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WBAN-based remote monitoring system utilising machine learning for healthcare services

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Abstract: The field of wireless sensor networks has grown significantly due to notable research contributions in the domain of wireless networks and semiconductors. It has been noted in the recent past that WBANs significantly support a range of pervasive medical and healthcare applications. A wireless body area network (WBAN) is a task-oriented, self-organising sensor network and is an interconnection of a multitude of biomarker sensors and medical diagnostic gadgets. These backbone nodes may be embedded in the human body or planted on the human body. In this paper, we proposed a secured WBAN-based system for healthcare facilities. This model will help patients and medical professionals monitor the health of patients at any time despite their physical presence. It also discusses the utilisation of a machine learning based cloud system which keeps learning from new data sets and remains updated about new symptoms.

Keywords: wearable wireless body area network; healthcare; machine learning; cloud database; wearable devices; EHR; electronic health record; telemedicine.

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Biographical notes: Sonali Vyas is serving as an academician and researcher for more than a decade. Currently, she is working as Assistant Professor (Selection Grade) at University of Petroleum and Energy Studies, Uttarakhand. She has been awarded as "National Distinguished Educator Award 2021", instituted by the "International Institute of Organized Research (I2OR) which is a registered MSME, Government of India". Also awarded as "Best Academician of the Year Award (Female)" in "Global Education and Corporate Leadership Awards (GECL-2018)". Her research interest includes healthcare informatics, blockchain, database virtualisation, data mining, and big data Analytics. She has authored the ample number of research papers, articles and chapters in refereed journals/conference proceedings and books.

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1 Introduction

Wearable wireless body area network (WBAN) which is configured to fulfil needs of applications that take care of health and well-being, presents tangible cost saving and non-invasive options to both healthcare workers and remotely located patients. A WBAN system can offer the following advantages compared to current systems based on online patient monitoring.

- a The pervasiveness of usage by remote and mobile patients as the device portability is of essence and value.
- b Independence of monitoring facility in view of portability of a wearable system, which with elementary training of patients and on field staff of healthcare departments can be affected for the specific tasks.

A WBAN node being an autonomous device is capable to search a communication network of choice for data dissemination to remote cloud storage and servers for necessary processing. The promise of non-invasiveness is met by the fact that autonomous WBAN node shall automatically connect to internet for data transmission to generate lean feedback for helping the user to diagnose and generate a prognosis.

The healthcare sector over a period of time has looked forward to ICT adoption for administering healthcare services for variety of services that national and local health departments have set out to offer in view of PMJAY for 50 billion potential beneficiaries in India. Wearable WBAN based data driven ICT biomarker feedback monitors will be able to deliver healthcare to patients in hospitals and Community health centres and pervasively in their homes and workplaces. These solutions provide a cost effective and convenient interfaces for providing ease of living and thereby promising better standard of living for target beneficiaries of PMJAY.

A WBAN normally encompasses a multitude of miniature sensor nodes and a separate in-proximity gateway node, which is responsible for connecting to the database server process instance on Private and Secure Cloud. The Gateway node implanted on mobile device will provide an interface of connection between sensor node aggregate and available telecom networks in vicinity of patient. The communication network can be a standard PSTN, GSM based 3G/4G network, a wired/wireless network that serves needs of a dedicated public medical care utility/ local hospital or it can be even a public WLAN or Wi-Fi hotspot. The user will have provision to store her own health data in form a HER on their PDA/Mobile phone handset or Cloud storage for reuse or verifiability with locally available medical personnel or pathology labs/diagnosis centres. The user at their discretion can transfer the data to said utilities/centres/individuals who use the same framework for providing services. In near future a variety of applications that utilise the concept of WBAN to improve the healthcare and sports training facilities

are expected to show up on horizon. In last few years a lot of attention has been given to issues of WBAN for healthcare by researchers in domain of WSN, ML and ICT in general. The ICT systems that are being already used for medical care are limited in the application area they can be used for, and are mostly standalone system doing a single task. Additionally, these systems are location dependent and not portable due to nature of the device, dependency on handling staff or harsh terrain where patients are residing. WBAN applications can also be mass used while imparting trainings in sports to the athletes for better body management of athletes, whereby athletes are reported of deficiency in their bio parameters so that a corrective action can be initiated in time and chance of injury can be minimised.

2 Literature review

Nowadays a wearable technology became three times in the last five years, people are moving to wear fitness devices like smartwatches, and fitness bands. These devices help the consumer to give the health record of personnel. In the US market, the consumption of wearable devices moves from 9% in 2014 to 58% in 2021, according to an Accenture survey report. These devices help in monitoring and reporting the record of user health. In the Covid-19 situation, the demand for these is increasing day by day to check their health records.

The wearable technology will be embedded with a telemedicine approach that helps the user and doctor to communicate the information. In Covid -19 both telemedicine and wearable, instruments come in demand for the healthcare sector. Some of the points are listed below.

Telemedicine and wearable technology already proved their existence worldwide in pandemic situations like COVID-19. This technology and various available platforms were required for remote guidance when physical presence for doctors and patients is not possible. Some of the most popular Web/Mobile based Telemedicine systems used worldwide are given below.

- 1 Teladoc (US)
- 2 Doctoroo (Australia)
- 3 Livi (UK)
- 4 Practo (India)
- 5 WhiteCoat (Singapore) and many more

In 2018 the market size of Telemedicine was USD 34.28 billion. It has been projected in a survey that it will be USD 185.66 billion by 2025, having a CAGR of 23.5% in the predicted timeline. As per Telehealth Index (2019) by American Well's, 350,000 – 595,000 US physicians will be active on Telehealth technology by 2022. As per the survey of American Well's, the following points were identified:

- 1 77% efficient use of the time of Doctors and Patients
- 2 Reduced healthcare cost by 71%

- 3 71% effective communication between doctor and patients
- 4 60% enhancement in Doctor and Patient relation.

If we can implement and embed both technology it will create great help in users to communicate with nearby doctors. The Augmented reality gives the touch to experience the physical mode of presence of doctor and patient to give prescription and treatment.

In some research in Iqbal et al. (2021) give highlights on advancement in healthcare wearable devices. They give a review on how wearable devices are used in monitoring and diagnosis of diseases. The author discusses the limitation and how we remove in future for the same.

Lee and Lee (2020) give the analysis of the key factor for healthcare devices. They observed the effect on behaviour of user based on internal and external factors to improve the health and intension to wear the devices The author gives the practical and theoretical inferences about how the wearable devices is helpful for the prevention of the diseases.

In the Year 2021 Aleksandr et al. give a broad survey on wearable technology. The author contributes the survey on wearable devices based on the factor of communication technology, its processing and the status of the market. They provide the challenges and some solutions that help the user in future for adopting this technology.

In India, before COVID-19 Pandemic, Online education in Schools and work from home (WFH) was considered a Myth, and society believe that these activities are not possible without face-to-face interaction. In the same way, Telemedicine and health-based wearable devices are also considered impossible processes. Most health service providers and patients considered that Telemedicine is also a myth in the healthcare sector. However, Digital India Mission started a few years back, this association helped in the corona-virus situation and proved that Telemedicine and Wearable devices are not a myth and it played a phenomenal role in bridging some of the pain of the lockdown. Doctors are consulting patients on Mobile apps/ Phone Calls. Govt. of India has also started web portals for Telemedicine services (e.g., <https://esanjeevaniopd.in/>, <https://ehospital.gov.in/>). The citizens of India are using these facilities and getting the consultancy at their homes by good doctors across India. The implanted approach of wearable device with telemedicine provides a user with knowledge of their report and health at a moment, and if they want, they easily connect with their nearby doctor in a secured environment.

Many Indian researchers give their views on wearable devices and the telemedicine approach, some of them are working on the security of telemedicine. The following work is based on the security implementation of telemedicine with WBAN. Hu et al. (2017) took Chaudhary's scheme as a case study. They demonstrated that the bouquet of schemes based on two-factor authentication is not appropriate for TMIS as they do not succeed to withstand offline dictionary attacks and offer valid smart card revocation facilities. They also presented an improved scheme to protect users' privacy by preserving the anonymity of the user. It can be seen from the literature review, that most of the proposed user authentication and key agreement schemes for accessing TMIS (whether single or multiple) are not still fully developed to be completely free from security shortcomings. Therefore, there is a strong need to develop a secure and efficient user authentication and key agreement scheme for the TMIS system. Jebrane et al. (2018) proposed a new real-time telemedicine approach using elliptic curve cryptography (ECC) and differ, Hellman, for secure communication between doctors and patients. Author use voice-over IP protocol based on an elliptic curve to provide security. In the year 2021

Mehedi et al. proposed a robust and secure access scheme for cloud-based e- healthcare, where doctors remotely diagnose the patient. The author uses the scheme of multiple keys using the key derivation function for end-to-end encryption and privacy.

3 Proposed architecture for WBAN enabled healthcare system

Wireless body area network helps in integrating smart sensor nodes whether invasive or non-invasive, over human body for constant monitoring of health. Such sensor-based system helps in tracking the health of a person and provides better medical services when required. Facilities like healthcare monitoring, wearable tracking devices, medical data access and communicating with caregiver or doctor in emergency (Taiwo and Ezugwu, 2020). Future of healthcare is promised by use of WBAN having potential of:

- low budget and wireless mini-size sensor nodes
- methods for optimising energy
- security of data
- integration of transmission technique with WBANs
- reliable data storage.

Nowadays, there's increasing requirement of smart healthcare services such as remote patient monitoring systems, e-consultations, m-health, telemedicine, electronic health record (EHR) etc. These smart healthcare services are utilised for better monitoring, predictions and diagnosis (El-Rashidy et al., 2021).

We are proposing a secured WBAN based system for healthcare services which will help patients to accomplish their daily chores while their vitals are continuously monitored and also aids medical staff/doctors to keep track of patient's health anytime despite of their physical presence. It will also reduce pointless visits to hospitals or clinics thus saving time and cost. It will provide e-consultation and nearby doctor details to the patient as and when required. It will also provide measures to secure data flow over cloud and storage.

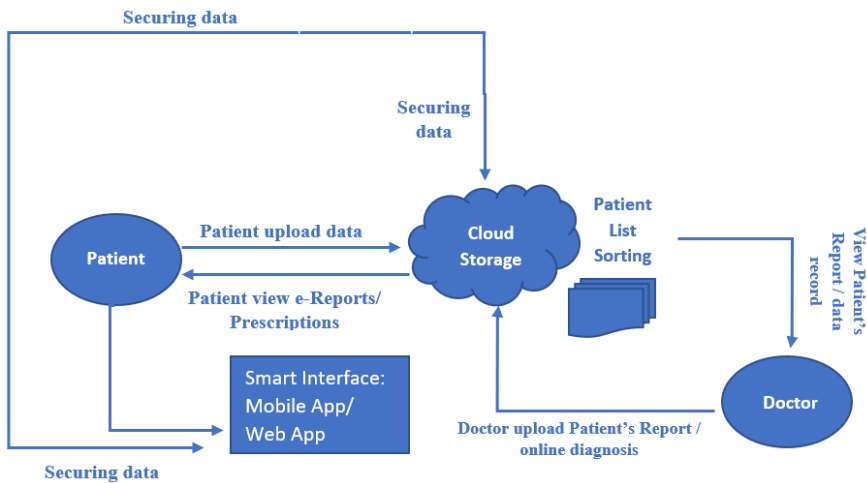
The main objective is to build a secure WBAN based system for providing healthcare services such as:

- 1 providing remote patient monitoring (by wearable device)
- 2 smart interface for e-consultation on the basis of symptoms
- 3 suggestions for nearby medical facilities/doctors (GPS locations)
- 4 machine learning model deployment for smart suggestions
- 5 information security.

In the proposed architecture (as shown in Figure 1), WBAN will be implemented by wearable and implantable sensor nodes on patient's body in order to monitor health related parameters in daily activities. These nodes will transform physical biometrics like pulse rate into electrical signals. This data related to patient's health will be stored in cloud database which can be accessible by medical staff/ services anywhere and anytime. On the basis of data gathered from WBAN nodes, the health condition of a patient is

determined and related feedback will be provided through a reliable user-friendly smart interface. So, a smart user interface will be developed by implementing machine learning algorithms for accessing the data related to health of patient securely by authorised person. This interface will also provide patient e-consultation or suggestions based on daily monitoring of their health and symptoms. It will provide information regarding nearby medical services and doctors available for fast communication. This interface will also generate alarms/ notifications in case of emergency. It will also have facility of chatbot for easy troubleshooting and communication facility. This will help in saving time and cost-effective solution for patients. They will feel more connected to the medical staff anywhere and anytime. Above all, this will be a secure system as it will follow security standards like verification and validation at patient level as well as doctor's level. This interface will be platform-independent, making it accessible on any device.

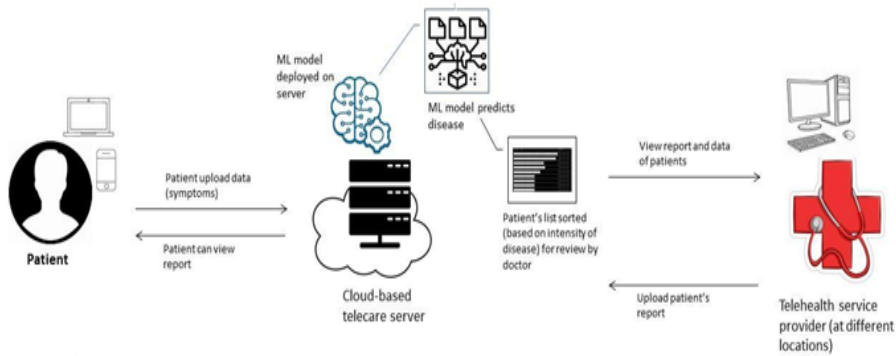
Figure 1 Proposed architecture for WBAN enabled healthcare system (see online version for colours)



This architecture will be based on client-server technology and make use of cloud databases to maintain EHR of patient and Smart user interface will be developed in python with Machine Learning algorithms for giving e-suggestions and predictions to the patient based on their daily monitoring of health.

The cloud-based telecare server has a Machine Learning model deployed on it, which is trained using previous patient data. This model is trained to predict disease and its severances, based on symptoms. Continual learning can be applied to this ML model so that it keeps learning from new datasets and remains updated about new symptoms.

Figure 2 shows a cloud-based telecare server with the implementation of a machine-learning model. The patient query in form of data is stored in the cloud server and the prescription is based on the received data. The ML techniques help future patients to detect the symptoms and prescribed the report based on the learning of the stored database. These techniques help to solve the query raised by the user.

Figure 2 Cloud-based telecare server with ML model (see online version for colours)

4 Benefits of cloud-Based telecare server with ml model (Iqbal et al., 2022)

- *Security and privacy:* The protection of customer personal data in online services is supported and regulated by the CSF HITRUST Alliance industry standard, the US Health Insurance Portability and Accountability Act (HIPAA) and the European GDPR.
- *Collaborative approach:* With the implementation of cloud-based ML model for telecare it becomes easy to collaborate with medical staff and patient. This enables easy distribution of medical data and test reports from anyplace, accelerating a cooperative approach to improvising patient's health.
- *Data management and storage:* With the failure of manual methods to handling patients' health records in clinics, healthcare specialists have quickly accepted EHRs as it permits better management of data records across all medical centres. As we are in ever evolving digital era, cloud computing enables the distribution of EHRs in the cloud server where healthcare experts can have accessibility of EHRs and make necessary update in a timely manner.
- *Scalability:* As we know that cloud computing elements can dynamically scale as needed to meet computing needs. The rise of medical and healthcare IoT devices can dramatically increase the amount of data a healthcare company uses. As the amount of data and types of data increases, so does the complexity of what can be analysed and the number of possible correlations. Cloud medical systems are designed to reduce data management costs. In addition, many healthcare organisations dealing with cloud services have taken advantage of the pay-as-you-go model. This allows them to embrace the rapidly changing digital transformation at their own pace.
- *Cost-friendly:* As the modern cloud computing services with aid of ML operates on flexible models, healthcare benefactors can save expenses on exclusive systems and toolkits. Further resiliency can be guaranteed by adoption of a devoted cloud-server with definite predefined functions.

- *Automated real-time analytics*: Converging ML with cloud-based telecare model provides automated real-time analytics which is built on AI procedures. Given the workload of healthcare experts, these competences can be perilous to support the management of huge databases, medical decision-making and abbreviated treatment times.

5 Conclusion

With major advances in wireless technology and the advent of 5G technology, the growth of the WBAN has accelerated to improve the quality of human life. This paper discusses an architecture which will provide an easy-to-use platform for patients to communicate to medical staff and doctors virtually in real time. It will facilitate users to avail clinical services at their feasible time and place. With the advent of ML model, it will also help medical professionals and patients to get smart prescriptions at fast speed and with accuracy. The proposed cloud-based ML model will help in predicting diseases and its impact. Moreover, the continuous learning approach will help in updating new symptoms and enhancing efficiency of the results. In future we will implement this model in real time data and also compare results with existing system.

This system can also be enhanced for securing data at both patient and doctor levels. As we are moving towards the era of healthcare 5.0, many new trends and immersive technologies can be developed like implementing robots-enabled medical services and AR/VR enabled disease diagnosis. The utilisation of metaverse concepts for remote care of elderly and disabled patients can also be explored in enhancing the medical facilities.

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