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RESEARCH ARTICLE

Improved QoS Aware Routing Protocol (IM-QRP) for WBAN Based Healthcare Monitoring System

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ABSTRACT Wireless Body Area Network (WBAN) is a special purpose wireless sensors network designed to connect various self-autonomous medical sensors and appliances located inside and outside of human body. Interests in human Healthcare Monitoring System (HMS) are based on WBAN due to the increasing aging population and chronically ill patients at home. HMS is expected to reduce healthcare expenses by enabling the continuous monitoring of patient's health remotely in daily life activities. This research focuses on routing protocols in WBAN. The major problems in routing protocols are maximum energy consumption, path loss ratio, packet delivery ratio and maintaining stable signal to noise ratio. Real time analysis is required in HMS to support the patients through doctors, caregivers and hospital systems. Collected data is relayed by using existing wireless communication schemes towards the access point for further retransmission and processing. In this research, an Improved Quality of Service aware Routing Protocol (IM-QRP) is proposed for WBAN based HMS to remotely monitor the elderly people or chronically ill patients in hospitals and residential environments. The proposed protocol is capable to improve 10% residual energy, 30% reduction in path loss ratio, 10% improvement in packet transmission (link reliability) and 7% improvement in SNR as compared to existing CO-LEEBA and QPRD routing protocols. Convolutional Neural Network is used outside the WBAN environment to analyze the medical health records for healthcare diagnosis and intelligent decision-making.

INDEX TERMS Wireless body area networks, quality of service, energy-efficiency, received signal strength intensity, signal to noise ratio, path loss ratio, convolutional neural networks.

I. INTRODUCTION

Wireless Body Area Network (WBAN) is one of the major applications of Wireless Sensor Networks (WSNs), used for remote health monitoring and is adopted by individuals in daily life activities. WBAN consists of wearable and implantable sensors nodes mounted on the human body. The medical sensors work independently, compute various physiological conditions of patients and communicate to external server for medical analysis and intelligent decision-making [1]. The traditional healthcare method is reimagined in WBAN by the healthcare applications that incorporate implanted sensors to collect physiological data [2]. The various human physical parameters that are retrieved, computed and stored include pulse and heartbeat rate, respiratory rate, glucose levels, body temperature, blood pressure level, and postural body movements [3]. The parameters collected through sensor nodes are samples that are wirelessly transmitted to sink/base station for analysis and computing or processing [4], [5]. These sensor nodes constantly monitor the physiological body parameters and sensed data is analyzed for optimum level. If any of the parameters are out of the normal range, these sensor nodes are capable to send an alert message by using analog signal [6]. The WBAN medical

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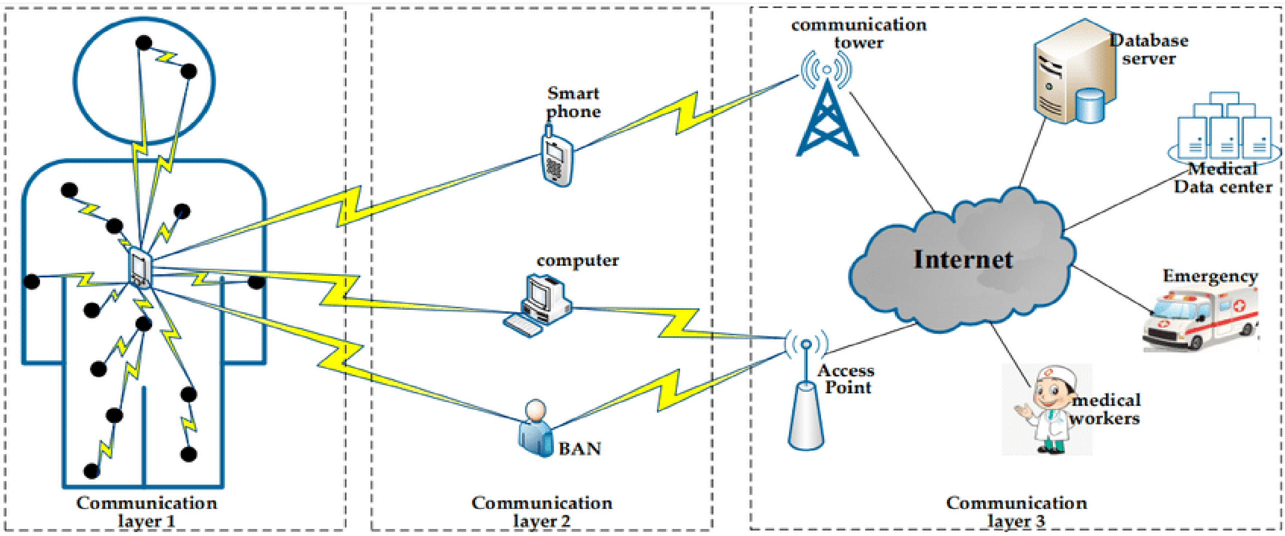

FIGURE 1. A 3-tier WBAN architecture [21].

sensors "on the patient body" actually establish wireless links [7].

WBAN reduces the need for caregivers and help the elderly and chronically ill patients to live their life with quality care [8]. WBAN can improve the patient health conditions through tracking [9] and by providing effective and quality healthcare procedures and services [8] including the control of home appliances inside the smart homes. Moreover, also plays role in accessing remote patient medical data and emergency communication in case of critical situation [10]. Continuous monitoring of the health status of a patient by using wearable and implanted sensor nodes will increase early detection of diseases in patients who are at risk and provide a wide range of healthcare services for chronically ill patients at home or hospitals [11]. WBAN technology provides better ways to monitor the health of patients in real time [12] and it's a cost effective solution [13]. Healthcare systems are not only limited to elderly and chronically ill patients; rather working men or women can get the benefit for their babies lying at home. To realize the communication between sensor nodes, routing protocols from WSN are not always applicable for WBAN [14]. A debate on different WBAN routing protocols is presented in [15]. Sensor nodes are placed over clothes or directly on the body, or implanted in tissue, that can facilitate measurement of blood pressure, heart rate, blood glucose, ECG and respiration rate. The WBAN applications for smart home are classified as wearable WBAN, Implantable WBAN and Remote Health Monitoring. In wearable WBAN there is real-time health monitoring, the mobile phone of a diabetic patient can detect the glucose levels and transmit the information to the doctor for analysis. In Implantable WBAN Sensor nodes are implanted inside the human body tissues for real-time healthcare monitoring. In Remote health care monitoring the WBAN is connected to the hospitals and doctors over the internet to monitor health condition of a patient, thus reducing the dependency of patients for multiple visits at hospitals. Energy efficiency is a key parameter of different healthcare systems in WBAN [16], [17]. Optimal path finding, in order to disseminate emergency response, is a significant point to consider [18].

The communication in WBAN is classified into two subtypes, Intra body communication and Extra body communication [4]. Intra body communication allows the sensor nodes to communicate with each other on human body. Extra body communication allows sensor nodes mounted on human body to communicate with external outside environments for example access points, base stations or internet. The three most frequently used layers in architectural design of WBAN are Intra WBAN, Inter WBAN and Beyond WBAN [19]. Multi-tier architecture of WBAN for healthcare systems is shown in Figure 1. The 3-tier architecture consists of intra-body sensor network communication module referred as Tier-1. Tier-1 consists of sensor nodes deployed on the human body like ECG sensors, ear sensors, blood pressure sensors, EMG sensors and body motion sensors. Tier-2 consists of inter body sensor network communication module referred to as access point. This module is responsible to receive the health status information from Tier1 and routes this information to Tier 2. Tier 3 consists of beyond body network communication-based infrastructure. This module is responsible for transferring data from Tier 2 (access point) to Tier 3. Tier 3 is responsible for providing wireless healthcare services by using internet [4]. Tier 3 also consists of data management unit for analysis and intelligent decision-making by doctors and emergency rescue staff at hospital [20].

The sensors deployed on the human body are intelligent enough for sensing, processing and hold storage capability. Due to this reason, mostly senor nodes used in medical applications consist of microprocessor module, RF module and memory module. IEEE 802.15.4 wireless standard is adopted as a radio communication infrastructure between the body sensor nodes. In view of physical layer different energy efficient MAC protocols are designed to save energy and to improve the network lifetime. The radio technologies used in modern healthcare systems are Bluetooth, Wi-Fi, Zigbee, RFID, IEEE 802.1.5.6, IEEE 802.15.4 and IEEE 802.15.6.

Communication protocols are specially designed for WBAN. WBAN medical applications improve the performance reliability by patients' remote healthcare monitoring using wireless network like cellular or internet. Generic body sensors are used as an input for data processing. The optimized performance of WSNs is key requirement in healthcare systems [22], [23]. Bio feedback sensors are used for monitoring heart function, muscle activity and brainwaves. Power consumption factor in case of wireless sensor nodes is an important factor to consider. The parameters such as reliability, latency, security should also be considered especially in prototype development [5].

Providers can benefit from artificial intelligence across a range of patient care and intelligent health systems in WBAN. For the diagnosis of diseases, the development of new drugs, and the identification of patient risk factors, artificial intelligence techniques ranging from machine learning to deep learning are widely used in healthcare. To accurately detect diseases using artificial intelligence approaches, a variety of medical data sources, including ultrasound, magnetic resonance imaging, mammography, genomics, computed tomography scans, etc., are needed. Additionally, artificial intelligence primarily improved hospital visits and accelerated the process of getting patients ready to continue their recovery at home [76].

Deep learning models are effective at picking up the characteristics needed to precisely grasp complicated patterns. This work presented a deep learning-based classification system for skin diseases using MobileNet V2 and long short-term memory (LSTM). The MobileNet V2 model, which can run on portable computing devices, has shown to be effective and accurate. The suggested model is effective at preserving stateful data for accurate predictions. The progression of sick growth is evaluated using a grey-level co-occurrence matrix. The effectiveness of the model has been compared to various cutting-edge models, including convolutional neural networks (CNN), very deep convolutional networks for large-scale image recognition developed by Visual Geometry Group (VGG), and fine-tuned neural networks (FTNN) [77].

The selection of features is regarded as a significant stage in data preprocessing in machine learning and data science. Sometimes we find that the learning algorithms do not work well when we apply the raw data directly for classification or clustering purposes. The datasets' inclusion of redundant, noisy, and uninformative characteristics or attributes is one potential cause for this. In order to find the subset of pertinent features that can improve the performance of the model, feature selection techniques are applied. Additionally, the model's training time and storage requirements can be decreased due to the reduction in feature dimension. The authors of this study provide a three-stage architecture for feature selection based on wrapper filters for the goal of detecting diseases from medical reports using machine learning [78].

In this study, automatic segmentation of CT scan images is carried out in order to find abnormalities in the human liver. This research makes use of the computationally effective AW-HARIS algorithm. Contrary to supervisory processes that require a significant amount of computational work for training, the proposed approach can identify irregularities with greater accuracy without training. The CT scans are preprocessed using an Adaptive Multiscale Data Condensation Kernel in the early stages to normalise the underlying noise and improve the contrast of the picture for improved segmentation. With an accuracy of 78%, it has been found that the suggested technique has performed better in most situations. The medical team would be able to precisely predict the anomaly and disease progression in earlier stages of the illness with the use of the smart diagnosis approach [79].

Retinal blood vessels have been suggested to provide evidence for tortuosity, branching angles, or diameter changes brought on by ophthalmic illness. The Jerman filter responds quite well at vessels, edges, and bifurcations and enhances the visualization of structures, despite the widespread use of several enhancement filters. Curvelet shrinkage, on the other hand, can be used to recover from noisy data because it is particularly made to link scale with orientation. This article outlines a technique for further enhancing curvelet transform performance. For the purpose of segmenting retinal blood vessels, a unique combination of the curvelet transform and the Jerman filter is provided. When segmenting data, Mean-C thresholding is used. Average accuracy for the suggested method is 0.9559 and 0.9600 [80].

To better manage the chronic condition, Alzheimer's disease (AD) progression prediction is necessary. Data from AD patients are typically time series and multimodal in nature. This study suggests an unique ensemble learning framework for AD progression that employs the stacking technique to incorporate diverse base learners into an integrated model. Based on the multimodal time-series data, this framework is used to create a 4-class ensemble classifier that forecasts the progression of AD 2.5 years in the future. The longitudinal data has been utilized to obtain statistical measures that will be employed by traditional machine learning models. K-nearest neighbor, extreme gradient boosting, support vector machines, random forests, decision trees, and multilayer perceptrons are some of the ensemble members that were evaluated [81].

Length of Stay (LOS) mortality prediction at a hospital is crucial because it's one of the most important factors in managing patients with serious illnesses. These models acquire significant significance when forecasts of patient mortality and readmission are combined. The longer the LOS, the more likely it is that a patient may need to be readmitted to the hospital. LOS and readmission rates are consequently the most expensive aspects of patient treatment. They are prioritised in health care management because of this. Readmission to the hospital has been evaluated in a number of studies as a single-task problem. When numerous connected tasks are optimised, the model's performance, resilience, and stability improve. This research creates a deep learning model for multimodal multitasking with long short-term memory (LSTM). Using wrist-worn Bosch multi-sensory data from 47 patients, this work constructs a multimodal multitasking Long Short-Term Memory (LSTM) deep learning model that can predict both LOS and readmission for patients. In a number of scenarios, the suggested deep learning model is contrasted with traditional machine learning methods like a random forest. The proposed model is compared to a random forest for a single-task problem (classification or regression), as the multitasking barrier cannot be overcome by conventional machine learning algorithms. Additionally, sensory data was coupled with other cost-effective modalities including demographics, lab tests, and comorbidities to build trustworthy models for tailored, affordable, and medically acceptable prediction. The proposed multitask multimodal deep learning model classifies the patient's readmission status with a high accuracy of 94.84% and calculates the patient's length of stay (LOS) in the hospital with a minimal Mean Square Error (MSE) of 0.025 and Root Mean Square Error (RMSE) of 0.077, which is encouraging, reliable, and efficient [82].

Rest of the paper is divided into 4 sections. Section II is about background and literature review. Section III is about proposed framework. Section IV explains the proposed routing protocol. Section V is about experimentation and results. Last Section VI concludes the research and recommends future research directions.

II. BACKGROUND AND LITERATURE REVIEW

A. HIGH-LEVEL DESCRIPTION

WBAN applications are not only limited to medical applications but they are typically used in electronic bill payment, office security, driving assistance and automatic operations [4]. According to the World Health Organization (WHO) almost 75 % of the people suffer from diseases due to the inactive healthy lifestyle. In such cases, long term medication and proper healthcare monitoring is required in cities and as well as remote areas. Patient alarm monitoring system is typically designed for elderly people living at home in case of emergency. The WBAN applications are responsible to monitor the health of patients by using lightweight sensors mounted on the human body [5]. The lightweight sensor devices are typically used in monitoring the health of patients in cardiovascular diseases, cancer detection, glucose level monitoring, asthma and organs monitoring. There are various routing protocols in WBAN related to different Network frameworks. The routing protocols in WBAN are classified into further sub-types based on routing topologies [24]. The routing topologies are based on Quality of Service (QoS) aware, temperature awareness, cluster based and postural movement-based routing protocols [25], [26], [27]. The centralized clustering routing techniques play a significant role in network stability. The computational load of WSNs devices is shared by applying centralized energy-efficient path planning [28].

B. RESEARCH MOTIVATION

WBAN routing strategy faces many issues like power consumption issues, routing and clustering, localization and mobility issues, network communication range and node density, fault-tolerant communication in WBAN along with security issues. The power consumption issue in WBAN is one of the biggest challenges. The medical sensors used typically for WBAN have limited source of power. Such limitation has been resolved by introducing the technology of wireless power transmission to biomedical implants, as in [72].

The significance of routing challenges is to explore various energy efficient routing schemes. The power consumption issue in WBAN is one of the biggest challenges [74]. The medical sensors used typically for WBAN have limited source of power. Hence, it is very difficult to recharge or to replace the sensor node working in WBAN framework [4], [5]. The sources of useful power consumption are the transmission of data along with processing query requests and forwarding the data to the neighboring sensor nodes [29].

The routing protocol plays a vital role in data exchange among wireless sensor nodes. Energy efficient routing schemes provide an optimal mechanism to maintain a suitable route to transfer the data among WBAN [6], [30]. Routing protocols used in WSN cannot be directly used in WBAN due to the communication of sensor nodes on human body [10]. WBAN devices are most frequently used in indoor hospital environments, especially for remote patient monitoring [31], [32]. The patient healthcare monitoring is also based on mobility management model [33], that is used to maintain the record of patients moving in hospital environments [10]. In WBAN framework network communication range is used to achieve maximum connectivity, coverage and network lifetime [34]. The sensor nodes having maximum distance from the sink node consume large amount of energy to route the data. These sensor nodes die early due to the maximum power consumption, that results in degradation of network performance [20]. Fault-tolerant communication in WBAN occurs at node level. It is classified into three sub-categories of Data Faults, Hardware Faults and Software Faults. Eliminating the occurrences of faults in the WBAN communication will prevent the network failure. For accurate fault tolerance, the network will need optimal fault prediction system [35].

To design secure and low power consumption protocol in WBAN application is the key fundamental challenge. IEEE 802.15.4 standard is the reliable and secure technology for WBAN communication, that is most suitable for hospitals and healthcare institutions [10]. A QoS aware routing protocol for data transfer in emergency is the key factor to be considered as motivation for this research work. Moreover, the reliable data transfer is also a key issue in WSNs [36]. Hence, to cope with the situation a 4-Tier Body Area Network architecture is developed by the Researchers for existing

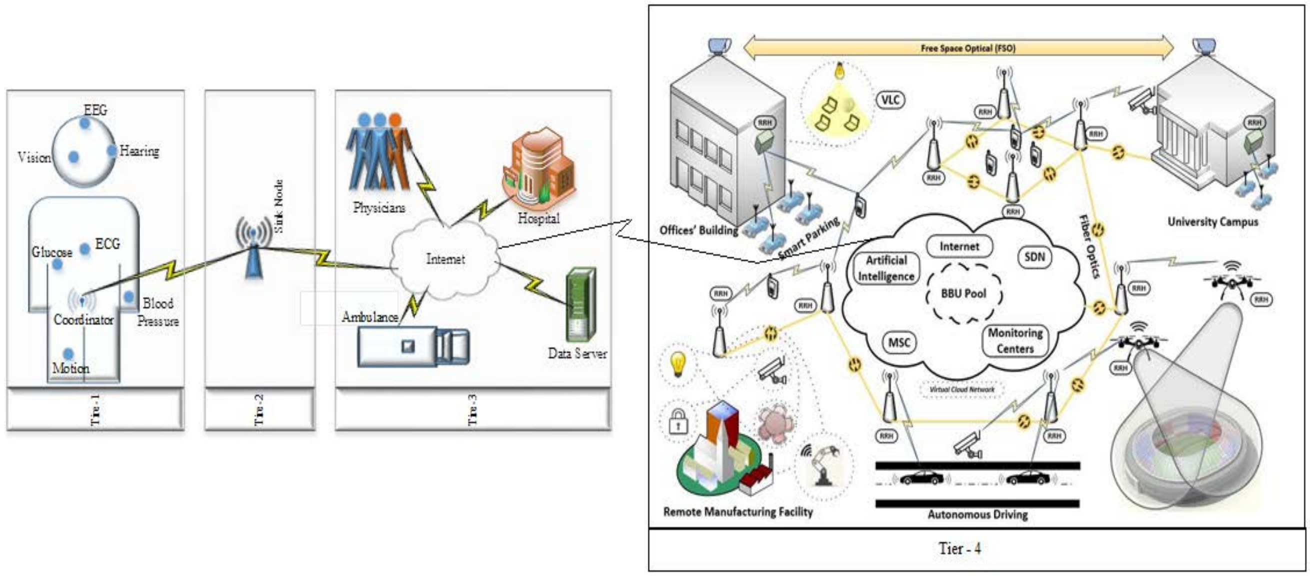

FIGURE 2. **A 4-tier WBAN architecture.**

healthcare systems [37]. Figure 2 describes about the 4-tier body area network.

The Authors [37] introduces Tier 4 connected with Tier 3 through internet. The Tier 4 consists of Internet of Drones connected with automatic driving system, office buildings, university campus, smart parking and remote manufacturing industry. A person's health condition can be monitored anywhere, anytime by using Internet of Things (IoTs) based pool [38].

In wearable WBAN, energy efficient functioning of devices depends on the selection of appropriate communication protocol. In WBAN, wireless communication characteristics like sensing and computation consume a huge amount of energy. This section highlights important features of possible low-power routing schemes that must be taken into consideration when choosing a particular technology. There are some low-power wireless communication schemes in WBAN that can accomplish the optimal routing strategy. The protocols ATTEMPT, M-ATTEMPT [39], RE-ATTEMPT [24], SIMPLE [33] and CO-LEEBA are more frequently discussed in the literature.

Energy aware Peer Routing protocol (EPR) is developed to balance the network traffic load and energy consumption factor [11]. Sensors are deployed on the human body, used to collect psychological parameters. Most common sensors deployed on human body include ECG sensors, body positioning sensors, hearing sensors, motion sensors, blood pressure and glucose sensors. The strength of the research work is based on the minimization of network traffic load. This also resulted in limited energy consumption of overall network.

The Balanced Energy Consumption (BEC) protocol is stores the residual energy of sensor nodes and stay alive for maximum time [40]. The conclusion of the research work is based on improvement in the network lifetime. BEC protocol attains maximum residual energy in case of limited no of rounds. BEC protocol also provides better residual energy in 5245 rounds. The simulation results show that the BEC protocol gives throughput ratio of 0.6%. The network stability period is less than 50 % and average path loss is equal to 32 % for the existing scenario. The improvement can be done to increase the stability, network lifetime and reduction in average path loss ratio.

In an Energy efficient routing scheme for low power WBAN the sensor nodes are deployed on the human body to collect real time readings, based on different postures of human body [41]. The route selection process is based on power control mechanism in WBAN. Collection Tree Protocol (CTP) is used for data collection among the sensor nodes. The functionality of Energy Efficient Routing Scheme (EERS) is based on route selection, link quality estimation and data forwarding. The performance evaluation of the proposed scheme is based on Packet Reception Ratio (PPR), Average Hop Count (AHC), Average Number of Transmissions per Packet (ANTP), Energy Consumption Per Packet (ECPP), Energy Consumption Per Hop (ECPH). The proposed network model is also implemented by using physical hardware. The simulation results had also been obtained by using MATLAB. The overhead and complexity factors are calculated based on number of messages (beacons) transmitted over the range of 0 dBm to −5 dBm, −10 dBm. The link between the sensor nodes at low power level are more unstable in the proposed scheme that may result in sending more beacons by the sensor nodes.

Energy Aware Routing Scheme (RE-ATTEMPT) is designed for low power consumption WBAN [24]. The major aim of this research is to design a routing protocol based on uniform distribution of energy among multiple sensor nodes. The objective is to increase the network lifetime to maximum

TABLE 1. Energy efficient routing scheme For WBAN.

Authors	WBAN Protocol / Standard used	Strengths	Limitations
Z. Khan et al. [11]	Energy-aware Peer Routing protocol (EPR) is designed for WBAN.	Limitation in network traffic load. Minimum energy consumption factor.	Mathematical model / algorithm is not designed.
M. Sahndhu et al. [40]	Balanced Energy Consumption (BEC) protocol is designed.	Stability in network lifetime.	Maximum path loss ratio.
L. Liang et al. [41]	Energy Efficient Routing Scheme (EERS) is not designed. Collection Tree Protocol (CTP) is used for data collection among wireless sensor nodes.	EERS is used for route selection, link quality estimation and data forwarding.	Scheduling schemes for data transmission in WBAN is not proposed.
N. Javaid et al. [39]	Mobility supporting Adaptive Threshold-based Thermal-aware Energy-Efficient Multi-hop routing Protocol (M-ATTEMPT) is designed.	Proposed algorithm is capable to sense the thermal heat of hotspot during routing process and thus possibly explore maximum number of routes.	Selects maximum number of cluster heads in each round by using multi-hop communication.
A. Ahmad et al. [24]	Energy-aware routing protocol for WBAN is designed (RE-ATTEMPT).	Reduction in temp rise, energy consumption, delay and select route with min hop count.	Average number of packet drop ratio of sensor nodes is high in each round.
C. Abreu et al. [29]	IP version 6 based routing scheme for low power WBAN (6WLoWBAN) is designed	Energy Aware routing protocol for WBAN is designed. Low power sensor nodes are used to calculate blood pressure, temperature, heartbeat and pulse rate	Maximum power consumption factor is an important issue to consider.
S. Ahmed et al. [43]	Cooperative Low Energy Efficient Body area network routing protocol (CO-LEEBA) is proposed for a single hop & multi-hop communication.	Co-LEEBA protocol is used to select the most suitable route with minimum path loss.	Maximum energy utilization of sensor node in single hop in emergency circumstances.
Chen et al. [44]	Harmony Search-based Energy Efficient QoS based Routing protocol (HSBEER) is designed for Medical WSN.	HSBEER routing algorithm is designed for maximizing the network lifetime. Improvement in convergence speed & accuracy of routing.	Multi-hop routing in case of cluster head selection increases the power consumption overhead.
N. Javaid et al. [45]	Improved stable increased throughput multi-hop link efficient routing protocol (IM-SIMPLE) for WBAN is designed.	Energy consumption-based model, linear programming based mathematical model is designed for maximum throughput.	Greater path loss ratio as compared to M-ATTEMPT.
Ha et al. [46]	Addresses the limitations in M-ATTEMPT routing protocol.	Routing algorithm for sensor node deployment in case of back and the front side of the human body is designed.	Integration with Medical Emergency server is not available.
N. Javaid et al. [47]	Distance-Aware Relaying Energy Efficient (DARE) Routing protocol is designed. Heterogeneous network is deployed in case of body sensors and body relays.	MI-DARE does not transmit redundant packets as M-ATTEMPT, which leads to prolonged network lifetime. Intelligent routing for data messages using swarm optimization technique.	Energy-aware QoS routing is under consideration.
Z. A. Khan et al. [48]	Energy-aware routing protocol for indoor hospital BAN communication is designed.	The protocol ensures end to end network link reliability. Reduces network traffic load and energy consumption.	The protocol is most suitable for moving patients as compared with stationary.

extent. The research contribution focuses on energy efficient route selection mechanism in case of single hop and multi-hop communication. The route selection process is helpful in delivering normal and emergency data by using minimum hop count. The significance of the research work is based on capability of sensor nodes to scan the body parameters. If emergency data is found the data is routed to the sink node. If emergency data is not found the algorithm is capable to predict all the possible routes with minimum hop count to transmit the data to the sink node. MATLAB simulation software is used to analyze the performance of the proposed protocol.

In multi-hop routing there is a great chance for increased energy consumption factor. The issue is successfully resolved by reducing the number of relay nodes with reference to energy distribution. Throughput of the system has been increased in case of large number of packets received at the sink node. The future work relies on cross layer design protocols in case of WBAN. The average no of packet dropped ratio of sensor nodes is high in each round. M-ATTEMPT protocol [39] is thermal aware whereas RE-ATTEMPT is not a thermal aware protocol.

Protocols based on cross layered routing schemes are also addressed in WBAN domain. In WBAN cross layered routing concept exists between Medium Access Control (MAC) layer and network layer for routing purpose and to increase the network throughput and performance [42].

A mobility supporting adaptive threshold-based thermal-aware Energy-Efficient Multi-hop Protocol (M-ATTEMPT) is proposed in [39]. Time Division Multiple Access (TDMA) scheme is used for data transfer among multiple sensor nodes. M-ATTEMPT selects maximum no of cluster heads in each round by using multi-hop communication between sensor nodes and sink node. Single hop communication is used for emergency services due to high energy consumption cost. Multi-hop communication is used for normal packet delivery transmission. It supports the movement of human body along with the medical sensors. M-ATTEMPT is capable to sense the thermal heat of hotspot during routing process and thus possibly explore maximum number of routes. M-ATTEMPT utilizes minimum energy as compared to the existing schemes [24], [40], [41]. Route discovery and cluster head selection is an important research challenge in this scheme.

Dynamic Energy Aware Fault Tolerant Routing Protocol (DEFTR) is an energy efficient reliable protocol for routing as well as fault tolerant [35]. DEFTR is suitable for multi-hop communication between the sensor nodes and is capable to divide the sensor nodes into multiple clusters depending upon the WSN size. To improve the network lifetime and reduce the energy consumption factor DEFTR is capable to deploy optimal number of sensor nodes in each cluster. The routing decision of this scheme is based on link quality, nodes distance and residual energy factor for each sensor node. To reduce the communication overhead DEFTR utilizes minimum number of intermediate sensor nodes in route discovery process. DEFTR adopts the inter cluster communication between the sensor nodes to improve energy efficiency that results in the improvement of network lifetime. DEFTR is capable to select the disjoint routing path. The alternate path is selected in case when the primary route is broken within each cluster. Cluster head selection during the routing mechanism is an important challenge for the researchers in selecting alternate routing path. The comparative analysis of core energy efficient routing protocols is presented in Table 1. The strengths and limitations of the routing schemes based on WBAN are also discussed that identify the research gaps to design an improved Energy Efficient Routing Protocol in WBAN.

The low power Energy Aware Routing Protocol for Biomedical wireless sensor network is based on IP version 6 [29]. The scheme offers a solution to increase the Network lifetime to a maximum extent. Energy efficient routing scheme 6WLoWBAN is designed for selecting the optimal path for packet transmission. Medical data has been used for analysis purpose, which includes blood pressure, sugar level, pulse rate and heartbeat. The research contributions in the existing framework are based on Energy Aware Routing, improvement in network lifetime, QoS, routing for low power and loosely networks and biomedical wearable WSN. The real time medical data collection is used for intelligent decision-making. Maximum power consumption factor is an important issue to consider.

The new priority framework aggregation scheduler is responsible for packet generation, packet selection, and packet aggregation [49]. The packets generated by these schedulers are emergency packets (EM), normal packets (NR) and on-demand packets (OD). The schedulers are integrated with WBAN for healthcare systems for packet transmission by using Wireless Local Area Networks (WLAN). The WBAN architecture is based on three layers and consists of WBAN sensor nodes. A personal server for the data collection from sensor nodes that perform functionalities like data collection, data processing, data aggregation and data communication. A medical server is designed for rescue operations. The future challenge relies on designing WBAN traffic scheduling algorithm. One of the major bottlenecks is to maintain the QoS and to overcome the problem of starvation.

A novel Energy-aware WBAN scheme is designed for minimizing the Network deployment cost and maximizing the coverage area for packet transmission between sensor nodes [50]. The framework is successfully capable to route the data towards the sink node. The network model consists of 13 biosensors mounted on the human body. The sensors are responsible to monitor heartbeat, pulse rate, body temperature, glucose level and echocardiogram. Framework model is not designed in case of proposed scheme.

The aging population is increasing day by day, hence, the people needs medical care at home in case of emergency [43]. Hence, most of the developed countries are using Medical Information and Communication Technologies (MICT) which are based on WBAN. A novel Cooperative Link aware and Energy Efficient routing protocol (Co-LEEBA) is proposed for WBAN. Co-LEEBA routing protocol can rout the data with minimum path loss and select the most suitable route towards the sink node. The route selection mechanism is based on minimum hop count. The data transfer mechanism between the sensor nodes is based on two strategies. Single hop communication that is used to route the emergency data and multi-hop communication is used in case of normal data transmission. Eight wireless sensor nodes are deployed on the human body. The sensor nodes are responsible for sensing as well as processing. Maximum energy utilization of sensor node in emergency circumstances is an important issue to consider.

Healthcare Monitoring System is designed based on hierarchal cluster based WSN [51]. A mathematical model for energy consumption is designed based on HMS. The proposed system is difficult to implement in real life scenarios, typically in WBAN routing applications.

The route aware clustering protocol for WBAN is proposed based on the Multi-Level Routing and Clustering (MLRC) technique [31]. The cluster head selection scheme is based on route establishment and clustering algorithm for data aggregation and data forwarding. MLRC is based on a tree-based approach to route the data and minimize the power consumption overhead. Routing and clustering algorithm has not been proposed in this scheme.

Threshold Energy Optimized Static Cluster Head Selection (TEOSCHS) is an energy efficient routing and clustering technique for WBAN [52]. It is responsible for cluster head selection. Symmetric cryptography-based security feature abbreviated as Elliptic curve Hell man Iterative Block transformation is introduced in this scheme. Framework model is not designed in this scheme.

Mobile Adhoc Networks (MANETS) based healthcare monitoring scheme is proposed [53]. Simulation results are generated by using MATLAB software. Simulation results are based on mobility management scheme. Simulation results show that Adhoc On Demand Vector (AODV) protocol gives the better performance in routing as compared to the Dynamic Source Routing (DSR) and Distance Sequence Distance Vector (DSDV) routing schemes. The existing schemes as previously discussed are not suitable for WBAN applications.

An AODV based secure and reliable protocol is proposed to improve the QoS in data transmission and reduce the energy consumption in WBAN [54]. The protocol operates in two modes, direct mode and relay mode. In direct mode, the transmission power is set to maximum level. Single hop communication is required to transfer the data to WBAN coordinator node. In relay mode, multi-hop communication and limited energy is required to transfer the data to the sensor nodes. The WBAN coordinator is responsible for transmitting the data to the medical server for healthcare diagnosis and intelligent decision-making. The RSA based security features are also integrated in this scheme. Encryption and decryption of transmitted data is performed between the sensor nodes to achieve authentication and confidentiality. The scheme results in increasing the hop count among multiple sensor nodes and WBAN coordinator node that results in increased energy consumption factor.

Energy efficient QoS based framework model for WSN is proposed that uses multi-hop routing mechanism for cluster head selection based on inter and intra cluster routing and transmission mechanism [44]. An algorithm is proposed for multi-hop routing scheme based on minimum hop cost spanning tree (MCT). Self-stabilizing hop constrained energy efficient routing and clustering (SHE) protocol is designed for real time packet routing. SHE results in low power dissipation and increased network lifetime. To improve the convergence speed and accuracy of routing process, the authors proposed an Improved Harmony Search-Based Energy Efficient Routing algorithm IHSBEER to maximize the network lifetime [55]. The energy-balancing factor in WSN is more optimal by using IHSBEER algorithm as compared to the Energy Efficient Body Area Routing (EEBAR). However, the network model is not designed in this scheme.

Improved Stable Increased Throughput Multi-hop Link Efficient routing protocol IM-SIMPLE is designed to achieve high stability and throughput for WBAN [45]. The mathematical model is developed by using first order radio model based on energy consumption as in equation 1 and equation 2.

$$\boldsymbol{ETx}\,(\boldsymbol{k},\boldsymbol{d}) = \boldsymbol{ETx}\,-_{\boldsymbol{eleck}} + \left(\in -_{\boldsymbol{ampkd}}\right) \tag{1}$$

$$\boldsymbol{ERx}\,(\boldsymbol{k}) = \boldsymbol{ERx}-_{\boldsymbol{elect}} \tag{2}$$

where d represents the distance between the receiver and transmitter. ETx is the energy consumption per packet in case of transmitter; ERx is the energy consumption per packet in case of receiver. ETx-elec is the energy consumption value per bit in case of transmitter electronic circuitries. ERx-elec is the energy consumption value per bit in case of electronic receiver circuitries. €amp is the radio amplifier, and k designates the packet length. The throughput and path loss ratio of IM-SIMPLE protocol is much stable as compared to the SIMPLE and M-ATTEMPT schemes. The path loss ratio of IM-SIMPLE scheme is greater as compared to the M-ATTEMPT [39].

Stable Increased Throughput Multi-hop Protocol for Link Efficiency (SIMPLE) energy efficient routing scheme is used to select the optimal route towards the sink node [33]. The performance of the routing protocol SIMPLE is compared with ATTEMPT. SIMPLE protocol achieves maximum throughput, limited energy consumption and minimum path loss ratio as compared to the ATTEMPT protocol. The success ratio achieved by the SIMPLE protocol is obtained by using multi hopping routing strategy. The network model is not proposed in this scheme.

To improve the network lifetime, an improvement in M-ATTEMPT routing protocol is made to overcome the limitations of the proposed scheme [46]. In M-ATTEMPT protocol there is no consideration for sensor nodes on the backside of the human body. The sink node is attached to the front side of the human body, and the parent node communicates only with the multiple child nodes. Some of the routing protocols in WBAN are based on postural movements [46], [56]. The protocol scheme as mentioned in [46] considers sensor nodes deployed on the front and backside of the human body. The proposed scheme ensures the strategy for the postural change in the human body by using optimal route selection scheme. The experimental setup consists of the initial phase, routing phase, scheduling phase, and data transmission phase. The algorithm is developed to improve the sensor node connectivity and even energy consumption in WBAN. The power consumption factor is an important issue to consider, due to the deployment of multiple sink nodes on human body.

A postural movement-based routing protocol, On-Body Store and Flood (OBSF), for WBAN is proposed to minimize the delay in packet delivery with high energy consumption as a limitation [56]. Opportunistic Routing Protocol (ORP) is based on postural movement routing strategy with limited energy consumption factor. The scheme is able to identify the different human body postures. The scheme has limited energy consumption as compared to the Prediction to enable Secure and Reliable (PSR) routing scheme but with a maximum delay in packet delivery.

Distance-Aware Relaying Energy Efficient (DARE) and Mutual Information based DARE (MI-DARE) energy-aware routing protocols are designed for WBAN [47]. In this scheme the body sensors are deployed inside the human body. The network topology inside the BAN includes seven body sensors, surface mounted on the human body. A single sensor is also deployed inside the human body for example chest. The heterogeneous network is deployed in case of body sensors and body relays. The multi-hop communication infrastructure is used for data transmission. An energy efficient in-body wireless sensor network is presented for human healthcare systems. To reduce the energy consumption between sensor nodes, all the sensor nodes communicate with each other by using relay nodes. A linear programming based mathematical model is proposed to reduce the end to end delay and minimize the network lifetime [57]. The proposed model is difficult to implement in real world scenarios.

WBANs incorporate unsupervised healthcare monitoring during daily life activities of longer duration. To utilize this technology in healthcare domain, a number of challenging issues should be resolved, including lifetime of bio-medical sensor nodes deployed on human body for continuous monitoring of the health status of the patients. The vision behind using WBAN in healthcare applications can lead the scientists and researchers to effectively deploy the wireless technologies and protocols in healthcare domain [58]. There is no particular standard that may provide an energy efficient routing and clustering protocol for WBAN [20]. Healthcare schemes using WSN require extensive computations, large amount of data for training, large storage and high processing capabilities. The number, of input parameters, is fixed for different sensors that make it rigid one. The existing research studies lack in challenging attributes related to the patient's continuous health status monitoring by using wearable medical WBAN. The major problem arises in case of deployment of sensor nodes inside and outside the human body and the capability of sensor nodes in appropriate path selection for data transfer. Reactive routing protocols increases communication delay between sensor nodes and proactive routing protocols utilizes maximum resources of wireless network including processing power, memory and bandwidth [59].

III. PROPOSED FRAMEWORK

The methodology of the proposed framework is shown in Figure 3 and it consists of 4 clusters. Each cluster within the layer 1 consists of Ad hoc Relay Station (ARS), Relay Nodes (RN) and sensor nodes mounted on the human body. The cluster wise descriptions in WBAN network model are further classified into sub-components. ARS exists within each cluster. ARSs revive and transmit the information from the relay nodes and finally transfer this information to the access point. RN within each cluster receive the information from sensor nodes and route the information to ARSs. Sensor nodes are mounted on the human body transmit the health status information to the RNs. The sensor nodes are categorized into heartbeat, pulse rate, glucose level, blood pressure and body temperature sensor.

A. CONTRIBUTION AT LAYER 1

Selection of relay-based routing [57] inside **Layer 1** in proposed framework is based on the following factors:

1. Reliability: The framework delivers at least 90% of end-to-end packets when a route exists, even under challenging network conditions. The achievable packet delivery is 99.9% for the proposed scheme.

2. Robustness: The framework is capable to operate in a wide range of network conditions including extensive network workloads, topologies and environments.

3. Efficiency: The framework is capable to transmit the packets in minimum time across the wireless network.

4. Hardware Independence: The framework is able to work on large number of hardware platforms.

B. CONTRIBUTION AT LAYER 2

The **Layer 2** consists of Smart Homes and cities. The IOT based smart homes provides an efficient solution for elderly and chronically ill people living alone in houses. We are incorporating IOT based solutions inside smart homes. Sensor nodes are deployed on almost every home appliance and human body, thus possibly develops an Ad hoc network within the fixed defined range. In smart homes there is no standard routing protocol to route the data from one device to another. Mostly Smart Homes establish a standard Ad hoc Network of devices including elderly patients [38]. We have introduced the relay-based routing inside the smart homes to effectively route the data from multiple sensor nodes towards the relay node. The use of relay-based routing in smart homes provides an efficient solution to transmit the patient health status information reliably from one sensor node to another in minimum time.

The research contribution at Layer 2 is based on following motivational factors.

1. Relay based routing scheme is used in Smart Homes.

2. To effectively route the data from multiple sensor nodes towards the RN.

3. IOT based provides an efficient and reliable solution for transmitting the elderly health status information from one sensor node towards another.

C. CONTRIBUTION AT LAYER 3

The **Layer 3** consists of Access Point (AS) / Base Station (BS). Relay based routing is normally used in data transmissions towards AS/BS [59]. Relay based routing has good communication reliability and minimum average end to end delay. Relay based routing is based on route discovery and route maintenance services in WBAN. Relay based routing is capable to successfully route the data from AS/BS in Layer 3. The proposed scheme results in successful packet delivery

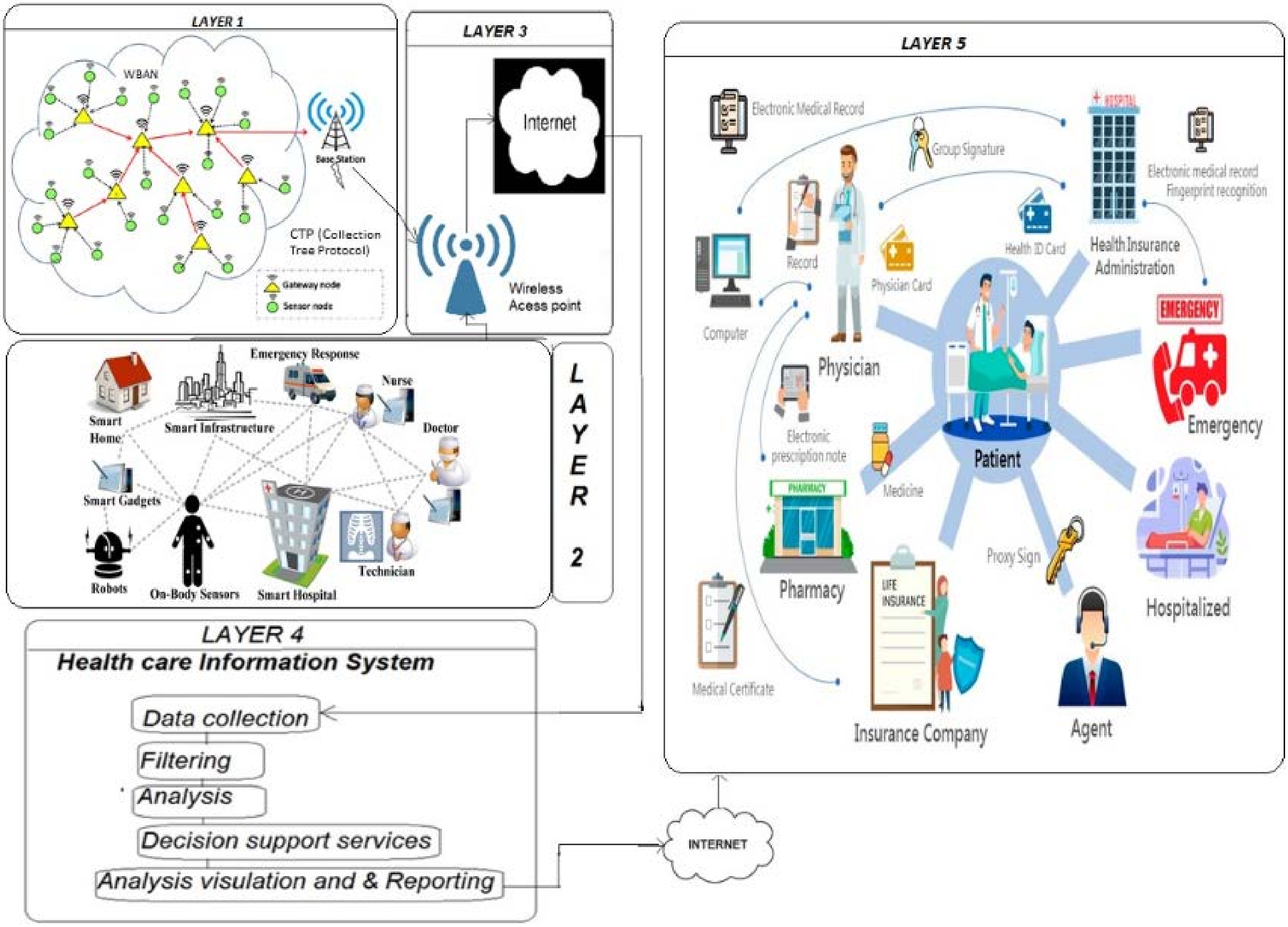

FIGURE 3. Proposed framework for WBAN application.

ratio from Layer 3 towards Layer 4. Relay based routing utilizes an efficient clustering technique based on a patient's health condition. The current scenario is based on 150 sensors deployed in the network field in Layer 1. Wireless sensor networks in this current scenario can maintain a packet data ratio greater than 80%, which is suitable for hospitals and healthcare institutions. Relay based routing supports efficient data transmission and routing mechanism for doctors and nurses who move around in a healthcare environment.

Limitation of packet loss ratio inside layer 3 is supported by relay based routing scheme [57]. Relay based routing is capable to successfully route the data from AS/BS towards Layer 4 through internet. The research contributions at Layer 3 are based on following motivational factors [60] that relay based routing guarantees.

1. QoS

2. Energy efficiency

3. Minimum end to end delay

4. Max packet delivery ratio

5. Relay based routing is capable to detect wireless signals in prolonging the network lifetime, load balancing, and scalability

6. Relay based routing supports efficient data transmission and routing mechanism for doctors/nurses who move around in a healthcare environment.

7. Relay based routing supports successful packet delivery ratio between Layer 3 and Layer 4.

D. NOVEL CONTRIBUTION AT LAYER 4

The **Layer 4** consists of Healthcare Information Systems (HIS) module that is responsible to collect, filter and analyze the data for intelligent decision-making. HIS is responsible for intelligent health status analysis by using machine learning techniques. We are using classification as machine learning technique inside the HIS module to sub-populate the trained set of healthcare data containing observations based on supervised learning. By using this technique, we are able to correctly identify the observations related to healthcare and to group the data into related categories. The research contributions at layer 4 are based on following motivational factors [61].

1. HIS server is responsible to collect, filter and analyze the data for intelligent decision-making.

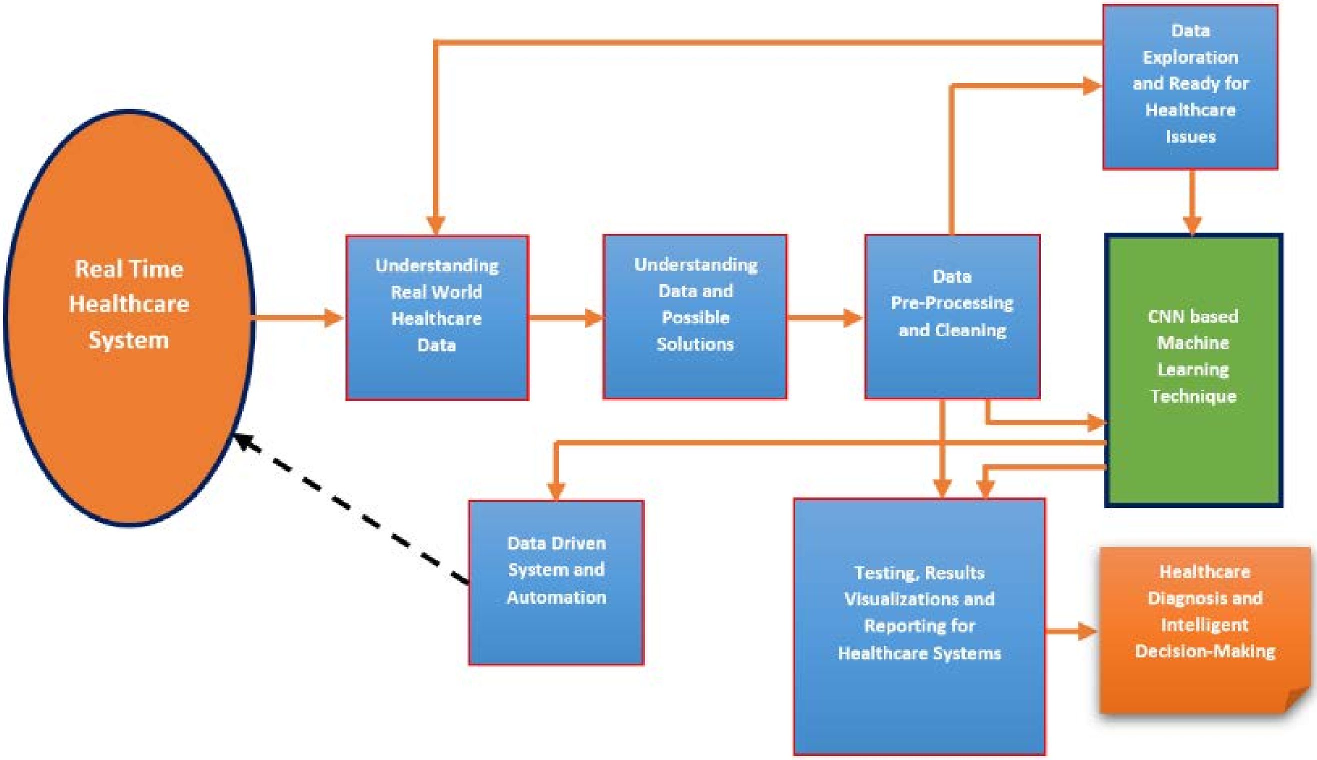

FIGURE 4. Example of healthcare model in intelligent decision-making.

2. HIS server is also responsible for intelligent health status analysis by using classification as machine learning technique [62].

Figure 4 describes the extraction of Real time information or meaningful insights from data that can be used for *intelligent decision-making* in various healthcare domains.

The domain of data science is largely dependent on the availability of data. Thus, a sound understanding of healthcare data is necessary in healthcare diagnosis and intelligent decision-making. Electronic Health Record (EHR) systems had facilitated data collection by health-care authorities and allowed doctors to access patients' important health status information at their earliest convenience for the diagnosis. Mosely the real-world datasets consist of noisy, missing and inconsistent values. In this regard data preprocessing and cleaning techniques are necessary for effective result visualizations in electronic healthcare record reporting. Data exploration using Convolution Neural Network (CNN) based machine learning techniques will help in healthcare diagnosis and intelligent decision-making [63]. CNN identifies the patterns of information and learn the most relevant information from textual data. CNN is one of the most effective models for the classification in healthcare diagnosis. CNN is used to support intelligent healthcare diagnostics based on EHR. The healthcare diagnosis falls under the domain of multiclass healthcare classification problem. Figure 5 describes the CNN model for healthcare intelligent decision-making.

The lifestyle dataset of people is obtained from Kaggle [64]. The Coronary Heart Disease (CHD) prediction dataset is used that is comprising of 4239 records. A partial sample of the dataset is shown in Figure 6.

The dataset consists of heartbeat, pulse rate and glucose level. There are 4 hidden layers in the CNN model. Table 2 describes the sample distribution for disease classification based on number of samples.

The input feedback parameters related to the simulation model scenario are mentioned in Table 3.

Table 2 describes the input parameters of the simulation model. CNN based Health care knowledge model is introduced [75]. Analysis of medical health care records are performed using LSTM and SVM. The data set is based on presence of obesity based diabetes and blood pressure is obtained using IOT based framework. The existing model lacks the learning accuracy based on available data set. From CNN model learning accuracy limitations identified in the existing research work we had selected the real time data set for Accuracy, discovery and diagnosis of individual health care to much better extent. The proposed model is tested using Tensor Flow Network Simulator [73] using 6554 epochs using Liner Regression technique with regularization rate equal to 0.3. From the Learning Rate of 0.03 it is observed that Healthy Lifestyle had significant effect on person's health for half year time period.

Figure 7 describes the effect of healthy lifestyle person's life for six months period of time (Kernel size) plotted on

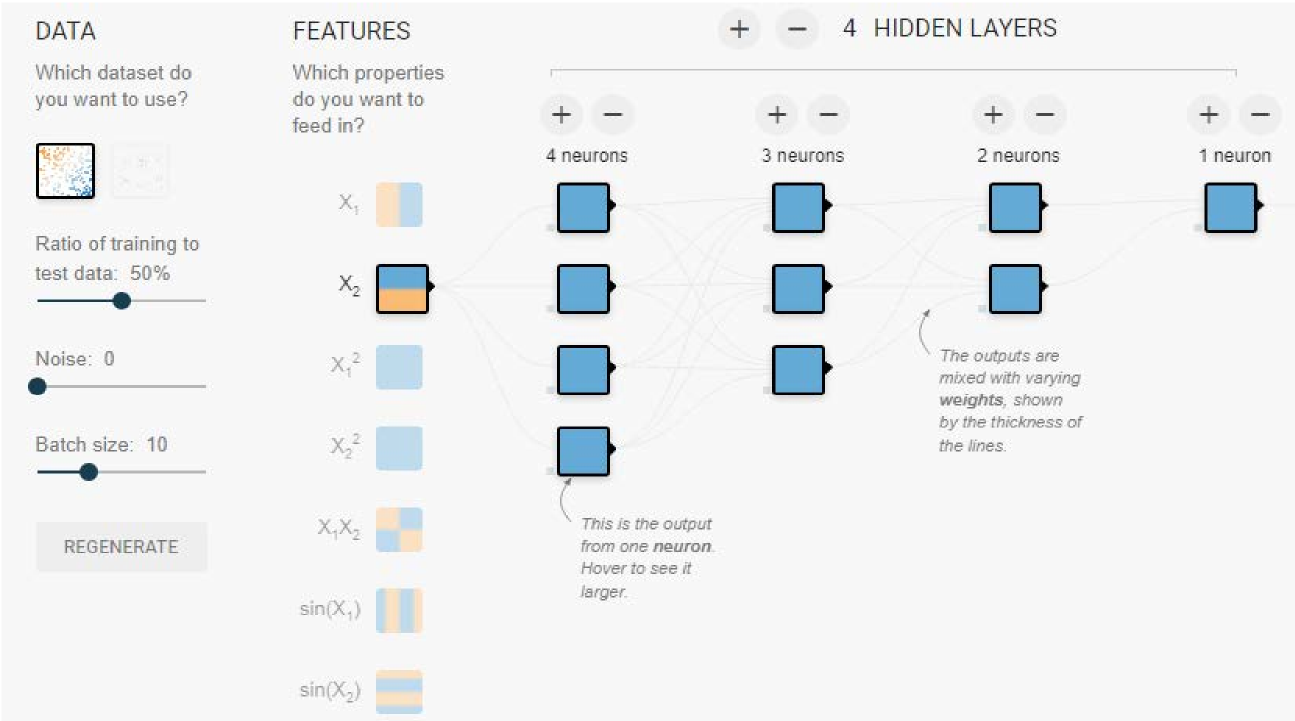

FIGURE 5. CNN model for healthcare intelligent decision-making.

male	age	education	currentSmoker	cigsPerDay	BPMeds	prevalentStroke	prevalentHyp	diabetes	totChol	sysBP	diaBP	BMI	heartRate	glucose	TenYearCHD
1	39	4	0	0	0	0	0	0	195	106	70	26.97	80	77	0
0	46	2	0	0	0	0	0	0	250	121	81	28.73	95	76	0
1	48	1	1	20	0	0	0	0	245	127.5	80	25.34	75	70	0
0	61	3	1	30	0	0	1	0	225	150	95	28.58	65	103	1
0	46	3	1	23	0	0	0	0	285	130	84	23.1	85	85	0
0	43	2	0	0	0	0	1	0	228	180	110	30.3	77	99	0
0	63	1	0	0	0	0	0	0	205	138	71	33.11	60	85	1
0	45	2	1	20	0	0	0	0	313	100	71	21.68	79	78	0
1	52	1	0	0	0	0	1	0	260	141.5	89	26.36	76	79	0
1	43	1	1	30	0	0	1	0	225	162	107	23.61	93	88	0
0	50	1	0	0	0	0	0	0	254	133	76	22.91	75	76	0

FIGURE 6. Partial dataset of coronary heart disease [64].

TABLE 2. Sample distribution for disease classification.

Disease	No of samples
Heartbeat	3193
Pulse rate	927
Glucose level	660

X-axis and predicted Health status Accuracy on Y-axis. The blue circles in the graph represent the percentage of heart beat level of the person, whereas orange circles represent the obesity based diabetes level. The results obtained from a dataset of male persons between the age of 25-40 years in Figure 5. The graphical results predicts about the Accuracy level of unhealthy lifestyle of people suffering from percentage risk of diabetes and blood pressure. From the graphical results it has been observed that there is minimum 4.5% accuracy and maximum 9.5 % accuracy of person suffering from blood pressure based on heart beats. There is minimum 1% and maximum 6.5% Accuracy of person suffering from obesity based diabetes. These predicted results using CNN will be

TABLE 3. Input parameters for simulation.

Input Parameters	Description
Learning Rate	0.03
Activation Function	Linear
Regularization	Level 1
Regularization Rate	0.3
Problem Type	Regression
No of Epochs	6.554

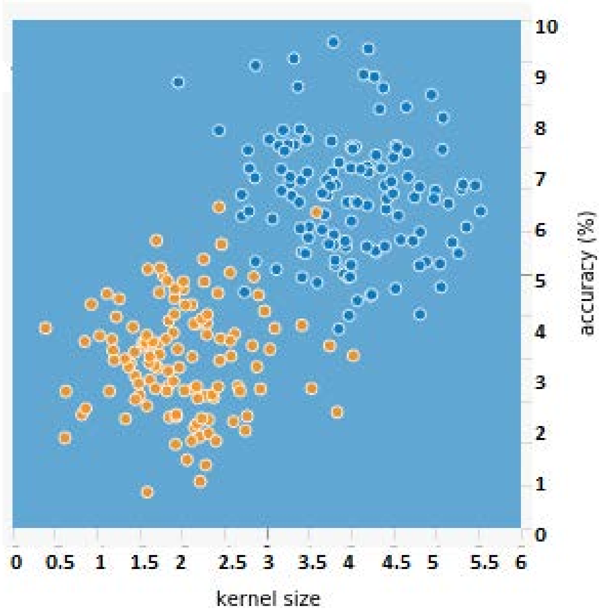

FIGURE 7. CNN results.

very helpful for health care authorities and doctors for early medication in order to balance their vital parameters related to the patients' health.

E. TRUST-BASED REMOTE PATIENT MONITORING SYSTEM ARCHITECTURE

1. Capable to send and receive the patient's health status information from Layer 4 using internet. From the previous mentioned scenario the medical emergency server in introduced at **layer 5** can receive the patient's health status information from layer 4 using internet. The medical emergency server is connected to the doctors at remote locations, ambulance for emergency operations and hospitals for medical diagnosis and intelligent decision-making [65]. Layer 5 consists of Medical emergency server. The Layer 5 is based on following motivational factors

a) the doctors at remote locations
b) ambulance for emergency operations
c) hospitals for medical diagnosis and intelligent decision-making [66].

IV. PROPOSED IM-QRP ROUTING PROTOCOL

The proposed IM-QRP routing protocol works at Layer 1 and Layer 2. Figure 8 describes the communication flow-chart for IM-QRP routing protocol based on QoS aware routing strategy.

The IM-QRP routing protocol for normal and emergency circumstances. The description of the flow chart is based on the algorithm for route selection and QoS aware routing in case of WBAN as mentioned below:

Algorithm 1 //Algorithm for QoS Aware Routing Protocol for WBAN

Initial Phase:
1. All the sensor nodes transmit test messages.
2. All the sensor nodes and relay nodes update their neighboring nodes and routes to the sink nodes.
Routing Phase:
3. SN=sensor node
4. SN=[11.......SNk]: all sensor nodes send the data to the sink node
5. For each (SNi ∈ SN)
6. //Routing algorithm for sensor nodes deployed on the human body
7. //Start
8. //system initialization and configuration
9. ***if*** *(SNi==Recives_signal_([Residual_energy_max]))*
10. Node_selected_transmitting( )
11. // Methods deployed for transmission to sink node
12. L1: QoS
13. ***if*** *(SNi==(QoS_max_IM-QRP]))*
14. [Min_path_loss_ratio_model_selection ( )
15. +Max_link_reliability_model_selection()+
16. Max_residual_energy_model_selection()
17. +Max_SNR_model_selection()]
18. ***Else***
19. Jump to L1
20. ***if*** *(routing_decision_normal_QRP)*
21. Selection_optimal_route_normal( )
22. Transmits the data in multi-hop to sink node
23. ***if*** *(routing_decision_emergency_QRP)*
24. Selection_optimal_route_emergencyl ()
25. Transmits the data in single-hop to sink node
26. ***Else***
27. Node_not_selected_transmitting( )
28.//start again from system initialization and 29 configuration
30. ***End***
31. // Energy consumption algorithm procedure
32 in the selection of the optimal route
33. NNF=Neighbouring node as a forwarder
*34.****Deleted Text //*** *all 35candidate nodes as neighboring forwarder node*
36. REin= residual energy of sensor node i in case
37 of normal data transmission
38. REie= residual energy of sensor node i in case
39 of emergency data transmission
40. ECNi=Energy consumption of node i
41. ***switch*** *(NNFi ∈ NNF)*
42. case: ***1***
43. (In case of emergency)->REin=(REi − ECNi)
44 Energy consumption of each sensor node in
45 emergency
46. ***case: 2***
47. (In case of normal Trans)->REie = (REi − ECNi)
48 Energy consumption of each sensor node in
49 normal
50. ***end case***

V. SIMULATION AND EXPERIMENTAL RESULTS

In this section the comparative analysis of the proposed protocol IM-QRP is also made with existing routing protocols QPRD [67] and CO-LEEBA [43]. The simulation results are obtained by using MATLAB. Table 4 describes the simulation setup and the classification of sensor nodes deployed on the human body along with the abbreviations and functionality of each sensor node.

Depending on the health condition of patients, different categories of sensors are used on the human body. Deployment of sensors on the human body is capable to support multiple types of WBAN traffic within a defined range of radio networks.

In IM-QRP routing protocol, the sink node is deployed on center position on the human body as shown in Figure 9. The system model consists of 10 sensor nodes mounted on the human body inside Tier 1 having the processing power and transmission capability. Out of 10 nodes, 5 nodes (in red) are supposed to be classified as normal sensor nodes, 4 sensor nodes (in blue) are classified as relay nodes, and 1 sensor node (in black) is classified as a sink node. The sink node is also capable of communicating with the external gateway node inside Tier 2. Tier 3 provides remote healthcare services for healthcare diagnosis and intelligent decision-making. The network in Figure 8 uses a fixed number of nodes deployed on the human body but depending on the health condition and postural movements of patients, we can increase the quantity of sensor nodes and relay nodes mounted on the human body. The reason for the increase in sensor nodes is based on the disease for example, we may add glucose level monitoring sensor node on the human body for a diabetic patient.

The WBAN is heterogeneous and supports two different categories of sensor nodes that are classified as

1. Advance nodes can be further sub classified as (Relay nodes)

2. Normal nodes can be further sub classified as (Sensor nodes)

Relay nodes mounted on the patient body have a minimum distance from the sink node. Normal energy sensor nodes are randomly mounted on patient body to sense vital parameters related to the health status of the patient.

Cooperative routing is an integral component of WBAN communication. Cooperative communication is more reliable in establishing links between sensor nodes and sink nodes, other than a direct link for WBAN transmission. To reduce the power consumption overhead, cooperative links are to be established by introducing relay nodes [68]. The functionality of sensor nodes and relay nodes related to the proposed protocol in case of normal and emergency circumstances is mentioned as follows.

In the case of Emergency: The emergency arises in the case, when sensor nodes sense heartbeat, pulse rate, glucose level and temperature scale to a significantly maximum extent. The sensor nodes directly send the data to the sink node. The single hop communication occurs when the health status of the patient is in an alarming condition.

In the case of normal daily life: The normal circumstance occurs in the case when sensor nodes sense heartbeat, pulse rate, glucose level, and temperature scale to a desirable extent. The sensor nodes send the data to the relay node. The relay nodes act as a cooperative node, having a minimum distance from the sink node. The relay nodes cooperative node sends the data to the sink node. Relay nodes consume less power as compared with ordinary sensor nodes. The multi-hop communication situation occurs when the health status of the patient is in normal condition.

TABLE 4. Classification of sensor nodes mounted on a human body.

Type of Sensor Node	Abbreviation	Functionality
Sink Node	SN	Mounted at the middle of the human body, capable of receiving the information from sensor nodes and relay nodes.
Sensor Node	S1	To monitor the glucose level of the patient body.
Sensor Node	S2	Electro Encephalogram (EEG) sensors used to monitor the signals received from the human brain.
Sensor Node	S3	Echocardiography (ECG) used to monitor heartbeat signals.
Sensor Node	S4 & S5	Electromyography (EMG) used to record the muscle activity.
Relay Node	R1, R2, R3, R4	Capable to receive the information from sensor nodes and coordinates with sink node.

A. INITIALIZATION PHASE

In the proposed routing protocol three major tasks are performed. Each sensor node and relay nodes are informed with the location of the neighboring sensor nodes. The sink node is centralized and mounted on the human body. The relay nodes near to the sink node communicate with sensor nodes. In WBAN framework sensor nodes and relay nodes explore the possible number of routes towards the sink node. Each node in the network framework broadcasts its network ID and its residual energy. All the sensor nodes within the network framework become aware of the residual energy of nearby nodes and update their route section path appropriately. Table 5 describes the parameters related to energy and their desired values to be used in a simulation scenario [21].

B. SELECTION OF NEXT-HOP IN ROUTING

This section is based on next-hop selection criteria to select the forwarder node based on the IM-QRP routing protocol.

To save energy and increase the network throughput, we prefer the multi-hop routing scheme. Single hop routing is selected in case of emergency circumstances. IM-QRP selects the new forwarder/relay node in each round. Sink node is aware of neighboring sensor nodes and relay nodes, identifiers (ID), distance and residual energy. By these assumptions, the cost function selects a node to become a forwarder/relay node or not. The equation for computing the cost function is given below [20].

$$C(F) = \frac{d(i)}{R_E(i)} \tag{3}$$

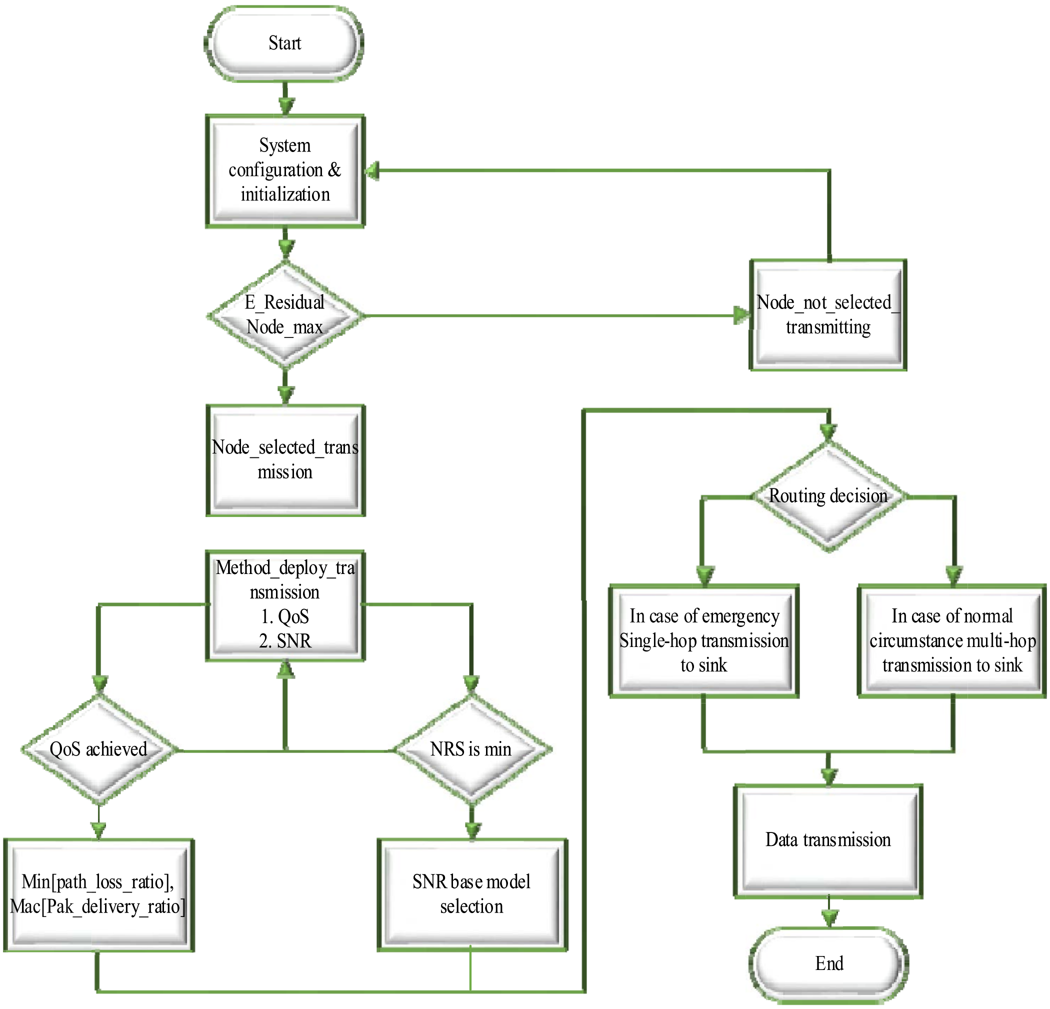

FIGURE 8. Flowchart description of IM-QRP routing protocol.

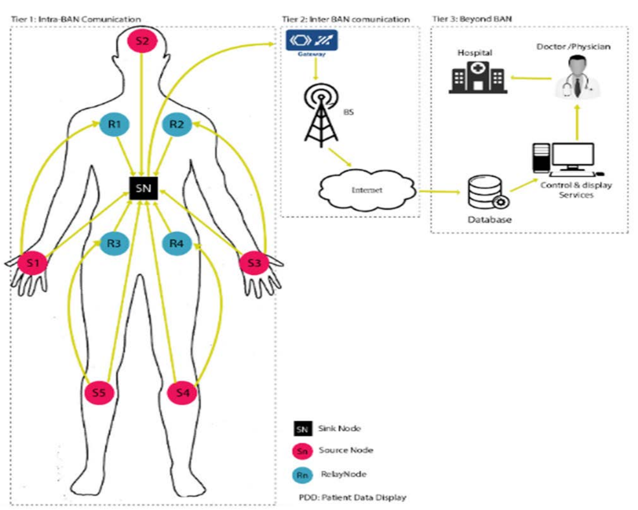

FIGURE 9. A Schematic for IM-QRP routing protocol.

where i is the node ID, $d(i)$ is the distance between sensor node i and sink node; RE is the residual energy of the sensor node.

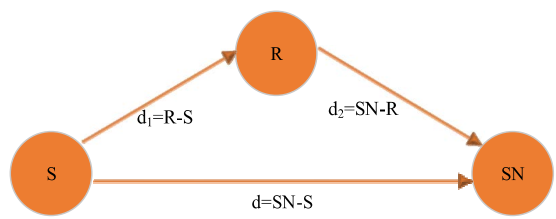

FIGURE 10. A Distance calculation for sink node.

Figure 10 describes the graphical representation for the calculation of the distance between the sensor node and a sink node in case of emergency and the distance between the sensor node and relay node and relay node and a sink node in case of normal circumstance. Based on these assumptions the cost function is modified in case of normal and emergency circumstances. The cost function in case of normal data transmission, the multi-hop transmission is described as follows.

$$CF_n(i) = \frac{(SN - R) - (R - S)}{R_E(i)} = \frac{d_2 - d_1}{R_E(i)} \tag{4}$$

TABLE 5. Energy parameters with desired values [21].

Energy parameters	*Desired values*
$E_{initial}$ (Initial Energy)	4 millijoules
Supply voltage	2.0 volts
Frequency (f)	2.4 GHZ
$E_{Transmission-amp}$	2.0nJ/bit
$E_{Transmission-circuit}$	17nJ/bit
$E_{receiver-circuit}$	10nJ/bit
DC Current (Transmission)	10.5 Ma
DC current (Reception)	18 mA
Wavelength (λ)	0.125 m

The cost function in case of emergency circumstance, the single-hop transmission is described as follows.

$$CF_E\,(i) = \frac{(SN - S)}{RE(i)} = \frac{d_{(i)}}{RE(i)} \tag{5}$$

Comparing WSN with WBAN applications, radio propagation models allocate frequency spectrum at different interfaces [45]. The impact of the environment on propagating signals significantly affects the intra-body and extra-body WBAN radio signals. WSN based radio frequency signals are not suitable for WBAN, because the signal range has not been defined for the particular human body. In this regard latest technologies for WBANs such as Bluetooth low energy, IEEE 802.15.4 (ZigBee), and IEEE 802.15.6 Ultra-Wideband (UWB) standards are more frequently suitable for the proposed scheme [48]. To avoid hotspots on the human body, WBAN operates at low energy levels, to avoid adverse effects on the human body high data transmission rates are also avoided in the proposed scheme. High data transmission rates increase power consumption overhead that significantly degrades QoS for the WBAN framework. In radio propagation model, the communication between sensors placed on the human body, when transmitted signals propagate through the body, diffract around the body, reflected off by near-by directions, also the backside of the human body [46].

In the path loss ratio model, the direct link between transmitter and receiver is used to transfer the data from the source node to the sink node in event of emergency circumstance. The direct link between the sensor node and sink node may suffer from path-loss due to noise and channel fading in Line-of-Sight and Non-Line of Sight WBAN transmission. In Figure 8, path loss may occur in cases depending on the postural movement of the human body when the distance between the sensor nodes and relay nodes varies. RSSI is the factor, which is directly proportional to path loss. When the patient changes his body postures especially legs and arms the transmission distance between sensor nodes, relay nodes and sink nodes may increase which results in path loss. In the proposed model in Figure 8, there is a limited path loss. The reason is due to the postural state of the patient's body when the sensors mounted on arms and legs are positioned near to the sink node deployed on the abdomen side of the human body. The minimum communication distance of few centimeters between sensor nodes, relay nodes and sink nodes on arms legs and abdomen side may result in limited path loss. Limited signal to noise ratio may cause the maximum packet drop ratio towards the sink node due to a maximum bit error rate (BER) in the WBAN framework. The Friis formula for Path Loss Model [69] is used to calculate the path loss between two communicating nodes, based on distance d can be defined as follows in equation 6.

$$P_L(d) = P_L(d_o) + 10log_n\left(\frac{d}{d_o}\right) \tag{6}$$

where $P_L(d_0)$ is path loss in dB.

The cost function based on the optimization model in WBAN is defined by the equation 7 as mentioned below:

$$cost\_function \xrightarrow{elect\_optimized} forwarder\_node(relayNode) \tag{7}$$

Equation 8 gives the residual energy for the sensor node to communicate between the sensor node and a sink node in case of emergency circumstance.

$$E_{residualenergy(Emergency)} = \frac{Ek_{emergency\,max}}{E_{max}} \tag{8}$$

Equation 9 gives the residual energy for the sensor node to communicate between the sensor node and the relay node and from the relay node to the sink node in case of normal data transmission.

$$E_{residualenergy(Normal)} = \frac{Ek_{normal\,max}}{E_{max}}. \tag{9}$$

The QoS for data transmission among the sensor nodes is dependent on efficient link reliability and minimum path loss ratio [31]. The link determines the bandwidth of the path P. The equation 10 gives the link reliability between two nodes $LinkRSK$.

$$LinkRsk = (1-\gamma)LinkRsk + \frac{Tx_{xsucc,sk}}{Tx_{tot,sk}} \tag{10}$$

$Tx_{xsucc,sk}$ is the total no of packets transmitted between the source and Relay Node and from the relay node to the sink node. $Tx_{tot,sk}$ is the total number of times the transmission and re-transmission attempts are made for all packets and r is the average weighing factor. The path loss ratio for the sensor node to communicate with the sink node in case of emergency can be calculated using equation 11

$$P_{Loss(emergency)} = \frac{PLk_{emergency)max}}{PL_{max}} \tag{11}$$

Path losses ratio factor will be minimum in case of emergency. The path less ratio of a sensor node to communicate with the relay node and from the relying node to sink. Equation 12 is used in normal circumstances.

$$P_{Loss(normal)} = \frac{PLk_{normal)max}}{PL_{max}} \tag{12}$$

Equation 13 can express the Signal to Noise Ratio (SNR) relationship.

$$SNR = P_{rss} - N_i - N_e \tag{13}$$

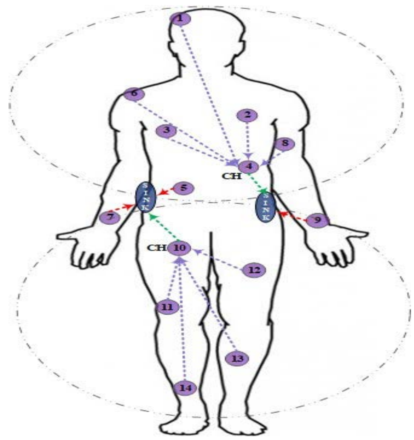

FIGURE 11. Sensor Node Deployment on Human body.

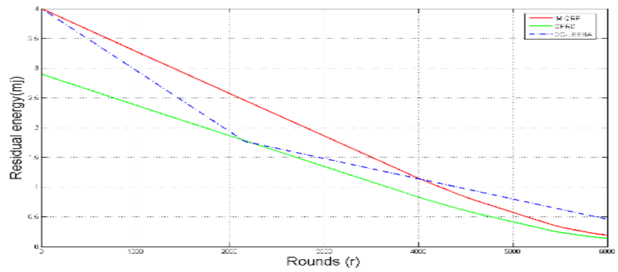

FIGURE 12. Residual energy.

where,

$$P_{rss} = P_{tx} - PL_d + X_\partial \tag{14}$$

$$P_{rss} = P_{tx} - PL_{do} - 10log_n\left(\frac{d}{d_o}\right) + x_\partial \tag{15}$$

The SNR ratio is calculated in dB at the receiver side. $PL_{(d)}$ is the path loss at distance d, d_0 is the reference distance d, n is the path loss exponent, $X_\eth$ is the zero-mean Gaussian with standard deviation, ∂ represents the effect of the time-varying channel fading, P_{rss} is the received signal strength, N_i is the Internal Noise, N_e is the environmental noise, and P_{tx} is the transmission power.

Figure 11 describes about the phantom of sensor nodes deployed on human body. There are total 14 Sensor nodes deployed on human body. Two clusters are scheduled on human body. Each cluster is having its own cluster head (CH) which is responsible to communicate with Sink Node. For effective data transmission Sink nodes had been deployed to maximizing the data transmission coverage on human body. The Simulation and Experimental results are discussed which are based on the residual energy of sensor nodes, path loss ratio, QoS and SNR ratio versus 6000 number of rounds.

In Figure 12, a comparison of QPRD, CO-LEEBA and proposed IM-QRP is performed based on residual energy for sensor nodes deployed on the human body.

Table 6 describes about the experimental results achieved on the basis of simulation parameters achieved in case of

TABLE 6. Analysis of residual energy vs total number of rounds.

Sr No	Protocol Name	Number of Round (1000)	Number of Round (2000)	Number of Round (3000)	Number of Round (4000)	Number of Round (5000)	Number of Round (6000)
1	QPRD	4J	3.3 J	2.8 J	2.1 J	1.1 J	0.2 J
2	CO-LEEBA	4J	2.9 J	2.3 J	1.8 J	0.9 J	0.2 J
3	IM-QRP	4J	2.6 J	2.2 J	1.9 J	1.2 J	0.3 J

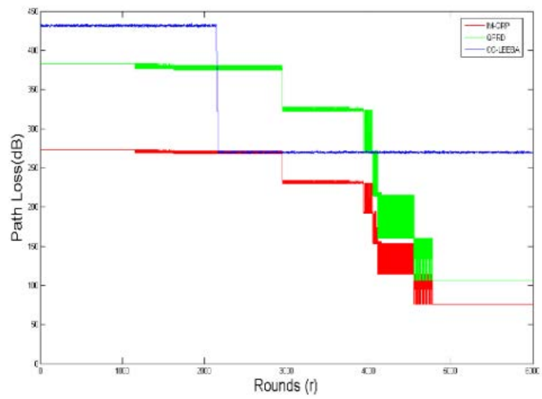

FIGURE 13. Path loss ratio.

TABLE 7. Analysis of path loss vs total number of rounds.

Sr No	Protocol Name	Number of Round (1000)	Number of Round (2000)	Number of Round (3000)	Number of Round (4000)	Number of Round (5000)	Number of Round (6000)
1	QPRD	83 dB	118 dB	176 dB	260 dB	320 dB	380 dB
2	CO-LEEBA	196 dB	265 dB	310 dB	391 dB	416 dB	440 dB
3	IM-QRP	79 dB	133 dB	166 dB	204 dB	236 dB	270 dB

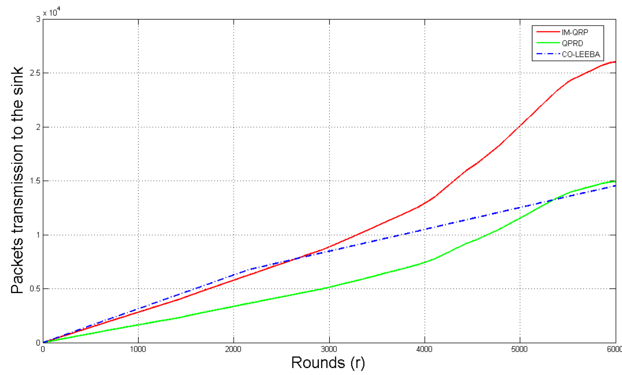

FIGURE 14. Link reliability (packet delivery ratio).

Figure 11. In case of IM-QRP the residual energy achieved is 4 joules initially in the start. However, in QPRD and CO-LEEBA protocols sensor nodes have the same amount of initial energy as in case of proposed IM-QRP in the start. The proposed protocol results are much better as the number of rounds increase in the network. The maximum residual energy of sensor nodes is 0.3 Joules achieved at approximately 6000 number of rounds in case of IM-QRP and in

TABLE 8. Analysis of link reliability vs total number of rounds.

Sr No	Protocol Name	Number of Round (1000)	Number of Round (2000)	Number of Round (3000)	Number of Round (4000)	Number of Round (5000)	Number of Round (6000)
1	QPRD	3200 packets	4700 packets	7600 packets	11300 packets	13400 packets	15000 packets
2	CO-LEEBA	4800 packets	6400 packets	8900 packets	10700 packets	12900 packets	15000 packets
3	IM-QRP	6900 packets	9900 packets	13400 packets	17600 packets	21000 packets	26000 packets

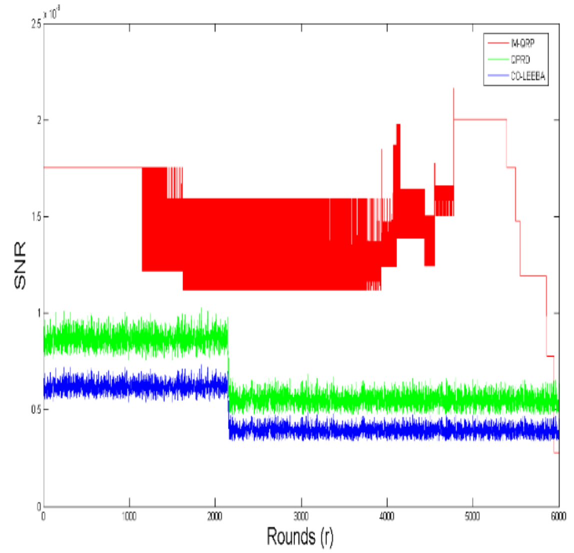

FIGURE 15. Signal to noise ratio.

TABLE 9. Analysis of link reliability vs total number of rounds.

Sr No	Protocol Name	Number of Round (1000)	Number of Round (2000)	Number of Round (3000)	Number of Round (4000)	Number of Round (5000)	Number of Round (6000)
1	QPRD	0.2	0.3	0.44	0.52	0.57	0.6
2	CO-LEEBA	0.39	0.4	0.64	0.74	0.83	0.9
3	IM-QRP	0.86	1.09	1.26	1.84	2.08	2.2

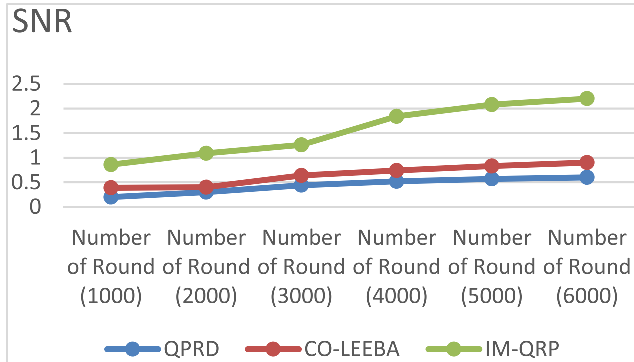

FIGURE 16. Analysis graph of SNR VS total number of rounds.

TABLE 10. Comparison Of IM-QRP With CO-LEEBA And QPRD Protocols.

WBAN Routing Protocols vs Evaluation parameters	Residual Energy	Path loss	Link Reliability	SNR
Co-LEEBA **[43]**	YES	YES	NO	NO
QPRD **[67]**	YES	NO	YES	NO
IM-QRP	YES	YES	YES	YES

case of QPRD it is 0.2 Joules at 6000 number of rounds. This means that in case of the proposed scheme, the sensor nodes will retain the maximum amount of energy for the greater amount of time within 6000 number of rounds as compared to the QPRD scheme. There is an improvement of 10 % of the residual energy in IM-QRP as compared to the QPRD. The reason for attaining the better residual energy as compared to the existing schemes is due to the arrangement of sensor nodes and relay nodes on the human body.

In Figure 13, a comparison of QPRD, CO-LEEBA and proposed IM-QRP is performed based on path Loss for sensor nodes deployed on the human body.

Table 7 describes about the experimental results achieved on the basis of simulation parameters achieved in case of Figure 12. Path loss ratio is calculated for 6000 number of rounds. In case of CO-LEEBA scheme, the maximum path loss ratio is 440 dB at initial number of rounds. In case of proposed scheme, the maximum path loss ratio is 270 dB at initial number of rounds. In case of QPRD, the maximum path loss ratio is 380 dB at initial number of rounds. However, in case of IM-QRP, the performance analysis of path loss ratio is 30 % minimum as compared to the QPRD and CO-LEEBA. Path loss ratio is the difference between the transmitted and received signal power [70]. In the WBAN communication path loss ratio occurs due to movement in different human body postures and clothes that affects the transmitted signal [2]. The position and arrangement of sensor nodes on the human body along with the capability of the relay node to effectively communicate with sensor nodes and sink nodes reduce the path loss in IM-QRP routing protocol.

In Figure 14, a comparison of QPRD, CO-LEEBA and proposed IM-QRP is performed based on Link reliability for sensor nodes deployed on the human body.

Table 8 describes about the experimental results achieved on the basis of simulation parameters achieved in case of Figure 13. The Link reliability improves the QoS. The QoS depends on maximum number of packets delivered to the sink node. Improvement in RSSI also increases QoS [70]. In case of proposed scheme, IM-QRP protocol sends 26000 packets to the sink node at maximum 6000 number of rounds. In case of QPRD and CO-LEEBA 15000 packets are sent to the sink node at maximum 6000 number of rounds. From results, it is observed that there is an improvement of 10% in IM-QRP protocol in the transmission of packets towards the base station as compared to the QPRD and CO-LEEBA. By introducing the relay nodes deployed on the human body near to the sink node effectively improved the QoS.

TABLE 11. Comparitive analysis of complexity of routing protocols in wban.

Sr No	Algorithms	Contributions	Limitations	Time Complexity
1.	M-ATTEMPT [39]	• Select thermal heat of hot spot during Routing Mechanism. • Temperature Aware Routing Protocol for WBAN	• Maximum power Transmissions is utilized by sending maximum number of packets directly towards the sink Node.	$O(n^2)$
2.	RE-ATTEMPT [24]	• Selects the Route for data transmission with minimum hop count and lesser delay as compared with M-ATTEMPT. • Routing Path quality is better than simple M-ATTEMPT	• Minimization in Network Life time due to increased energy consumption. • Short range transmission using IEEE 802.15.6 Standard	$O(n)$
3.	QPRD [67]	• QoS Aware Routing Protocol in WBAN. • Ensures Higher data transmission rate (maximum throughput) and limited packet drop with stable Network Traffic	• Less coverage rate and exploration • Transmission link failure can occur. •	$O(n \log n)$
4.	CO-LAEEBA [43]	• QoS Aware Routing Protocol for WBAN having minimum path Loss. • Having Low Energy Consumption and High packet delivery ratio	• Minimized Network life time, i.e. limited number of alive nodes for maximum amount of time	$O(n * m)$
5.	IM-QRP [proposed]	• Improved QoS Aware Routing protocol for WBAN. • Higher SNR, Maximum throughput, maximum residual energy of sensor nodes, Maximum number of packets transmissions, Enhanced Network life time	• Integration with 6G wireless framework is future research challenge.	$O(n)$

In Figure 15, a comparison of QPRD, CO-LEEBA and proposed IM-QRP is performed based on Signal to Noise Ratio for sensor nodes deployed on the human body.

Table 9 describes about the experimental results achieved on the basis of simulation parameters achieved in case of Figure 14. Figure 14 represents the SNR of proposed IM-QRP. The maximum SNR of IM-QRP is 2.2 * 10^8 dB as compared to QPRD and CO-LEEBA. QPRD achieves 0.9 * 10^8 dB where as CO-LEEBA achieves 0.6 * 10^8 dB. High SNR improves the communication performance of the proposed IM-QRP by the addition of a limited amount of noise added to the original signal [71]. By deploying the proposed network model on the human body at home as compared to the hospital environments, IM-QRP provides improved SNR as compared to the existing schemes. QPRD and CO-LEEBA schemes are developed for deployment of WBAN inside hospital environments. IM-QRP provides 7% improved results in case of SNR as compared to the QPRD and CO-LEEBA due to the deployment of relay nodes on the human body. Table 10 is about the comparison among existing routing protocols Co-LEEBA, QPRD and the proposed IM-QRP. From the graphical results obtained in Figure 16, it has been observed that the proposed routing protocol is more efficient as compared to the existing routing protocols in terms of residual energy, path loss, link reliability and in SNR. SNR is a new parameter being considered in IM-QRP.

Table 11 describes in deep detail about the comparative Analysis of Routing Protocols in WBAN. IMQRP Routing protocol Algorithm time complexity is compared with CO-LAEEBA, QPRD, M-ATTEPT and RE-ATTEMPT. The complexity of the Algorithms for routing protocols are based on their strengths and limitations. From the Analysis of the existing protocols it has been observed that M-ATTEMPT routing protocol achieves $O(n^2)$ time complexity as Best case.

Thereason for $O(n^2)$ time complexity is based on direct data transmission from sensor nodes towards the sink node i.e. direct transmission in long and short range. RE-ATTEMPT Routing protocol achieves the Algorithm time complexity as $O(n)$. The reason for using $O(n)$ Time complexity is based on minimum hop count and lesser delay in packets transmissions. QPRD Routing protocol had time complexity of Algorithm $O(n \log n)$ as Best case. The algorithm time complexity $O(n \log n)$ is based on higher data transmission and maximum throughput. Algorithm Time complexity for Co-LEEBA routing protocol is $O(n^*m)$. The reason for $O(n^*m)$ time complexity is based on in achieving QoS in Low Energy consumption based data transmissions. The time complexity of IM-QRP proposed routing protocol is $O(n)$. The reason for achieving $O(n)$ time complexity is based on stable data transmission and enhances Network life time including maximum residual energy of sensor nodes and sink nodes in each cluster.

VI. CONCLUSION AND FUTURE RECOMMENDATIONS

In this paper, we have proposed Improved QoS Aware Routing Protocol (IM-QRP) for WBAN. The proposed protocol is capable to select the most feasible route and significantly improves the network lifetime by introducing arrangement of sensor nodes and relay nodes mounted on the human body based on the postural movement of patients. The major Contribution of this research work is based on improvement in QoS provision. Improvement in residual energy of sensor nodes and High SNR results in strong link reliability of the overall network. The strong link reliability improves the RSSI which enables the maximum number of packets to receive at receiver side (sink node). Validation of the proposed protocol is performed by simulations, using MATLAB. QRP protocol is compared with the QPRD and CO-LEEBA protocols. IM-QRP protocol shows significant improvement in residual energy, QoS, minimization of path loss and improvement in SNR. The future works are focused on integrating the proposed WBAN framework with smart homes by deploying Internet of Things (IoT) based framework.

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