12 leads are used in an ECG, each represented by different colors or letters, such as Lead I, Lead II, and so on. These leads offer different perspectives on the heart's electrical activity.

In an ECG waveform, several distinct components can be observed, each corresponding to different phases of the cardiac cycle:

- The P wave signifies the electrical activity associated with atrial depolarization, which represents the contraction of the atria.
- The QRS complex indicates the electrical activity associated with ventricular depolarization, which represents the contraction of the ventricles.

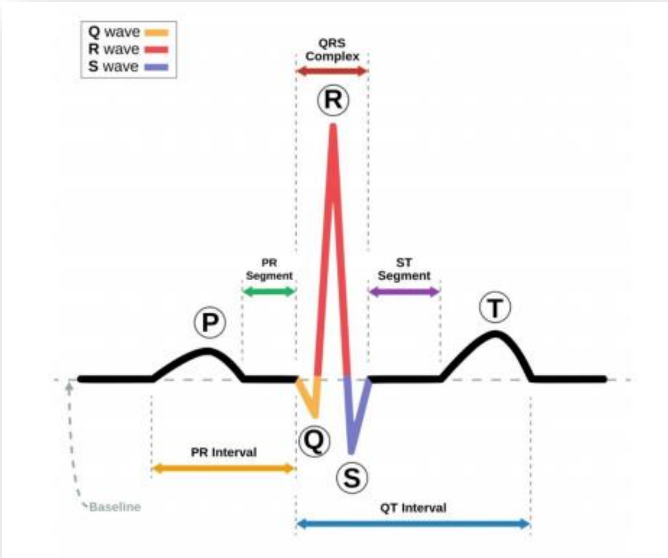

Figure No.01: ECG Wave

- The T wave show the electrical activity associated with ventricular repolarization, reflecting the relaxation of the ventricles.

By examination these components and the overall pattern of the ECG, healthcare professionals can detect abnormalities in the heart's function, such as irregular heart rhythms, ischemia, and other cardiac conditions, helping to guide appropriate medical interventions and treatments.

DETECTING DISEASE: THE ROLL OF AN ECG[8] :

An electrocardiogram (ECG) serves as a valuable diagnostic tool used to record the heart's electrical activity. By analyzing the ECG results, medical professionals can detect various heart conditions, which are as follows,

- **Arrhythmias:** These are irregular heartbeats or abnormal heart rhythms, such as atrial fibrillation, ventricular fibrillation, and supraventricular tachycardia.
- **Coronary artery disease:** This condition affects the arteries responsible for supplying blood to the heart muscle. It often leads to symptoms like chest pain or a heart attack.
- **Heart attack :** Occurs when there is a blockage in one of the coronary arteries, resulting in damage to the heart muscle.
- **Heart failure:** This condition caused when the heart cannot efficiently pump blood, leading to symptoms like shortness of breath, fatigue, and other related issues.
- **Congenital heart defect:** Structural heart disease in the heart that are present from birth, such as atrial septal defect or ventricular septal defect.
- **Cardiomyopathy:** A disease which affecting the heart muscle, which can cause the heart to become enlarged, thickened, or stiff.
- **Valvular heart disease:** This abnormalities occurs when one or more of the heart valves fail to function correctly, leading to issues like regurgitation, stenosis, or prolapse.

SYSTEM DESIGN & IMPLIMENTATION[6,10,11,12,13] :

1. **ESP32 Arduino Module :**

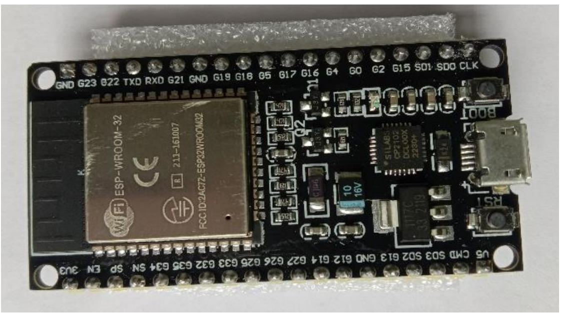

Figure No.02 : An ESP32 Microcontroller

The ESP32 is a low-cost, low-power system-on-a-chip (SoC) microcontroller module designed by Espressif Systems. It is designed for embedded applications such as IoT, home automation, and wearable electronics. The ESP32 module includes two CPU cores that can be individually controlled, a Wi-Fi and Bluetooth module, and a variety of I/O peripherals such as SPI, I2C, UART, and ADC. It also has a built-in RTC (real-time clock) and supports multiple low-power modes to help reduce power utilisation. The ESP32 module is based on the Xtensa LX6 CPU architecture. It includes up to 520KB of RAM and up to 16MB of flash memory for program and data storage. The Wi-Fi module supports 802.11 b/g/n standards. The ESP32 can be programmed using a most relevant of programming languages, including C/C++ and Python.

2. **ECG sensor AD8232 module :**

Figure No.03 : AD8232 ECG Sensor

It is construted to extract, amplify, and filter small bioelectric signals in the presence of noisy conditions, like motion or remote electrode placement.The AD8232 is available in a small, surface-mount package, manufacturing it satisfactory for portable and wearable applications.

3. ECG ELECTROD :

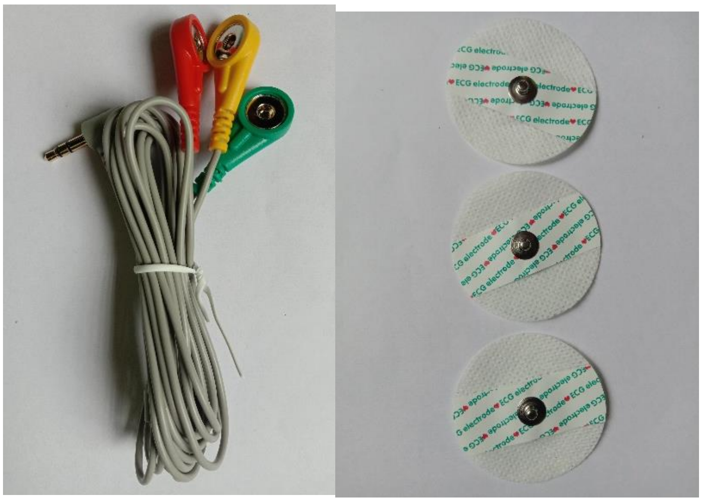

Figure No.04 : ECG Cable and Electrodes

ECG electrodes are small, adhesive patches that are placed on the skin of a patient to measure the electrical activity of the heart. These electrodes are an essential component of an electrocardiogram (ECG) machine, which is used to diagnose various heart conditions. There are several types of ECG electrodes which are as follows,

1] Disposable electrodes: These are single-use electrodes that are typically made of a conductive gel or foam that adheres to the skin. They are easy to apply and dispose of, making them a popular choice for many healthcare settings.

2] Reusable electrodes: These are designed to be used multiple times and are typically made of a metal or plastic plate with a conductive gel or paste. They are more durable than disposable electrodes and can be more cost-effective over time.

3] Dry electrodes: These are a newer type of electrode that does not require a conductive gel or paste. Instead, they use a special material that can measure the electrical signals of the heart through dry skin. Regardless of the type of electrode used, it's important to ensure proper placement on the skin for accurate readings. The most common placement of ECG electrodes includes four limb leads and six precordial leads, but the exact placement can vary depending on the specific test being conducted.

4. BREADBOARD :

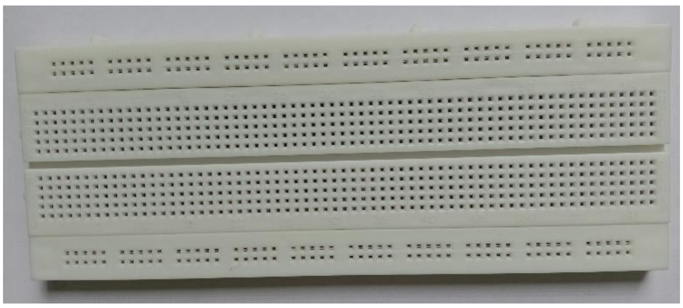

Figure No. 05 : Breadboard

A breadboard, also known as a prototyping board, is a device used for creating temporary electronic circuits. It allows you to at high speed and simply connect electronic components together without the need for soldering. Breadboards come in different sizes, with the most common being a rectangular board with rows of holes for inserting components. The holes are typically arranged in two sets of rows, with a gap in the middle for dividing the board into two sections. Each row is electrically connected vertically, while the two sections are isolated from each other, allowing you to create both parallel and series circuits. To operate a breadboard, you easily insert the leads of electronic mechanics, such as resistors, electrical condenser, and LEDs, into the holes on the board. The components are held in place by metal spring clips beneath the holes, providing a secure connection. You can then use jumper wires to connect the components together, forming a circuit. Breadboards are commonly used by hobbyists, students, and professionals to quickly prototype and test electronic circuits. They are also useful for experimenting with different circuit designs before committing to a permanent soldered solution.

5. CONNECTING WIRES :

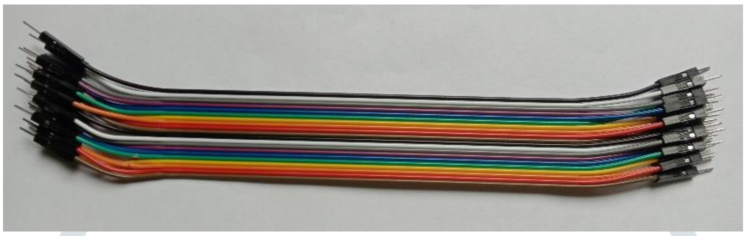

Figure No.06 : Connecting Wires

Connecting wires are electrical wires used to establish a connection between two or more components of an electrical circuit. These wires are commonly made of copper, which is a very good conductor of electricity.Connecting wires come in varioudsizes and shapes, depending on the implimentation and the amount of current they need to carry. Connecting wires can be insulated with various materials, such as PVC, rubber, or Teflon.

When choosing connecting wires, it is important to consider the following factors:

• Wire gauge: The gauge of the wire determines the amount of current it can carry. The larger the gauge number, the thinner the wire, and it carry less current.

• Insulation: Connecting wires can be insulated with different materials, such as PVC, rubber, or Teflon. The insulation protects the wire from damage and prevents electrical shorts.

• Connectors: The type of connector used on the wire depends on the application and the type of component being connected. The most common types of connectors are crimp connectors, screw terminals, and spade connectors.

• Length: The length of the wire should be sufficient to reach the components being connected but too long, as this can cause signal loss and interference

DEVICE CONNECTION:

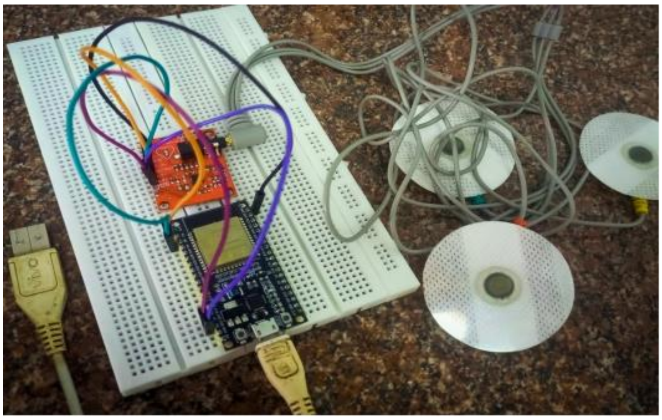

Figure No.07 : Circuit Connections

CLAIMING THE SYSTEM AS COST EFFECTIVE:

The claim that ECG monitoring is cost-effective is based on following factors:

1. Comparison with traditional monitoring methods: Traditional ECG monitoring methods typically involve expensive equipment, such as standalone ECG machines or Holter monitors, which can be costly to purchase and maintain. In comparison, developing an ECG monitoring system using affordable components like the ESP32 microcontroller and leveraging cloud-based platforms like Ubidots can significantly reduce the cost of hardware

and infrastructure.

2. Reduced healthcare costs: ECG monitoring plays a crucial role in early detection and prevention of cardiac abnormalities. By providing timely insights into a patient's heart health, potential issues can be identified early, leading to more effective and less costly treatments. This can help prevent the progression of cardiac conditions and reduce the Requirement for costly mediation, hospitalizations, or emergency care.

3. Remote monitoring capabilities: ECG monitoring systems developed using the ESP32 and cloud platforms like Ubidots enable remote patient monitoring. This eliminates the need for frequent clinic visits, reducing transportation costs and time off work for sufferer and also allows healthcare professionals to monitor a larger number of patients simultaneously, Enhancing efficiency and reducing overall health management costs.

4. Scalability and flexibility: The ESP32 microcontroller and cloud-based platforms provide scalability and flexibility, allowing the ECG monitoring system to be tailored to the specific needs and budget of a project. The usage of open-source software and libraries further enhances customization capabilities, eliminating the need for expensive proprietary solutions.

5. Potential for home-based care: Cost-effective ECG monitoring systems can enable patients to monitor their heart health from home, reducing the need for hospital stays or visits to healthcare facilities. Home-based care can be more convenient and less expensive for needful, while also set free healthcare resources for more critical cases.

6. Affordability for healthcare providers: By reducing the cost of acquiring and maintaining ECG monitoring equipment, healthcare providers can allocate their resources more efficiently. This enables broader adoption of ECG monitoring gadget, facilitating preventive care, and reducing overall healthcare expenses. cost-effectiveness of an ECG monitoring system depends on components used, the scale of deployment, and the target market. However, the utilization of affordable hardware, cloud-based platforms, remote monitoring capabilities, and the potential for cost savings in healthcare make a strong case for the cost-effectiveness of ECG monitoring systems developed using the ESP32 and Ubidots platform.

ADVANTAGES[2] :

1. Affordability: The low-cost nature of the system makes it accessible to a wider population, especially in resource-constrained areas where expensive medical equipment may not be readily available or affordable.

2. Remote Monitoring: With an IoT-based ECG monitoring technique, medical professionals can remotely monitor patients' heart health in real-time and allows for well timed intervention and decrease the need for frequent hospital visits.

3. Continuous Monitoring: The system enables continuous monitoring of the patient's ECG, providing a more comprehensive understanding of their heart health. Device can help in the early detection of abnormalities and facilitate proactive healthcare interventions.

4. Easy-to-Use: The ESP32 microcontroller and Ubidots platform provide a userfriendly interface, making it easier for both healthcare professionals and patients to use the system without extensive technical knowledge.

5. Data Analytics: The system can collect and analyze large amounts of ECG data over time. This data can be utilized to identify graphics and abnormalities Implement personalized healthcare suggest and interventions

DISADVANTAGES[2] :

1. Connectivity Reliability: The system's reliance on Wi-Fi or other internet connectivity may introduce challenges, such as connectivity dropouts or delays.

These issues can impact the real-time monitoring capabilities and the overall effectiveness of the system.

2. Security Concerns: IoT devices are vulnerable to cybersecurity threats. If not properly secured, unauthorized access to the ECG data or system can compromise patient privativeness and confidentiality, which is a significant concern in healthcare.

4. Limited Functionality: Low-cost systems may lack advanced features and capabilities compared to high-end medical devices.

APPLICATION :

- **Home Healthcare:** This system provides patients with the ability to monitor their ECG from the comfort of their homes, offering use and reducing the need for frequent hospital visits. It is especially beneficial for individuals with chronic heart conditions or those recovering from cardiac procedures.

- **Rural and Remote Areas:** Deploying low-cost ECG monitoring systems in underserved regions with limited access to specialized healthcare facilities can be life-saving. Healthcare professionals can remotely monitor patients' heart health and intervene promptly when necessary.
- **Elderly Care:** Nursing homes and assisted living facilities can utilize the system to monitor the heart health of elderly residents. This proactive approach helps in detecting cardiac abnormalities or emergencies early, ensuring timely medical attention.
- **Sports and Fitness:** Athletes and individuals involved in intense physical activities can benefit from real-time heart health monitoring during exercise or training. The system assists in assessing cardiovascular performance and identifying potential health issues.
- **Research and Data Collection:** Due to its cost-effectiveness, the system is well-suited for research studies and large-scale data collection. Researchers can gather ECG data from diverse individuals, enabling analysis of heart health patterns and studying specific cardiac conditions.

- **TOTAL COST OF THE DEVICE :**

SR NO.	COMPONENT	PRICE (Rs)
1.	ESP32	380
2.	ECG Cable, AD8232	400
3.	Bread Board	70
4.	Jumper Wire	45
5.	Electrodes	35

Total = 930 Rs

EVALUATION AND PERFORMANCE TESTING[3]:

The evaluation of the IoT-based ECG monitoring system and the standard ECG machine involved several critical aspects:

- **Functionality:**

During the evaluation, we thoroughly assessed the functionality of our ECG monitoring system to ensure it operated as intended. We confirmed that the system effectively captured and transmitted ECG data in a reliable manner. Moreover, we verified that the system supported real-time monitoring, timely alerts, and notifications for detecting any abnormal cardiac activities. This was crucial in enabling healthcare professionals to respond promptly to any emergent situations.

- **Data Accuracy:**

We conducted an in-depth analysis to assess the accuracy of the ECG data collected by our IoT-based system. To do this, we compared the readings obtained from our device with those obtained from standard ECG machines, which are widely recognized for their accuracy. This comparison allowed us to determine the level of precision achieved by our system. We also ensured that the IoT-based ECG monitoring system demonstrated the capability to identify and eliminate any artifacts or noise present in the ECG signal, thus providing reliable and clear data.

- **User Interface and Experience:**

The user interface of the device was thoroughly examined to assess its performance in terms of user experience. Evaluations were conducted to gauge the ease of use for both patients and healthcare professionals. Special attention was given to testing the clarity and comprehensibility of the displayed ECG data.

To gather relevant feedback, user engagement was encouraged, and their opinions were solicited. This approach helped identify areas that required improvement to enhance the overall user experience. By incorporating user suggestions and addressing their concerns, we aimed to optimize the device's usability and perfomence, making it more intuitive and easy to use for both patients and healthcare professionals.

In the process, we captured and analyzed ECG graphs generated by both the IoT-based ECG monitoring system and the standard machine. The comparison revealed several similarities between the two sets of ECG graphs, indicating that our IoT-based system was capable of providing ECG data comparable to that of the industry-standard machines. Our evaluation and performance testing, conducted with the participation of random cardiac patients in the hospital, was overseen and supported by medical professionals, including doctors and nurses. Prior to monitoring the patients with our device, we obtained explicit permission from each patient, ensuring ethical considerations were met. Overall, the evaluation results demonstrated the effectiveness and accuracy of our IoT-based ECG monitoring system, paving the way for its potential applications in remote monitoring and data analysis for diagnosing and managing cardiovascular conditions.

Performance Testing of IoT-Based ECG Monitoring System:

- **Response Time:**

The performance testing phase involved the meticulous measurement of the system's response time concerning various critical operations, including data transmission, data processing, and the generation of alerts. Throughout the testing process, we assessed the time taken from the initial ECG data capture to its seamless display on the user interface. The ultimate goal was to ascertain that the system delivers near real-time monitoring capabilities.

- **Security:**

During the evaluation of the IoT-based ECG monitoring system, special attention was dedicated to scrutinizing its security measures. Our rigorous assessment included comprehensive tests to validate the system's capability to safeguard sensitive patient data. We specifically focused on the implementation of robust encryption techniques for both data transmission and storage to ensure that patient information remains protected at all times. Additionally, we thoroughly analyzed the authentication and authorization mechanisms to guarantee that only authorized personnel could access patient information, thus preventing any unauthorized breaches.

FUTURE SCOPE[2] :

Instead of body worn ECG electrodes one can use capacitive electrode which can be fitted in clothing instead of sticking to body using gel. Wi-Fi can be used as it can be directly connected to phone and hence to internet directly with dedicated android app.

- Ultra-low power system can be build with low power and longer battery life.
- Solar powered ECG electrode can be used in future.
- Micro electrodes with all electronics can be built in future so there is no need to carry extra electronics.

CONCLUSION :

The development of an affordable IoT-based ECG monitoring system using the ESP32 and the Ubidots platform has shown promising results. The system successfully captures ECG signals and provides real-time visualization and analysis. The real-time visualization and analysis of ECG data on the Ubidots platform were assessed for usability and performance. The accuracy and most relevant of data presentation, as well as the functionality of analytical tools, were evaluated. The accuracy and quality of the captured ECG signals were assessed by comparing them with reference ECG recordings.Its cost-effectiveness, user-friendliness, and integration with the Ubidots platform make it a viable solution for remote ECG monitoring in various healthcare settings.

REFERENCE :

1) H. T. Yew, Y. Aditya, H. Satrial, E. Supriyan and Y.W Hau,“Telecardiology system for fourth generation heterogeneous wireless networks,” ARPN J. Eng. Appl. Sci., vol. 10, no. 2,(2015)

2) Mohamed Adel Serhani Hadeel T. El Kassabi Heba Ismail and Alramzana Nujum Navaz ECG Monitoring Systems: Review, Architecture, Processes, and Key Challenges. Sensors 2020, 20, 1796; doi:10.3390/s20061796 (2020)

3) T. Yokotani and Y. Sasaki, “Transfer protocols of tiny data blocks in IoT and their performance evaluation,” 2016 IEEE 3rd World Forum Internet Things, WF-IoT 2016, pp. 54–57, (2017).

4) Zhe Yang Senior Member, IEEE An IoT-cloud Based Wearable ECG Monitoring System for Smart Healthcare. IEEE Publications. (2019)

5) Zhe Yang, Qihao Zhou, Lei, Wei Xizng, “An Iot cloud based wearable ECG Monitoring system for smart healthcare”, Journal of Medical System December 2016, DOI: 10.1007/s10916-016-0644-9.

6) Onder Yakut, Serdar Solar, EmineDogruBolat, “Implementation of Web Based Wireless ECG Measuring and Recording System”, International Journal of Information and Communication Engineering, Vol: 9, No: 10,2015

7) Gertsch M (2009) The Normal ECG and its (Normal) variants. In: The ECG manual. Springer, London, pp. 17-36

8) https://www.who.int/newsroom/factsheets/detail/cardiovascular- diseases-(cvds), accessed: 2020-11-11.

9) Y.-J. Lin, C.-W. Chuang, C.-Y. Yen, S.-H. Huang, P.-W. Huang, J.-Y. Chen, and S.-Y. Lee, “Artificial intelligence of things wearable system for cardiac disease detection,” in 2019 IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS). IEEE, 2019, pp. 6770.

10) K. A. Vysiya and N. S. Kumar, “Automatic detection of cardiac arrhythmias in ecg signal for iot application,” Int. J. Math. Sci. Eng., vol. 5, no. 2, pp. 66–74, 2017.

11) A. Gurjar and N. A. Sarnaik, “Heart attack detection by heartbeat sensing using internet of things: Iot,” Heart, vol. 5, no. 03, 2018

12) T. Geethalakshmi and T. Sivakumar, “Real-time monitoring and detec- tion of “heart attack”using wireless sensors and iot,” 2018.

13) N. Patel, P. Patel, and N. Patel, “Heart attack detection and heart rate monitoring using iot,” International Journal of Innovations & Advancement in Computer Science (IJIACS), vol. 7, pp. 611–615, 2018.

14) K. U. Nigam, A. A. Chavan, S. S. Ghatule, and V. M. Barkade, “Iot- beat: An intelligent nurse for the cardiac patient,” in 2016 International Conference on Communication and Signal Processing (ICCSP). IEEE, 2016, pp. 0976–0982. “Developing an Affordable IoT based ECG Monitoring System using an ESP32 and Ubidots Platform” Yashwant Redekar College Of Pharmacy, Nesari 30

15) R. K. Kodali, G. Swamy, and B. Lakshmi, “An implementation of iot for healthcare,” in 2015 IEEE Recent Advances in Intelligent Computational Systems (RAICS), 2015, pp. 411–416