Implementation of IoT based patient Health Monitoring Framework for Medicine Industrial Applications

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Abstract

Physiology, biomedical equipment, and communications are just a few of the many disciplines involved in telemedicine, which enables medical care to be delivered remotely. When it comes to people's health, distance is often a limiting factor. Telemedicine aims to bridge that gap by connecting people from all over the world through the use of information and communication technologies to share accurate data on everything from disease and injury prevention to treatment options. It's an efficient solution to issues like a dearth of doctors, dispersed populations, and an overabundance of patients. Telemedicine includes remote diagnostics, monitoring, and treatment provided by a physician who is not physically present in the same room as the patient. Travel time between locations is reduced as a result. The core components of telemedicine services are the collection of data, its subsequent storage and processing, and its dissemination to the appropriate parties. The expensive price of equipment used in telemedicine systems has prevented the phenomena from reaching its full potential, despite its many benefits. The primary limitation of this kind of telemedicine is that it does not allow the doctor to do a physical examination of the patient. To combat this, we need a system equipped with sensitive sensors to track key health metrics.

Keywords: Telemedicine, Biomedical, Tele-education, Communication, IoT and physician.

1. Introduction

In order to deliver healthcare at a distance, the notion of telemedicine draws from a wide range of disciplines, including physiology, biomedical instruments, and communications. When resources for providing medical care are scarce, such as when doctors are in short supply or when there is a huge population to serve, telemedicine can be an efficient replacement. Because of the relatively high cost of the required equipment, telemedicine has not yet reached its full potential in spite of the many advantages it offers. This kind of telemedicine is not very effective since the physician may not be aware of the subject's physiological parameters when communicating with them through phone or video chat. In order to do this, it is required to put into place a complete system that is comprised of a number of sensors. This will enable the medical practitioner to work with a believable simulation of the patient's physiological condition. The most current developments in embedded systems and the Internet of Things are used in the production of a telemedicine system that is both lightweight and inexpensive[1]. These sensors are driven by an energy-efficient technology that does not compromise their precision or dependability in any way. Complex algorithms, written in a variety of computer languages, are utilized in order to analyse and show the data collected by the sensors. The bespoke graphical user interface of the system is used to monitor and display the parameters in real time as they are being monitored. The newly designed technology, in contrast to earlier medical gadgets, calls for a very little amount of user training. The devised apparatus is capable of accurately measuring a broad spectrum of physiological indicators. Included in the package are the percentage of oxygen that is found in the blood, the temperature of the skin, the heart rate, an electrocardiogram of the pulse rate of the heart, and the non-invasive blood pressure that is computed from the pulse transit time. The delivery of medical treatment to patients at a distance via the use of various forms of electronic communication and computer technologies is an example of the field of telemedicine. Teleconsultation, tele-education, telepathology, teleradiology, and telecardiology are just a few of the telemedicine applications that have been shown to be effective uses of the resources that are now accessible [2]. The two basic ways that telemedicine may be put into practice are known as the store and forward approach and the real-time implementation. Under the store and forward technique, the information pertaining to patients might be kept in either electronic or paper format. After that, the material is sent to the medical professional for evaluation via a variety of different methods. The second approach involves the specialist observing the therapy from a distance while simultaneously reviewing the patient's medical history. The telemedicine data contains a variety of different types of information, including personal details, medical histories, clinical data, and patient reports. The broad use of telemedicine is essential since the global population continues to increase while spending on medical care continues to decrease. The patients need to be diagnosed with and treated with standard medical equipment. With an ever-increasing patient load, many hospitals and clinics lack the necessary health monitoring tools. Traditional systems are time-consuming and labor-intensive to maintain and run. For instance, traditional mercury thermometers can make taking a temperature reading take anywhere from three to five minutes. The time spent taking a patient's pulse, blood pressure, and other vitals is time that could be better spent treating the patient. Most hospitals and clinics still lack the technology necessary to accurately and rapidly measure patients' vitals[3]. Low-cost telemedicine technology makes this method of healthcare accessible to more people in less time. The distance between the healthcare facility and the patients is a major problem in the larger countries. Health care facilities staffed by specialists are difficult to set up in every small community of 500 people or less; as a result, most such facilities are located in urban and semi-urban areas. Subjects report that it is difficult for them to make the long journey to urban centers for routine medical care. With the advent of telemedicine and advancements in high-speed communication, less time is spent on the road. The data storage capabilities of telemedicine equipment are also useful for doctors on medical missions to outlying areas.

2. Importance of Embedded IoT

Embedded system improvements allow for the development of small, portable, and user-friendly electronic equipment to record the physiological signals. Embedded systems are commonly understood to be computerized systems whose hardware and software work together to accomplish a certain job. Since the advent of microcontrollers, embedded systems have been developing rapidly. Because of the versatility afforded by their inclusion, microcontrollers/microprocessors, sensors, and actuators can be found practically anywhere. With the development of IoT technology, millions of embedded devices are networked to provide people with a wide variety of useful new capabilities[4]. As can be seen in Figure.1, the embedded systems and their internet connectivity form the backbone of the internet of embedded things architecture. Embedded systems are task-specific devices built around a microcontroller or microprocessor and a collection of sensors and actuators. The sensors send an electrical signal representing the physical parameters to the microcontroller as an input[5]. Microcontrollers are responsible for processing the data and storing it in memory. Microcontrollers use the processed data to power the actuators. Connecting to the IoT also allows for the transmission of data and control signals to far-flung gadgets. A microprocessor is a type of integrated circuit that can rapidly execute a variety of arithmetic, logic, and control tasks. The microcontroller is an integrated circuit that contains a CPU, memory, and programmable peripherals. Microcontroller units are often preferred by embedded engineers due to their built-in program memory and random access memory. Companies like Intel, Advanced Micro Devices, National Semiconductor, Microchip, Texas Instruments, and Silicon Labs are just a few of the many that produce microcontrollers[6]. As more and more components like co-processors, wireless fidelity modules, and graphical processors are integrated onto a single chip, modern microcontrollers are transitioning into SoCs (Systems-on-chip).

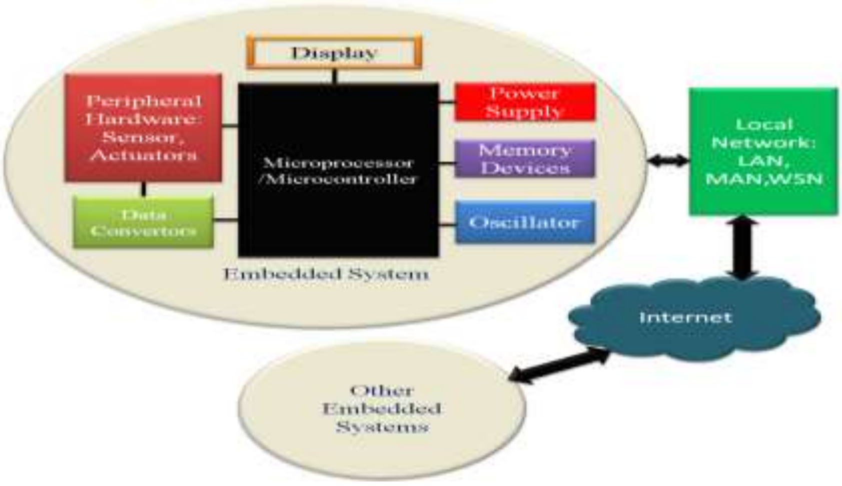

Figure.1: An Overview of Embedded Internet of Things Architecture

Physical values can be detected and converted into electrical impulses by means of sensors. In the modern era, when nearly everyone has at least one electronic device, sensors have become deeply embedded in daily life. Sensors are typically located near the input of embedded systems and collect a wide variety of data[7]. There have been many different kinds of sensors, distinguished by factors like the nature of the information they provide, the materials used in their construction, the guiding principles and metrics by which they are evaluated, and so on. In order to control and move the systems that are wired to it, electrical signals must be transformed by transducers called actuators. In an electronic sphygmomanometer, for instance, the actuator fills and drains the air cuff in response to an electronic signal from the system's microcontroller. Actuators connected to the Internet of Things can be used in robotics to move limbs using stepper motors and in home appliances to turn on and off water pumps[8]. Due to the lack of data converters in some transducers, not all transducers in embedded systems are capable of direct digital information exchange. The processing unit's in-built analog to digital data converter can be connected to the sensors' analog data. Digitizing data as soon as it is acquired, preferably with an external ADC if the distance between the sensor and controller is large, will improve noise immunity. At the same time, certain actuators are limited to working with analog signals because they lack built-in data converters[9]. Actuators must be interfaced with digital to analog signal converters because microcontrollers only output digital signals. Because of the low capacity of most microcontrollers' internal memories, it is common practice to connect these chips to external memory devices in order to boost their overall performance[10]. In order to run complex programs, an embedded system's operating system needs to be stored in a bootable read-only memory (ROM). The embedded devices are booted and their data is stored non-volatilely on read-only memory devices such CD-ROMs, hard drives, flash drives, and solid-state drives. Connecting the external RAM modules is another option for increasing RAM and hence improving processing speed. Single-inline, dual-inline, and small-outline dual-inline packages are all on the table when it comes to dynamic synchronous RAM modules. Power is essential for the operation of any embedded system. Power has been provided in various forms, including conventional AC power, DC batteries, and wireless energy transfer. Mechanical, thermal, magnetic, radiant, and biological energy are all being studied as potential sources of power for battery-free electronic gadgets[11]. The majority of embedded systems support both alternating current (AC) and direct current (DC) power sources via a regulated power supply circuit. It's important for designers of embedded systems to remember that not all devices have the same power requirements. In order to supply the various parts of the gadget with the power they need, level shifting circuits are used. Accurate clock pulses are required to keep the CPU running in time with the rest of the system. One of the determining variables of the speed of an embedded system is the oscillator circuit. To get top performance, the clock pulses should be generated at the highest possible frequency for the microcontroller[12]. A passive component oscillator, an integrated circuit oscillator, or a piezoelectric oscillator circuit are all viable options for generating the clock signals. Because of their ability to produce precise time intervals at extremely high frequencies, piezoelectric oscillators are ideally suited for use in embedded processing units. In addition to the microcontroller, clock circuitry is needed so that everything can operate in time with one another. It is common practice for microcontrollers to share the clock with other components like the real-time clock and random access memory. When a microcontroller doesn't have a method to split up clock signals, an external oscillator must be wired into each device.

2.1 Applications

High-speed processing, remote access to objects, and the capacity to do multiple tasks simultaneously have all contributed to the widespread adoption of internet-of-things-connected integrated embedded systems. Agriculture, meteorology, medicine, home appliances, industries, education, and the military are just some of the many disciplines that can benefit from integrated system applications.

Farmers' workloads can be lightened by installing Internet of Things (IoT)-enabled integrated systems in agricultural areas that are equipped with various sensors and actuators[13]. Common uses in agriculture include monitoring conditions like soil moisture and salinity, detecting rain, and controlling machinery like irrigation pumps. More systems that assess water factors such as pH, salinity, and polluted particles can be integrated to improve the water's suitability for agriculture.

Meteorology is the science that uses various equipment to measure the physical and chemical properties of the atmosphere. The embedded systems that measure things like temperature, humidity, barometric pressure, wind speed and direction, carbon monoxide, atmospheric ozone, and carbon dioxide all work together to help with atmospheric analysis. Improved integration of IoT systems and wireless sensor networks leads to more accurate weather and air pollution predictions.

In this, the fourth industrial revolution, integrated Internet of Things (IoT) devices are widely used. Industries are buying more IoT integrated embedded devices to speed up production and marketing as the fifth industrial revolution approaches[14]. Rapid progress in such systems, coupled with other technologies like AI and VR, has propelled industrial development. Numerous businesses, like those dealing with driverless vehicles, online advertising, and remote-controlled 3D printers, are confirming the importance of IoT embedded systems.

Education is essential to human flourishing. The traditional chalk-and-talk method of teaching is getting some support from online technological education technologies. Blended learning combines traditional classroom instruction with internet resources to provide a rich environment for learning. With the help of embedded IoT devices, students now have access to high-priced and geographically remote laboratory facilities. Knowledge sharing between distant students and lecturers is made possible without the requirement for physical travel. By collecting data in real time, streamlining administrative tasks, and bolstering safety measures, IoT-based technologies are improving classroom instruction.

The use of electronic devices has become crucial in all phases of medical practice, from diagnosis to treatment to monitoring the patient's progress. Temperature monitoring, endoscopy, heart rate measurement, blood testing, electrocardiography, electromyography, and other electrophysiological tests are only a few examples of the many embedded systems now being employed in the diagnostic process[15]. The production and implantation of implantable devices rely on the use of embedded systems. Embedded devices attached to patients allow for real-time monitoring of anesthetic effects during surgery, such as changes to oxygen saturation and blood pressure. During the postoperative observation phase, patients' vital signs are monitored to gauge any adverse physiological reactions to the procedure.

Telehealth apps combine medical software with telecom software to take advantage of recent developments in both domains. In order to transmit patient information through various communication channels, telemedicine makes use of integrated embedded communication systems that include diagnostic capabilities. The practice of fusing healthcare and telecom is still relatively new. In order to fully realize the potential of telemedicine, it will be necessary to mass develop a variety of different types of high-tech gadgets.

3. Literature Survey

Telemedicine refers to the process in which a physician examines, monitors, and treats a patient even when the physician is not physically present at the bedside of the patient. Telemedicine services consist essentially of three phenomena: the collection of images, their storage and analysis, and their transmission to a remote location. Low- and middle-income countries might use telemedicine to bridge the healthcare gap by linking doctors and patients via secure technology[16]. Telemedicine relies heavily on smart sensors for taking precise readings of vital signs including heart rate, blood pressure, and oxygen levels. These sensors report their readings to a central computer, which processes the information. Therefore, it is crucial to combine the sensors and the CPU into a single device for the purpose of measuring many health indicators simultaneously[17]. In order for hospitals and clinicians to take appropriate action based on the collected healthcare data, it must be made available in real time. The Internet of Things is crucial in relaying healthcare data to the appropriate professionals.

Ganapathy spoke on India's medical infrastructure, noting that it varies between urban and rural areas. Approximately 700 million Indians are without access to adequate healthcare since they reside in rural regions. Only around 20% of India's population has access to the 80% of the population that is comprised of medical experts. The author suggested a way to virtually bring metropolitan physicians to rural communities to raise healthcare quality there. E-home visits by medical professionals are made possible by video conferencing, which also facilitates international teleconsultation[18]. The telemedicine method allows the doctor to virtually visit with the patient and keep tabs on them from wherever the doctor happens to be. This reduces the time a doctor or patient must spend going from a rural to an urban region. Images are captured, analyzed, and displayed as part of the telemedicine system. Remote medical treatment is greatly improved by the virtual visit of a medical specialist to the intensive care unit (ICU). Patients in far-flung areas now have access to mobile telemedicine thanks to a technology developed by Görset et al. In highly populous and industrialized nations, providing sufficient medical care facilities might be difficult. Patients in rural areas of these nations have limited access to quality healthcare, sometimes resulting in their premature deaths. Therefore, a system must be created and made accessible at all times to monitor a person's health indicators from afar and relay that data to the appropriate authorities for action[19]. To assist the medical care system in a far-flung place, this research deploys a system consisting of certain sensors to monitor the health parameters, all of which are embedded in a distributed network architecture. The technology incorporates a teleservice-center that uses data analysis to help people in a dire situation from afar. Since patients won't have to go somewhere else to get the care they need, the system's design saves both money and time. Medical care units in outlying locations now have access to cutting-edge technologies thanks to the rapid development of the communications and data capture infrastructure. numerous illnesses may be treated more effectively with the help of this system because to the connection and integration of numerous sensors. A heart rate monitor, blood pressure gauge, scale, and electrocardiogram (ECG) are the primary components of this system. Data from the sensors is sent to a smartphone through a Data Acquisition Unit (DAU). In their research, Segato and Masella identified many elements crucial to the successful introduction of telemedicine programs. The authors' research into telemedicine yielded insights into the mechanisms that keep telehealth programs running well. The authors spent six years doing in-depth study on three Italian telemedicine programs[20]. The Italian Ministry of Health's database was used for the screening of telemedicine services in the country between 2008 and 2010. It's useful for identifying the many use cases for telemedicine services and the underlying elements that must be considered when designing such services effectively[21]. According to the research, the organizational and financial health of telemedicine services are significant factors. Knowledge of medicine and providing the necessary amount of care for patients may strengthen the organization's stability and increase the professionals' respect for one another. Availability of a nurse at all times is only one example of how patients' requirements may be met thanks to technological advancements that help boost organizational steadiness. Several solutions including hospital administration and policymakers were identified to improve financial stability.

3.1 IoT Enabled Medical Devices

Research by Rohokale et al. suggests an Internet of Things-based health monitoring system that may be used to better provide medical services to low-income and rural populations. Hemoglobin (HB), blood sugar (BS), blood pressure (BP), and aberrant cell proliferation are only few of the health characteristics that may be detected by modern sensors and communicated to those who are worried. The widespread lack of education is a major contributor to the high death rate, particularly in rural regions[22]. Knowing how to use modern technology to promptly relay health information to medical professionals is key to lowering this incidence. The World Health Organization and the United Nations Children's Fund indicate that many maternal fatalities may be prevented if better prenatal care were available. With the use of IoT technology, a patient and doctor are able to easily exchange information. With the use of Internet of Things (IoT) equipped devices, vital health data may be sent to a hospital at an early stage, increasing the likelihood that a patient can be saved. The Internet of Things (IoT) technology may also be useful for patient record keeping and improved health problem management. Lu and Liu summarize the importance of the Internet of Things in the healthcare sector. The authors explain how the Internet of Things (IoT) is organized, how its functions are implemented, and what part it plays in the telemedicine infrastructure. In the Internet of Things, sensors may talk to other IoT devices using a variety of protocols. The Internet of Things is built on a three-tiered structure, which consists of the perceptual, sensor network, and application levels. Several sensors in the perceptual layer monitor vital signs and other indicators of a person's health. In order to disseminate collected data, sensors build a network at the sensors layer and link to the internet. The application layer is where the IoT's established technology is put to use in practical situations. Each patient is assigned a unique ID in the IoT-based telemedicine system, and those IDs are linked to sensors that collect data on the patient's vital signs. A gateway relays sensor data to the host database management system. Patients, physicians, medications, medical devices, and illnesses must all be identified as part of the IoT medical unit process. With the Internet of Things interfaced with the medical device, all of these things may have instantaneous results. Patients may be identified from afar with the use of radio frequency identification (RFID) under an IoT system, which collects data from the patient. Wu et al. built a system in their research employing wearable sensor nodes that run on solar energy harvesting. An autonomous wireless body area network (WBAN) is then implemented to allow for the sharing of the detected data using Bluetooth low energy connection. The paper demonstrates the importance of IoT in healthcare and how cutting-edge technology may be used to enhance healthcare facilities. In order to monitor vitals like core temperature and heart rate, many sensors are attached to the person. The data collected by the sensors and a human body fall identification are shown on a web-based software designed for use on smartphones. Wearable sensors have longer operational lifetimes thanks to solar energy harvesting systems. The three primary components of the developed system are a solar energy harvester, a Bluetooth-connected sensor node, and a smartphone-friendly web application. Connecting sensors to a microcontroller (MCU) is a crucial aspect of any wearable sensor system. The system transmits the sensor data to a smartphone running a custom web app through a Bluetooth low energy (BLE) module (HM-10). Future iterations of the system might make sensors more comfortable to use and easier to attach. The solar panel may be further exposed to sunlight if the sensor node is configured to fit with other sensors to monitor additional health metrics and if it is worn on a smart hat or smart T-shirt. Zhang et al. developed a wristband gadget that may be used for monitoring heart rate and movement. Using IoT technology, the gadget may capture vital signs including a person's blood pressure, oxygen levels, and heart rate in real-time, and then transmit that data to the appropriate authority system. The system was created to measure the parameters precisely and be simple to use. The Bluetooth module in a mobile phone facilitates wireless communication. The Internet of Things (IoT) has enabled wireless connectivity to serve as a critical infrastructure component in the healthcare system. The sensors in the planned system relay data to the central controlling system, which processes the information. Next, the controlling system relays the performed data through a TCP connection, using cloud server technology. The cloud server utilizes a TCP control application to gather data from the sensors and save it to a database for later use. An app on a mobile device is used to access the patient's records in the proposed system, and historical data is also shown. Through the use of web technology and a personal computer, a doctor may see numerous patients at once and communicate with them in real time.

4. Proposed System

Embedded system development relies heavily on the careful selection of hardware components like CPUs and sensors. The device is expected to have a low power consumption and a fast reaction time. The system's brains are an AMD processor and an AVR controller, which together form the Advanced Virtual Reduced-instruction-set computing architecture. Signal conditioning circuitry connects the sensors to the AVR controller, which then gathers data. AMD's CPU is used to analyze and display data from the microcontroller. A functional block diagram of the system that was constructed for the purpose of this research is shown in Figure.2. The system may be broken down into its five key components: computing, sensing, displaying, storage, and the Internet of Things. The AMD processor and the AVR controller each make up one of the two blocks that make up the processing unit. The controller is the component that is responsible for receiving data from the sensors and then transmitting that data to the CPU. An AMD processor that has an integrated graphics processing unit is utilized because it allows for the processing of data coming from the microcontroller, the display of that data in the local unit, and a connection to the internet of things. The CPU that is running an operating system makes a wide variety of helpful applications accessible since it can work with a diverse selection of peripheral devices. The sensors' block is comprised of a temperature sensor, a SpO2 sensor, an electrocardiogram (ECG) and pulmonary function (PPG) sensor, all of which work in conjunction with one another. When taking the measurements, a contact-based human body temperature sensor manufactured by MAXIM is used, and the sensor is factory-calibrated before usage. In order to achieve a higher signal-to-noise ratio, the reflecting kind of SpO2 sensor that was used in this study was designed with low-noise circuitry. When calculating the amount of oxygen saturation, two light-emitting diodes (LEDs) and a photo-detector (diode) are used as measuring devices. For cuff-free blood pressure monitoring, a single integrated circuit with built-in analog to digital converters is utilized to gather data from both the electrocardiogram (ECG) and the photoplethysmograph (PPG). After attaching three electrodes to a person in order to record an electrocardiogram (ECG), the subject is then asked to touch the very tip of their finger to a sensor in order to capture a PPG signal. The display is a high-definition multimedia interface (HDMI) monitor with a built-in digital camera input. The HDMI display, which may be of a variety of sizes, can be linked to the display interface without any updates to the software or hardware being necessary. Through the use of a digital camera, the position of the patient may be seen and recorded. The system is connected to a capacitive touch screen display device that has a screen size of 7 inches. The adapter for wireless communication in the gadget that connects to the internet of things. The wireless adapter is plugged into the system via one of the SoC's USB ports, which acts as the connecting point. The memory block consists of an embedded multi-media card (eMMC) and a DDR4 memory module. A memory module with 32 gigabytes of storage space and an operating system is linked to the AMD central processing unit (CPU). The performance of the computer has been improved by the addition of an 8GB DDR4 RAM module, which can be accessed via the motherboard of the machine. A wireless mouse and keyboard provide access to the system while patients are being connected up for continuous monitoring. This access is provided without in any manner disturbing the patients in any way.

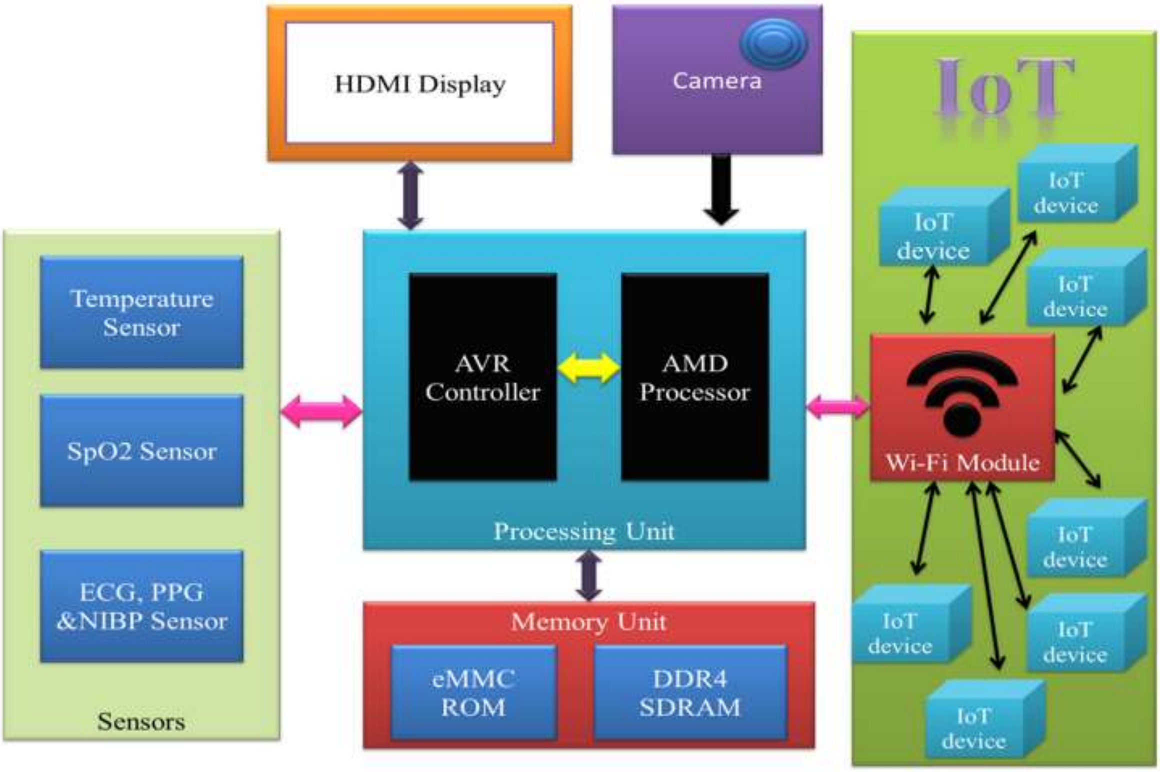

Figure.2: Block diagram of the proposed system

Taking a patient's temperature, one of the most common diagnostic procedures, is often done using a glass-filled mercury meter. Electronic memory is used to store the data collected by temperature sensors that employ a variety of sensing techniques. In this study, the smart temperature sensor MAX30205 is used to take direct readings of the skin's surface. The high-resolution temperature sensor's accuracy is guaranteed by its direct calibration to degrees Celsius. The sensor only needs 2.7–3.3 V to function, and it draws just 600 A of current. By switching to shutdown after each reading, you may further increase your sensor's power efficiency, since it will only use 1.65 A when inactive. Interfacing block, register block, logic block, and temperature measurement block are the four blocks that make up the sensor, as shown in Figure.3. A temperature sensor circuit, logic circuit, reference voltage circuit, and analog-to-digital converter make up the temperature measuring block. The ADC receives the analog output from the temperature sensor circuit, which measures the ambient temperature. The sigma-delta type ADC uses 16 bits of digital space to store the calculated temperature from an analog input. The analog-to-digital converter (ADC) uses a constant voltage supplied by the built-in reference voltage circuit as its point of reference. When the temperature rises over the setpoints, the logic block triggers the over-temperature shutdown output pin (OS pin) to sound an alert. The current temperature is compared to the lowest and maximum threshold temperatures using a digital comparator in the logic block. Lower threshold temperature (THYST), over temperature (TOS), configuration, and temperature registers make up the four registers accessible through the register pointer inside the register block. The lower threshold and over-temperature registers specify the lowest and maximum temperatures at which the sensor may function without activating the operating system. The 16-bit temperature data from the ADC is saved in the temperature register. The register pointer used by the microcontroller to communicate with the sensor is stored in the interface block. An address decoding circuit, which determines the MAX30205's address on the I2C bus, is also coupled to the interface block's serial logic circuit, which drives the I2C protocol.

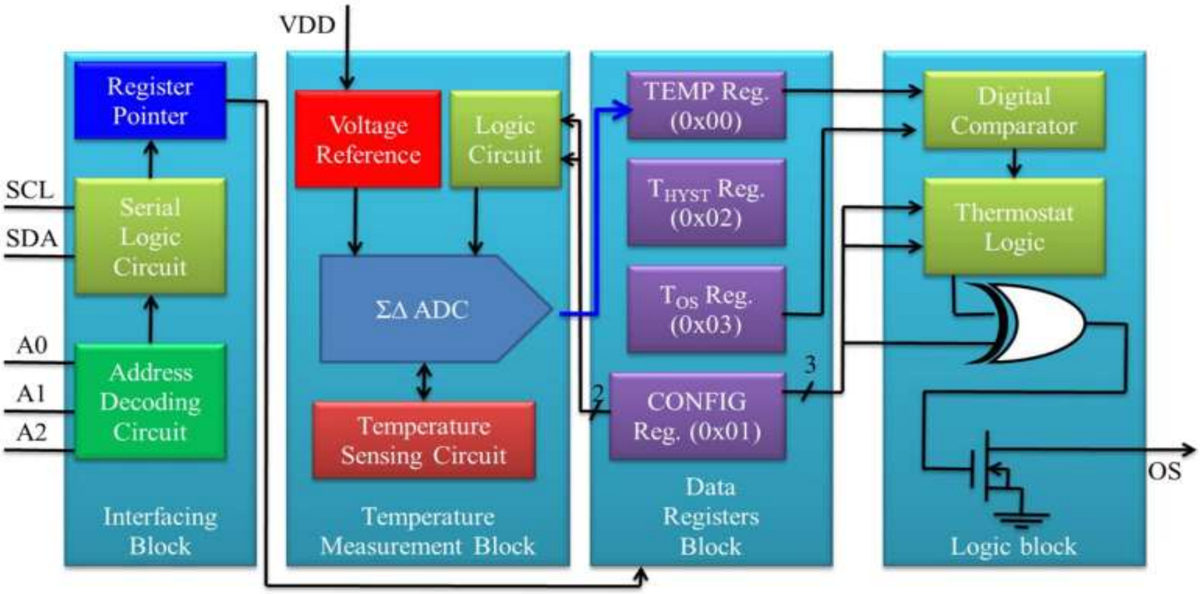

Figure.3: Block diagram of temperature sensor

5. Software Implementation

An embedded operating system is the software used to manage the resources of an embedded system so that it can carry out a predetermined job. The envisioned system runs on Disco Dingo, a distribution of Linux based on the 5.0 series of the kernel. The Ubuntu 19.04 (Petersen) version of the operating system is also known as "Disco Dingo." The created system utilizes an AMD processor, and the Kernel is optimized for communicating with the CPU and GPU of that chip. A Windows PC is used to download the OS and then to install it on the eMMC. Developers may use a cutting-edge toolchain made available by the Disco Dingo OS to create their own software. It includes updatable versions of languages including Ruby2.5.5, Python3.7.3, Perl5.28.1, and PHP7.2.15. Many system developers are drawn to the open-source Linux-like OS because of its many desirable qualities. Figure.4 depicts the intended system's software architecture.

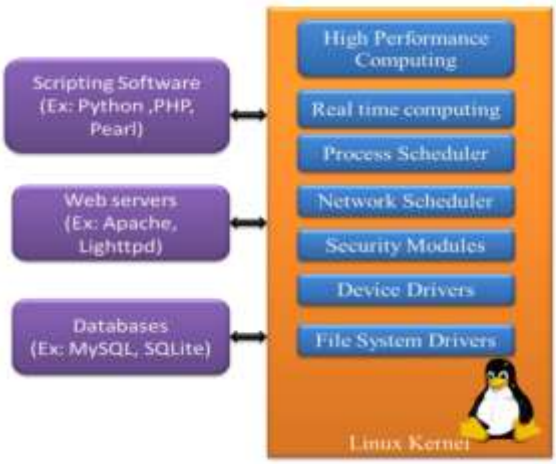

Figure.4: System architecture software design

The primary goals of the system's code are (1) measuring physiological parameters through signal collection and processing, and (2) displaying the results of the signal processing. Python scripts provide the interaction between the software and the sensors. Sensor samples are collected using two-wire communication protocols and accessible from several sensors concurrently. The first step of the coding process is to import a collection of library files. For instance, most of the mathematical operations in the software rely on the library file known as NumPy. By using address-based calls to both sensors and registers, the two-wire communication protocol is configured to take turns reading sensor samples. In addition, the gathered samples from the sensors are used by the subroutines to calculate the temperature, SpO2, pulse rate, heart rate, breath rate, and blood pressure. MySQL stores the finalized database there for future reference. The system is programmed in PHP and uses the d3.js JavaScript library to generate the visualization of the findings. The IEEE wireless communication standard 802.11b/g/n is used to send the data to Internet of Things devices.

6. Results and Discussion

For the sake of telemedicine, we devise a patient monitoring system. The data that can be monitored by using the system that has been built include temperature, pulse rate, SpO2, heart rate, respiration rate, as well as systolic and diastolic blood pressures. These are only some of the data that can be monitored. Graphic representations of the ECG and PPG signals are also provided by the system. Teleconferencing is made possible thanks to the technology, which enables remote access to the videographic information associated with patients. The newly developed system is delivered to the GITAM Institute of Medical Science and Research (GIMSR) hospital in Visakhapatnam so that its data may be compared with those of the traditional systems. The emergency department, the critical care unit, the operating room, and the ordinary ward are the four locations of the hospital from which the data is gathered. The acute care unit and operating theater have air conditioning, whereas the standard rooms and outpatient areas have lots of windows. Eighty adult patients with a mean age of 37.12 (SD) years are surveyed, and the hospital's established procedures and equipment are used to record their vital signs. The patients' ages range from 18 to 79 years old. The technique is used to measure the data of outpatients, and just one sample is obtained from each individual patient. The device gets data from each patient for a whole half an hour in the other sections. The portable system is first used at the GIMSR's outpatient ward, where a variety of patient parameters may be measured with relative ease. The records of 24 patients are gathered in the outpatient ward using the hospital's existing systems and the developed system. Standard devices used in the outpatient ward include a mercury thermometer, an infrared thermometer, a commercial pulse oximeter, a stethoscope, and a mercury sphygmomanometer for measuring temperature, heart rate, and blood pressure, respectively. With the guidance of medical experts, one may determine one's pulse rate by placing one's finger on one's pulse nerve and one's respiration rate by counting breaths taken in one minute. Figures 5–8 show graphs of several patient parameters collected from the outpatient ward.

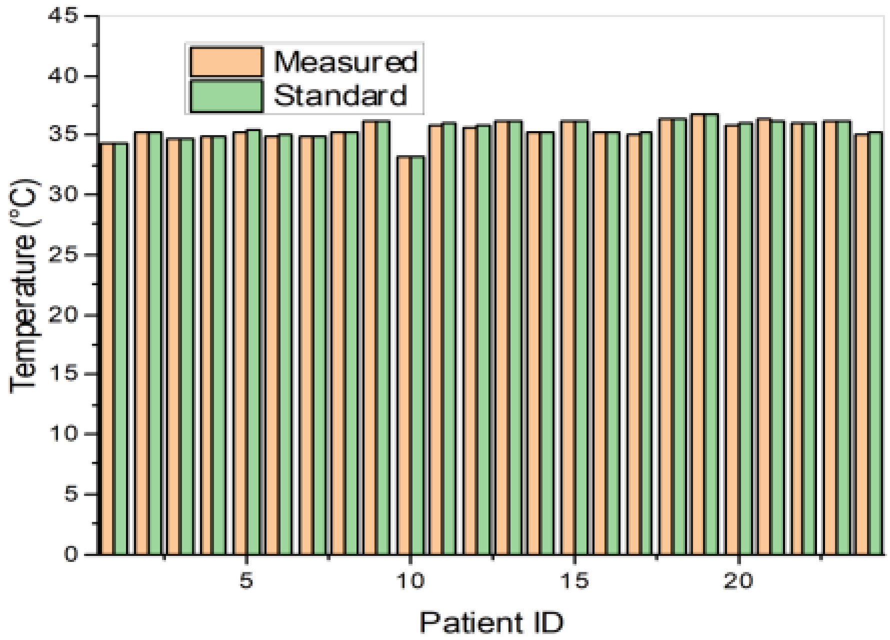

Figure.5: Temperature values at outpatient ward

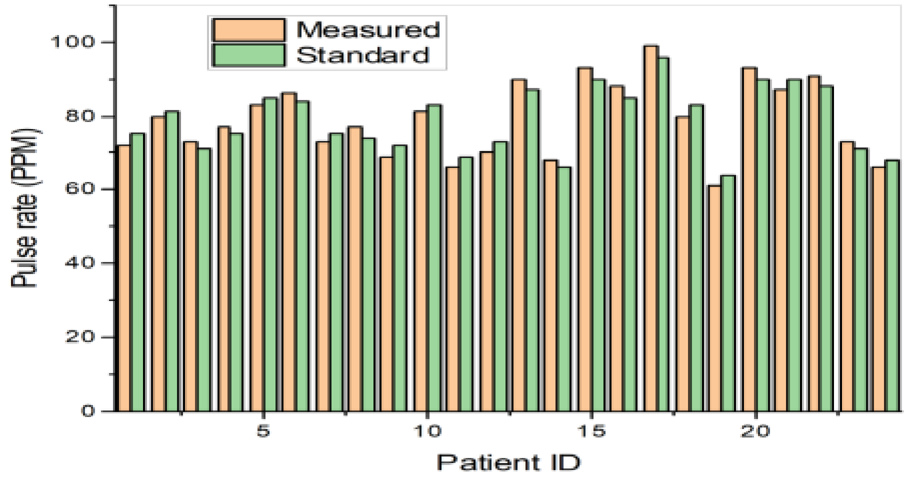

Figure.6: Pulse rate values at outpatient ward

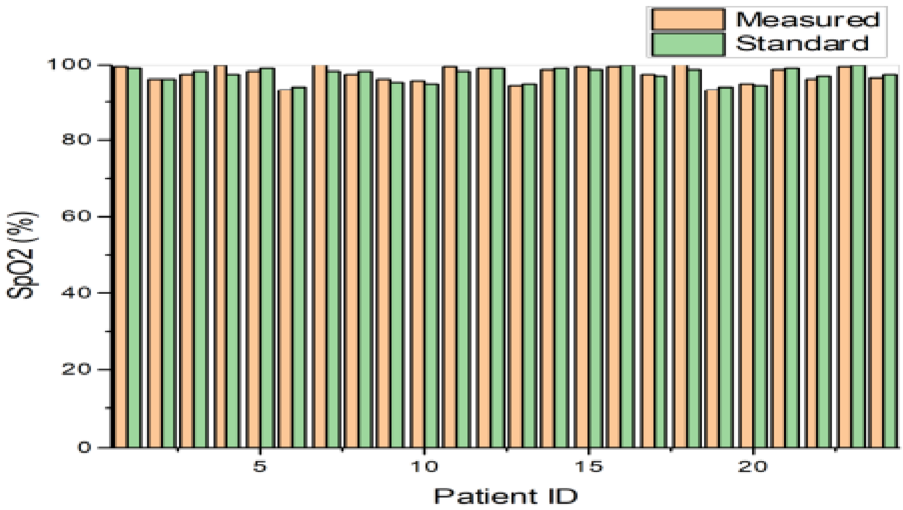

Figure.7: SpO2 values at outpatient ward

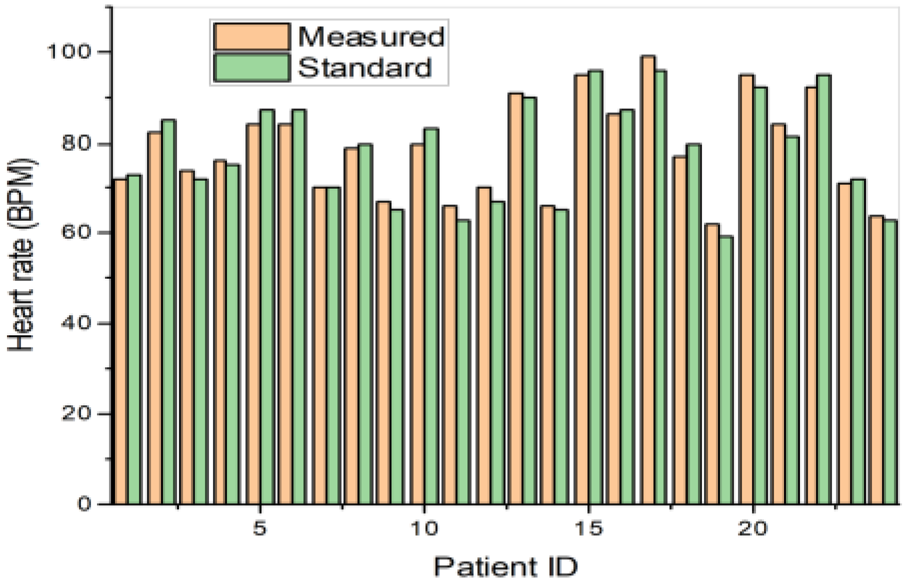

Figure.8: Heart rate values at outpatient ward

There is a standard variation of 0.8 degrees Celsius in the temperature of the patients in the outpatient ward, which brings the average temperature to 35.45 degrees Celsius. The standard deviation of the patients' pulse rates is 10.21 beats per minute (BPM), whereas the average pulse rate of the patients is 79 beats per minute (PPM). The data from the pulse oximeters of the patients reveal that the patients' average SpO2 is 97.57%, with a standard deviation of 2. The standard deviation of the heart rate was 10.76 beats per minute (BPM), which is the same as the pulse rate. The average heart rate was recorded at 78.58 beats per minute (BPM). The patients' average rate of breathing was 15.4 breaths per minute (RPM), and their standard variation was 2.7 RPM. According to the measurements taken by the system, the systolic blood pressure of patients had an average of 120.5 mm Hg, with a standard variation of 2.5 mm Hg. The diastolic blood pressure at the outpatient clinic is typically measured at 78.41 mm Hg, with a standard deviation of 2.5 mm Hg.

7. Conclusion

The need for telemedicine is growing as a result of the expanding population and uneven distribution of medical services. Since traditional techniques are not automated and need skilled personnel to operate them, they are a cumbersome procedure for monitoring and disseminating physiological data. For telemedicine applications to be deployed successfully, Internet of Things-based solutions that include physiological monitoring systems are required. Using Internet of Things (IoT)-based devices that are connected with a large number of sensors, the patient information must be recorded and communicated with a medical expert who is located in a different location for telemedicine to be effective. Patients in the operating room, general ward, intensive care unit, and outpatient ward may all contribute their physiological data to the newly developed system. The accuracy of the system is high when measured against the techniques that are standard according to ISO for the measurement of a number of physiological parameters. In contrast to the precision of the conventional systems, the blood pressure is measured with an accuracy of 5 mm Hg, the respiration rate of the patients is tracked with an accuracy of 3 PPM, and the SpO2 readings are determined with an accuracy of 3%. The temperature sensor has an accuracy of 0.1 degrees Celsius. A user-friendly device that is affordable to develop and sell may be used by the public to regularly monitor physiological indicators and be installed in primary healthcare facilities in rural and suburban regions to collect patient data. A specialized doctor in urban areas may get the measured data in real-time for advise, and the expert can access the historical data whenever required.

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