A Wearable Solar Powered Jacket for Health Monitoring System

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ABSTRACT–Wearable sensors and electronic devices have gained a lot of attention during the last few years. The advances in low power wearable gadgets have the research venue in the field of energy harvesting to exclude or supplement the battery's power. Solar energy harvesting is a suitable source to power wearable gadgets. This work presents a wearable solar energy harvesting based jacket that can power the in-situ vital health monitoring system (VHMS). This project describes the basic concepts and main components of multimodal sensing information collection, the design and implementation of a health monitoring platform and Internet-of-Things (IoT) based multimodal data sensing and aggregation, and high comfort sustainable physiological signal collection based on smart clinic environment. The feasibility and performance of the Quality-of-Service (QoS) framework proposed in this project are verified by hardware prototype. In this project, to integrate the Solar Energy harvester (SEH) and VHMS, a novel maximum power point tracking is designed, migration learning is used to implement cloud-based user data labelling, continuous conditional fields to identify health based on data collected from smart sensors, respectively, and finally decision layer fusion for medicine prescription prediction. The test results show the suitability of the system for in-home and hospital health management during a pandemic. Its performance compares favourably against various solar energy harvester for wearable sensors based on size, power, modes to communicate and sensors.

Keyword: Wearable sensor, Health monitoring system, Humidity sensor

I. INTRODUCTION

A. Overview

The manufacturing of wearable electronic products is growing fast and capturing the market to provide the monitoring, communication and data analysis capabilities to a human body. These wearable sensors (WS) are worn or attached to human body for directly providing the relevant information on spot or remotely communicated through internet of things (IoT) technology. The WS's collect the physiological data throughout the day which is not easily achievable with the stagnant laboratory equipment. Harvesting from ambient energy sources, almost eradicates the use of battery, which has a limited life span and hazardous to environment. Recently solar energy harvesters are being utilized to operate the wearable sensors and biomedical portable gadgets. Moreover, the combination of solar cells can easily generate reasonable power to operate wearable devices and biomedical sensors or any wearable gadget. The solar cell current is dependent on the illumination (mW/cm2) and the active area of cell. Moreover, the SEH modules are not permanently fixed and can be easily disconnected and disintegrated from the jacket. Even the number of SEH modules can be increased or decreased depending upon the requirement. Additionally, the wearable SEH jacket is completely portable and easy to wear.

The Internet of things (IoT) has become one of the major communication paradigms that is spreading over a different range of applications and provides the possibility of centralized data accessibility and fusion. The users and authorized personnel (e.g. medics and physicians in healthcare) might be able to access data depending on the task's definition for each individual.

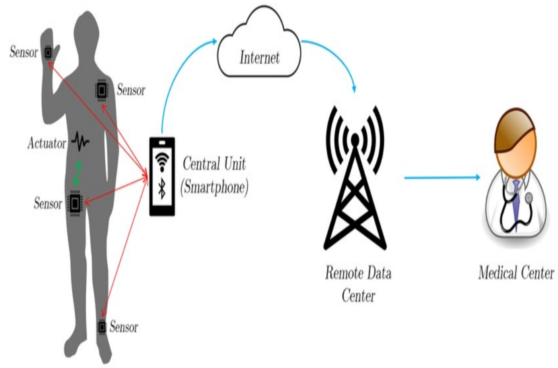

Figure 1 Wireless Body Area Network

This restricted accessibility is important in healthcare due to privacy and confidential data protection. IoT can connect numbers of sensors, vehicles, houses, and appliances, together to the Internet which allows users to share data, information, and resources. This leads to data fusion that can highly contribute to data analysis, accessibility and ease of use in applications. IoT flexibility has caused the development of many new trends for improving data accessibility, higher efficiency of resources usage and data communication between different sources to improve the overall performance of data integrity. This has become possible due to advancing technologies in protocol communication technologies, heavy concentration on the Internet and wide infrastructure usability by users. As a consequence, individuals are more interested in centralized data acquisition and observation to save time and effort. Smart city, smart home, healthcare, and environmental monitoring are important topics that have been adopted within IoT. In particular with rapid urbanization, industrialization and an increasing rate of elderly in European countries, healthcare has become one of the major concerns that have gained much attention in recent years.

Wireless Body Area Networks (WBAN)

A Wireless Body Area Network (WBAN) connects independent nodes (e.g. sensors and actuators) that are situated in the clothes, on the body or under the skin of a person. The network typically expands over the whole human body and the nodes are connected through a wireless communication channel. According to the implementation, these nodes are placed in a star or multihop topology.

A WBAN offers many promising new applications in the area of remote health monitoring, home/health care, medicine, multimedia, sports and many others, all of which make advantage of the unconstrained freedom of movement a WBAN offers. In the medical field, for example, a patient can be equipped with a wireless body area network consisting of sensors that constantly measure specific biological functions, such as temperature, blood pressure, heart rate, electrocardiogram (ECG), respiration, etc. The advantage is that the patient doesn't have to stay in bed, but can move freely across the room and even leave the hospital for a while. This improves the quality of life for the patient and reduces hospital costs. In addition, data collected over a longer period and in the natural environment of the patient, offers more useful information, allowing for a more accurate and sometimes even faster diagnosis.

IoT for Healthcare

Before Internet of Things, patients' interactions with doctors were limited to visits, and tele and text communications. There was no way a doctor or hospitals could monitor patients' health continuously and make recommendations accordingly.

Internet of Things (IoT)-enabled devices have made remote monitoring in the healthcare sector possible, unleashing the potential to keep patients safe and healthy, and empowering physicians to deliver superlative care. It has also increased patient engagement and satisfaction as interactions with doctors have become easier and more efficient. Furthermore, remote monitoring of patient's health helps in reducing the length of hospital stay and prevents re-admissions. IoT also has a major impact on reducing healthcare costs significantly and improving treatment outcomes.

IoT is undoubtedly transforming the healthcare industry by redefining the space of devices and people interaction in delivering healthcare solutions. IoT has applications in healthcare that benefit patients, families, physicians, hospitals and insurance companies.

IoT for Patients - Devices in the form of Wearables like fitness bands and other wirelessly connected devices like blood pressure and heart rate monitoring cuffs, glucometer etc. give patients access to personalized attention. These devices can be tuned to remind calorie count, exercise check, appointments, blood pressure variations and much more.

IoT has changed people's lives, especially elderly patients, by enabling constant tracking of health conditions. This has a major impact on people living alone and their families. On any disturbance or changes in the routine activities of a person, alert mechanism sends signals to family members and concerned health providers.

IoT for Physicians - By using wearable's and other home monitoring equipment embedded with IoT, physicians can keep track of patients' health more effectively. They can track patients' adherence to treatment plans or any need for immediate medical attention. IoT enables healthcare professionals to be more watchful and connect with the patients proactively. Data collected from IoT devices can help physicians identify the best treatment process for patients and reach the expected outcomes.

IoT for Hospitals - Apart from monitoring patients' health, there are many other areas where IoT devices are very useful in hospitals. IoT devices tagged with sensors are used for tracking real time location of medical equipment like wheelchairs, defibrillators, nebulizers, oxygen pumps and other monitoring equipment. Deployment of medical staff at different locations can also be analyzed real time.

The spread of infections is a major concern for patients in hospitals. IoT-enabled hygiene monitoring devices help in preventing patients from getting infected. IoT devices also help in asset management like pharmacy inventory control, and environmental monitoring, for instance, checking refrigerator temperature, and humidity and temperature control.

IoT for Health Insurance Companies – There are numerous opportunities for health insurers with IoT-connected intelligent devices. Insurance companies can leverage data captured through health monitoring devices for their underwriting and claims operations. This data will enable them to detect fraud claims and identify prospects for underwriting. IoT devices bring transparency between insurers and customers in the underwriting, pricing, claims handling, and risk assessment processes. In the light of IoT-captured data-driven decisions in all operation processes, customers will have adequate visibility into underlying thought behind every decision made and process outcomes.

RELATED WORK

Dongxiao G , The aging population and an unhealthy lifestyle have led to a considerable proportion of chronic diseases in many countries. A new generation of emerging technologies has set off a new wave of revolution around the world, such as cloud computing, the Internet of Things, artificial intelligence, and so on. In recent years, the literature associated with chronic disease research driven by emerging technologies has grown rapidly, but a few studies have used bibliometrics and a visualization approach to conduct deep mining and reveal a panorama of this field. This paper is a bibliometric analysis of chronic disease research driven by emerging technologies, and this paper analyzed and visualized the time distribution, space distribution, literature co-citation, and research focus. Moreover, this paper visualized and determined the dynamic knowledge structure of chronic disease research driven by emerging technologies, which will be helpful in understanding the current research status and identifying the future research directions in this research field for e-health and medical informatics scholars.

Yuan-Yao Shih, Wireless body area networks (WBANs) have emerged recently to provide health monitoring for chronic patients. In a WBAN, the patient's smartphone is deemed an appropriate sink to help forward the sensing data to back-end servers. Through a real-world case study, we observe that temporary disconnection between sensors and the associated smartphone can happen frequently due to postural changes, causing a significant amount of data to be lost forever. In this paper, we propose a scheme to parasitize the data in surrounding Wi-Fi networks whenever temporary disconnection occurs. Specifically, we model data parasitizing as an optimization problem, with the objective of maximizing the system lifetime without any data loss. Then, an optimal offline algorithm to solve the problem is proposed, as well as an online algorithm that allows practical implementations. To evaluate the scheme, we conduct a series of experiments with the prototype system in controlled and real-world environments. The results show that the lifetime is prolonged by 100 times, and it could be further doubled if the health monitoring application permits a few packet losses..

Joel J. P. C. Rodrigues, The Internet of Things (IoT) is one of the most promising technologies for the near future. Healthcare and well-being will receive great benefits with the evolution of this technology. This paper presents a review of techniques based on IoT for healthcare and ambient-assisted living, defined as the Internet of Health Things (IoHT), based on the most recent publications and products available in the market from industry for this segment. Also, this paper identifies the technological advances made so far, analyzing the challenges to be overcome and provides an approach of future trends. Through selected works, it is possible to notice that further studies are important to improve current techniques and that novel concept and technologies of IoHT are needed to overcome the identified challenges. The presented results aim to serve as a source of information for healthcare providers, researchers, technology specialists, and the general population to improve the IoHT.

Juan Botero-valencia, The measurement of environmental variables has become a daily problem in recent years. However, the equipment commonly used for these measurements is expensive and bulky, and therefore, it is not possible to have enough spatial resolution. In addition, many of the measurement methods do not provide real-time information to deliver to citizens in a timely manner. In some works, these issues have been handled through the deployment of wireless sensor networks based on low cost technologies. The improvement of the spatial and temporal resolution implies the increase in the amount of information to be transmitted and stored. For this reason, this paper presented a method for data reduction through a dynamic subsampling of the measured variable, data fusion from several sensors for the same variable, and data scaling taking into account the variables range. The reduction of data is implemented to save energy, reduce the transmission time, keep the channel available, and save storage space. The method is validated using a low-cost monitoring station that combines environmental, particulate matter (PM), gas, electromagnetic radiation, and inertial sensors to be transmitted in a 50-byte reduced packet using an LoRa network. The subsampling adjustment was developed for the PM signal. The results show a reduction in the volume of stored data and the relevant information is not affected. The transmitted data packet can be reduced from 96 to 50 bytes, and sampling can be reduced to 4% of the original sampling without affecting the trend of the PM information

Fei Tao Smart manufacturing is increasingly becoming the common goals of various national strategies. Smart interconnection is one of the most important issues for implementing smart manufacturing. However, Current solutions are not yet ready to realize smart interconnection in dealing with heterogeneous equipment, quick configuration and deployment, online service generation. To solve the issues, industrial Internet-of-Things hub (IIHub) is proposed, which consists of customized access module (CA-Module), access hub (A-Hub) and local service pool (LSP). A set of flexible CA-Modules can be configured or programed to connect heterogeneous physical manufacturing resources (PMRs). Besides, the IIHub supports manufacturing services online generation based on the service encapsulation templates, and supports quick configuration and deployment for smart interconnection. Furthermore, related smart analysis and precise management have the potential to be achieved. Finally, a case study is given to illustrate the functions of the proposed IIHub, and to show how IIHub realizes smart interconnection.

METHODOLOGY

A. Proposed Method

Recent years have seen a rising interest in wearable sensors and today several devices are commercially available for personal health care, fitness, and activity awareness. In addition to the niche recreational fitness arena catered to by current devices, researchers have also considered applications of such technologies in clinical applications in remote health monitoring systems for long term recording, management and clinical access to patient’s physiological information.

- In this project develop a IoT based solution for comprehensive measurement of ambient, physiological, and behavioural (partially) parameters by a convenient mode of wearability,
- Combine, synchronize, and process the physiological and ambient parameters for medical investigation on the parameter's interactions. This includes data visualization on the server as well
- Introduce and develop an innovative prototype for ambient monitoring
- Develop a flexible IoT-gateway, that can adopt different commercial products for measuring the physiological parameters. In such way, different users/patients owning products can use this solution, and the platform is not restricted to only specific vendors,
- Establish an end-to-end communication between the user and medics in real-time, for necessary recommendations to user
- Design a solution for everyone in every working class. Due to flexible IoT-gateway and end-to-end communication, the medics are given the possibility to define tasks, set up, and configure the measuring parameters for each person, particularly via activating/deactivating target sensors and parameters..

B. Proposed Block Diagram

As shown in figure 1, the developed self-powered wearable jacket is composed of three subsystems, comprising of a vital health monitoring system (VHMS), power management circuit and a solar energy harvesting unit. VHMS include of sensors and transmission modules (figure 1(a)). Initially, human oxygen level, blood pressure, pulse rate and temperature data are collected and transmitted through Bluetooth, GSM and Wi-Fi modules. Furthermore, VHMS is integrated to a power management circuit which has a potential even to route low voltage energy during diffused light. The power management circuit comprise of a dc-to-dc boost and dc-to-dc buck converter. During day light, dc-to-dc buck converter will regulate high voltage produced by a SEH and an ultra-low voltage produced by a solar energy harvester is amplified by dc to-dc boost converter to compensate a rechargeable battery during diffused light. The entire circuitry is powered by a wearable SEH. A SEH includes ten solar cells inserted inside stitched transparent pouches, where the solar cells can be connected in series/parallel depending upon the requirement of the system.

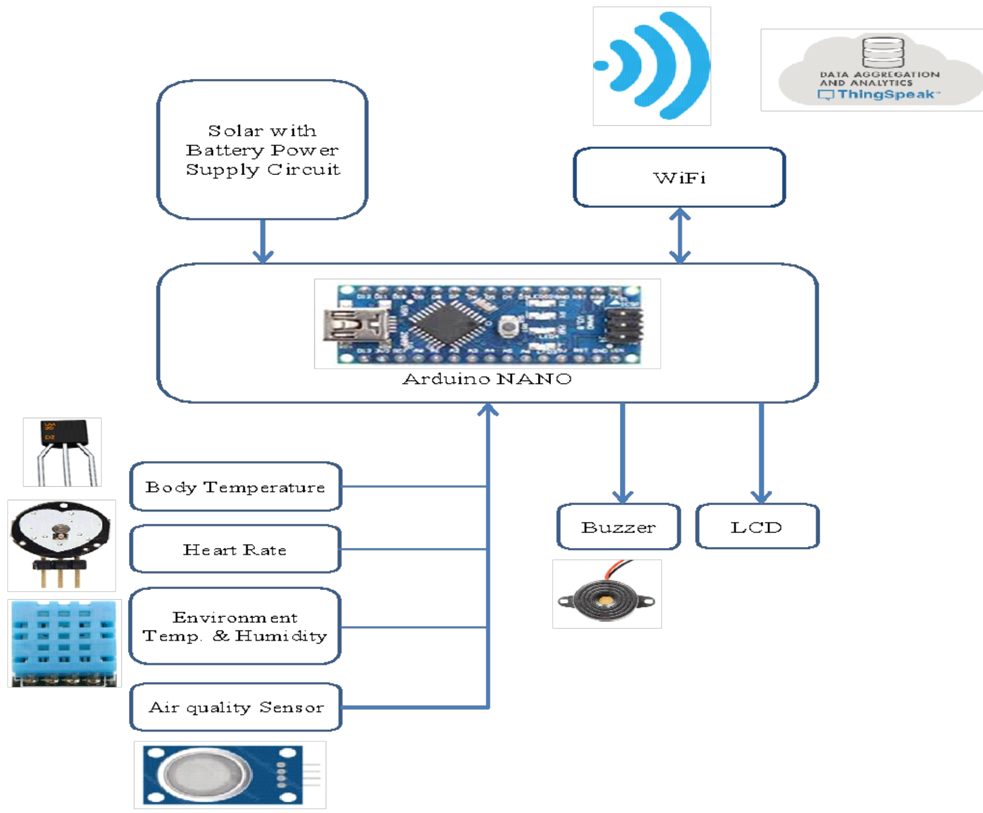

Figure 2 Proposed Block Diagram

The VHMS on the jacket is consisted of an Arduino (nano nodemcu) interfaced with a Wi-Fi module, Bluetooth module (HC-05), GSM900 module, SpO2 sensor (MAX30102), temperature sensor (Thermistor 10k), pulse sensor (MAX30102) and accelerometer (ADXL335). Sensors' data is transferred every 3 min through Wi-Fi and GSM module to mobile phone and laptop. A Wi-Fi module transfers data both to computer and mobile phone whereas, GSM module is communicating through a mobile phone. In case of an emergency, if the pulse, oxygen saturation or temperature reading is not in a normal range, an emergency message is to be sent to a mobile phone and laptop.

The total power consumption

$$P_t = P_{alot} + P_a + P_{gwb} \quad (1)$$

Of the developed VHMS prototype can be estimated from the power consumption of accelerometer, LCD display, oximeter, pulse rate sensor and thermistor P_{alot} ; power requirement of Arduino P_a; and the power consumption of GSM module, Wi-Fi module, and Bluetooth module P_{gwb}.

In the VHMS all modules are dynamic and are defined by the duty cycle activity between operation modes and sleep mode. After every 3 min, these modules wakeup into active mode to retrieve data from sensors and transmit the information to smart phone, laptop, web and mobile application.

Since, the wakeup mode of GSM module occurs after every 3 min, while the wakeup time T_{ws} = 3 sec (for every sleep mode time, T = 3 min), therefore the duty cycle

$D = T / T_{ws} = 0.0167$

Can be used to compute the wakeup current of GSM, Wi-Fi and Bluetooth modules by multiplying it with a transmission module current and is further added to the sleep mode current for the total current consumed by each module. The total current consumed by the modules is when multiplied by the operating voltage, the total power

$$P_{gwb} = P_g + P_w + P_b \quad (2)$$

Consumed by the GSM, Bluetooth and Wi-Fi modules can be estimated.

Calculates the power consumption of modules which is P_{gwb} = 68.22mW for equation (2) and the total power, P_t consumed is P_t = 91.826 mW.

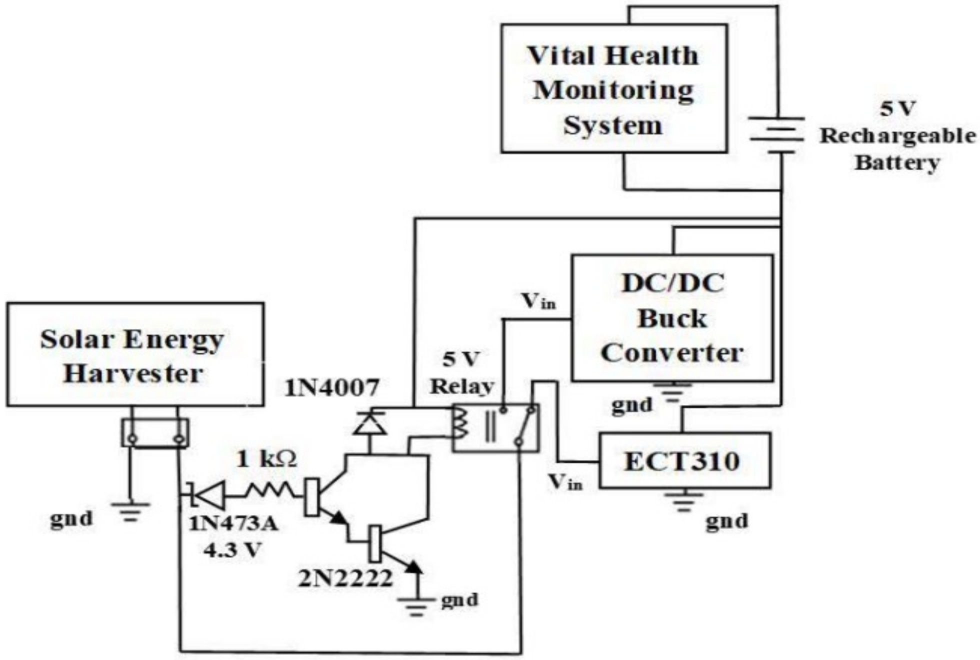

Figure 3: Power management circuit

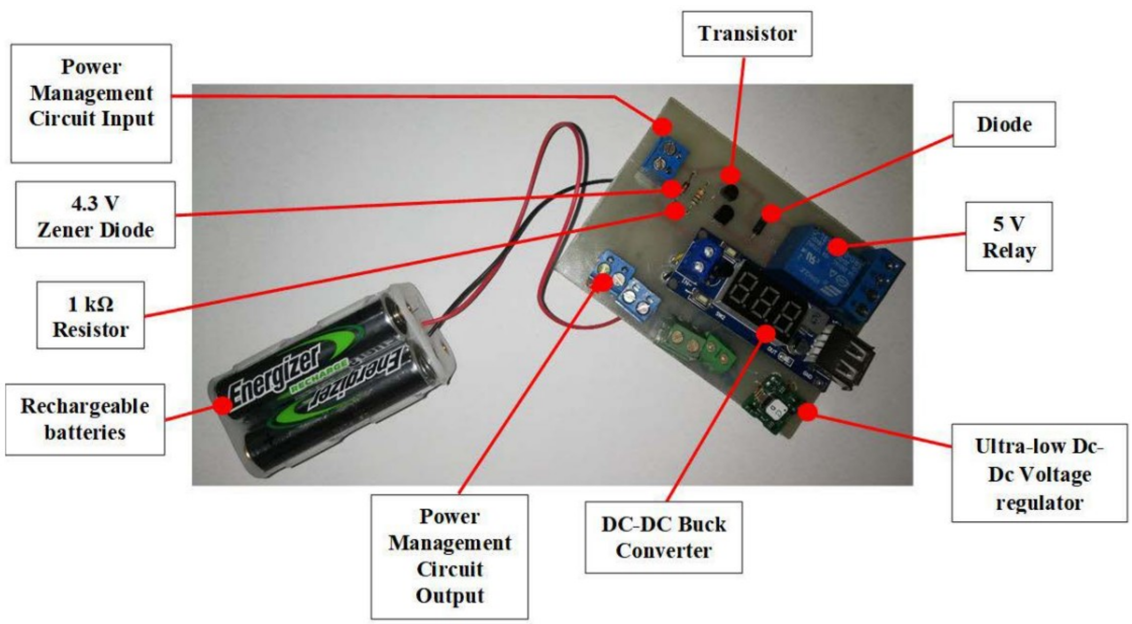

Figure 4 Maximum Power Point Tracking Circuit(MPPT) including buck and boost converter and control circuit.

The design of the devised maximum power point tracking (MPPT) with buck and boost converter is based on two different circuit chips, namely the DC-DC buck converter (YS-04) and an ultra-low-voltage boost converter (ECT310). Both Integrated Circuit (IC) chips are power management circuits. The ECT310 has acceptable extreme low input voltage (as low as 20 mV). As diffused light intensity energy is usually wasted, however, with the integration of ECT310 in the VHMS, the diffused light can also be harvested for use. A schematic and a photograph of the developed prototype MPPT can be seen in figure 3 and figure 4 respectively,

EXPERIMENTAL RESULTS

A low-cost and lightweight IoT node to monitor continually a person's body temperature, heart rate, and environment oxygen saturation, and periodically monitor climate patterns; A smartphone app to display the parameters and individual risk factors; A physical distance tracking mechanism using Bluetooth 4.0 technology to alert the user in case of violation of safe physical distance; and A fog server that collects data from the IoT nodes and applies a machine learning algorithm to send the necessary information to users. IoT based devices can exchange information with each other and are uniquely addressed and identifiable anytime and anywhere using the Internet. Remote health monitoring systems using IoT based devices can automatically exchange information with health institutes through the Internet. his work presents a wearable solar energy harvesting based jacket that can power the in-situ vital health monitoring system (VHMS). The developed VHMS comprised of sensors to measure several data and transferred through various Modules every 3 min with an emergency alert option. To integrate the Solar Energy harvester (SEH) and VHMS, a novel maximum power point tracking is designed.

In this project, A low-cost and lightweight IoT based continually a person's body temperature, heart rate, and environment oxygen saturation, and periodically monitor climate patterns; A solar based smart device to display the parameters and individual risk factors also send the data to IoT Cloud; The proposed solar based device can power pulse sensor, oxygen saturation sensor, temperature sensor and environment monitoring data is fetched and then transferred to web database through Wi-Fi, module. Both Vital health monitoring system design and overall maximum power point tracking (MPPT) design are crucial in order to achieve robust and power efficient device.

CONCLUSION

The proposed smart health monitoring system provides ease to the doctors to identify the patients' information individually simply on the display monitor at their place. Doctors can distinguish the data of the particular patient regarding previous values with the present one. Along with data logging on the cloud, the Internet of things also provides opportunities to add more advanced features or benefits and more biomedical sensors to this system. Therefore, the technology of IoT makes this monitoring system more flexible and more updatable in future. This paper presents a low cost and convenient patient vital sign monitoring solution for low-resource settings. The important vital signs are accurately measured, converted to clinical values, displayed on a centralized screen and web server using wireless communication system through the WiFi networks or dedicated wireless IoT devices. Due to the scarcity of specialized doctors and pandemic travel restrictions, especially for the elderly, in-home healthcare and symptom management would provide the next generation of healthcare support.

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