The Fusion of IOT and Wireless Body Area Network

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1 Introduction

Recently, there is an emerging interest in wireless body area networks (WBANs) since they enable real-time and continuous monitoring in various fields including telemedicine, entertainment, sports, and military training. Specifically, it is one of the most convenient, cost-effective, and accurate technologies for health monitoring [1, 2]. In traditional healthcare systems, patients have to stay in hospitals, but WBANs free the patients from staying. They reduce medical labor cost and cost of infrastructure. In WBAN, sensors are placed in or on the human body to quantify the physiological signals of the patients [3]. The utilization of WBANs may enable remote diagnosis of diseases in an early stage. These systems provide uninterrupted health monitoring accommodations, sanctioning patients to perform everyday activities, which leads to the enhancement of the quality of life [4]. Sensors sense the signal to the sink which is further remitted to the medical server room where medical experts monitor the patient's activities. WBAN is a resource-constrained technology by their circumscribed battery life, bandwidth, recollection, energy consumption, etc. These are issues that have to be considered while designing an incipient protocol or algorithms for network [5]. Sundry authors proposed routing protocols or MAC protocols to increase the network lifetime of the network. The number of growing inhabitants increases within the whole universe and swells as each further day protection of health cost is enhancing [2, 3, 8, 10, 14]. The number of lonely human beings is increasing as well. Entirely these elements are motivating

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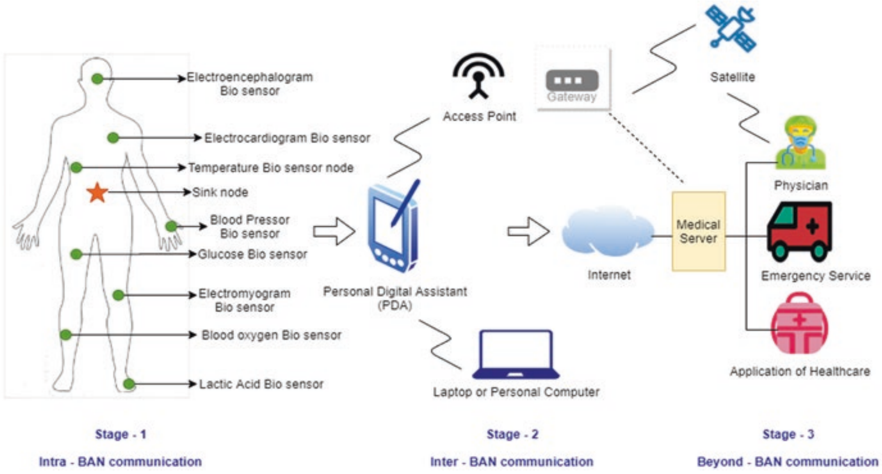

Fig. 1 Architectural model of wireless body area network

to introduce WBAN that helps enhance living wellness programs. M-health as well as telemedicine [6] gets many benefits from this concept [15–17] (Fig. 1). Routing is used to transmit message from one place to another.

Physical elements of the body observed with the use of sensors are respiratory rate, heart rate, blood pressure, movement of the body, levels of glucose, temperature of the body, and so on. By using such technique through Internet of things, remote tracking of disease detection, fitness monitoring, low collision rate, and faster message transmission occur sooner within this smart system.

Possibility may occur or not for sending anatomical signals whether sensor node dries up of battery power [18]. Because of resource limitation (processing power, memory, as well as battery power), low transmission reach, as well as path loss, one well-organized energy routing protocol is required in favor of maintenance of WBAN [19]. Stable Increased-throughput Multi-hop Protocol for Link Efficiency (SIMPLE) is a multi-hop routing protocol used inside WBANs [20]. By achieving efficient energy as well as high duration of network, this utilizes route as well as residual energy elements to choose the afterward hop. Even so, by using one sink, that disjoints problem abides equal. Inside DARE – Distance Aware Relaying Energy efficient routing protocol – patients in the hospital unit are observed in favor of various anatomical elements [21, 22, 11]. The on-body relay node has more energy compared with further sensor nodes. Those are duration of network addition, energy efficiency, classifications of anatomy, as well as management of position adjustment. Generally, duration of network addition should be regarded incorporating those classifications of anatomy for balanced performance as well as warranty of productive WBAN control. Additionally, WBANs' integration is accompanied by cloud computing shows within starting of recent cost effectual as well as data operated structure. It aids to boost this implicit hospital topic within future.

Thus, here we study dual sink technique utilizing clustering inside body area network (DSCB). This is very important at improving duration of network with effectively using nodes battery time duration. Additionally, connection of nodes toward forward nodes or sink is made certain as utilizing both sink nodes. Inside suggested protocol, we possessed the use of that dual sink accompanied by clustering technique. Utilizing clustering technique stabilizes the load of network at sink nodes. Calculation of SNR link occurs too as well as utilization inside searching power of transmission required as sensor node. Those elements make sure adeptly the use of nodes assets for improving capacity of network. Numerous demanding necessities inside WBAN are there like enhancing duration of network, end-to-end delay reduction, as well as path loss and achieving good communication. Though in WBAN health – care – data is critical type that requires to be redirected in the absence of whichever disruption as well as delay. Consequently, authors have suggested multiple routing protocols as well as algorithms for effective and fast data delivery. Few of them are studied and explored.

1.1 WBAN System Architecture

Millions of people die from chronic or fatal diseases every year. The most common reason of such fatal diseases is the lack of timely disease diagnostic services. The authors in [3] revealed that most of the diseases can be controlled if they are identified in their early stages. So there is a pressing need for proactive, affordable, and fast healthcare systems for continuous health monitoring and early detection of diseases. With the advancement of new wireless technologies, in WBANs, the system has different monitoring sensor nodes such as sensors and actuators. The sensor nodes are used to measure certain body parameters, whereas the actuators act on received data from other sensor nodes. In addition, personal devices act as a control unit to collect data from sensor nodes and transmit to the medical server using a wireless link [5].

A WBAN's systems architecture consists of several wireless devices and network components.

- **Sensors Nodes**

Sensor nodes measure the vital parameters of the human body and process the collected data and transmit to the control unit. Some types of these sensor nodes are heartbeat, temperature, humidity, DNA sensor, transmission plasmon biosensor, thermistor, magnetic biosensors, spirometer, blood glucose, pulse oximetry, motion, electrocardiogram (ECG), EEG, and EMG. The design of sensor nodes of WBANs is critical and should fulfill the main requirements such as wear ability, reliability, security, and interoperability. A sensor node consists of sensor hardware, processor, memory, power unit, and a transceiver.

- **Actuator Nodes**

This device acts according to the data received from the sensor node or through the interaction with the user. It consists of actuator hardware to administer medicine, processor, memory, power unit, and transmitter/transceiver.

1.2 Applications of WBANs

WBANs provide a wide range of monitoring applications in different fields such as ubiquitous healthcare, emergency, military, sports, interactive gaming, and many others [6]. In the section, we discuss the WBANs applications in the healthcare field. It provides continues health monitoring of patients and manages the necessary medication during their stay at home or elsewhere [7]. The in-body sensor nodes monitor patient's body organ functions such as pacemakers and implantable cardiac defibrillators, restoration of limb movement, and control of bladder function. On-body sensor nodes are used in medical applications to monitor blood pressure, heart rate, temperature, and respiration. Some of the WBAN applications are discussed in the following subsections.

1.2.1 Cardiovascular Application

This application is used to monitor cardiovascular disease which is one of the primary reasons of death. Healthcare service providers can prepare patient treatment in advance by any abnormal information from sensor nodes about heart rate or irregular heart functions [8].

1.2.2 Cancer Detection

Nowadays, cancer is one of the biggest threats for human life. It effects millions of people, and the number of effected people is increasing every year [9]. A set of small sensor nodes have capabilities to detect the nitric oxide which is usually produced by cancer cells. Sensor nodes can be placed in the patient's affected body part. This allows medical professionals to detect cancer tumors without any biopsy.

1.2.3 Blood Glucose Monitoring

Diabetes is one of the serious chronic diseases all over the world. According to the World Health Organization, diabetes has been gradually increasing over the years. More than 400 million adults are suffering from diabetes globally. If this disease is not treated properly, it can cause some other serious complicated diseases in the body like blindness, stroke, kidney disease, heart disease, and high blood pressure [10]. WBANs can provide effective treatment to diabetic patients by providing continuous and accurate blood glucose level monitoring. Currently, the typical way to measure blood glucose level is to prick the finger and place the blood drop on the test strip. This method can damage the tissues by constant pricking over the years. Wireless biomedical sensors can be implanted in the patient's body causing less invasion in monitoring glucose level several times a day. Through WBAN sensors, doctors also inject insulin in patients automatically using an actuator node whenever a glucose level is reached at a certain threshold [11, 12].

1.2.4 Stress Monitoring

Stress is a foremost cause of illness and different diseases. Chronic stress leads to production of psychological issues such as high depression and anxiety. It can also cause high coronary heart disease, morbidity, and mortality. WBANs can provide real-time stress monitoring in individuals and help their physicians provide proper treatment [13].

1.2.5 Artificial Retina

Retina prosthesis chips can be implanted in the human eye, which will help patients who are suffering from no vision or limited vision be able to see at an adequate level. In the Smart Sensors and Integrated Microsystems (SSIM) project by Wayne State University and Kresge Eye Institute, a retina test system was developed which consists of integrated circuits and array of sensors [11, 14].

1.2.6 General Health Monitoring

WBANs have also been proposed for general health monitoring. These types of applications help those patients which are out of the hospital; however, their health status is continuously monitored by these applications.

1.2.7 Non-medical Applications

WBANs also offer other non-medical applications such as public safety, monitoring battlefield activities, gaming, and entertainment applications.

2 Review of Existing Works

For WBAN, many authors suggested about the multi-hop routing protocol that functions effectively at consumption of energy, duration of network, as well as PDR, i.e., Packet Delivery Ratio [20]. Attached nodes are utilized within the network that's employed like relay nodes. Cost function is computed depending upon space by considering supervisor node, the residual energy, velocity vector of receiver, and transmission power of node for selecting promoter node. In WBAN, another routing protocol is used, i.e., Balanced Energy Consumption (BEC). In BEC, cost function for choosing relay node is dependent upon the distance of node from the sink. Relay nodes are being chosen for every stage for distributing uniform load. Whether that node is near to that sink, it transmits its information straightly, or else it's transferred to the closest relay node. In support of that protocol, Mobile-ATTEMPT (M-ATTEMPT) is being examined, and one enhanced technique is suggested. Such quality of proposed protocol is shown across different tests [13, 22]. The outcomes displayed obvious enhancements rather than before routing protocols with respect to duration of network, residual energy, and throughput. In diversified WBAN [23], NEW-ATTEMPT is an efficient energy routing protocol which attains an excessive throughput. For choice of relay node, by transferring its information to sink from node, a cost function is utilized. This is computed at residual energy, gap from data rate, as well as transmitter node's sink. Omar Smail et al. suggested efficient energy and genuine as well as secure routing protocol for Mobile WBANs [24, 25]. The routing protocol enhances duration of network with thoroughly utilizing the residual energy. Secure links and efficient energy are chosen for transmission utilizing the introduced model. Inside [26], those researchers suggested efficient energy on the basis of fuzzy adaptive routing protocol. This utilizes clustering method accompanied by straight transmission mode to sink node. This extracts the place as well as cruciality of sensor node toward the data forwarding conclusion also. In [27], the author's aim is to expand a strategy which assists a genuine data transmission for medical utilization of WBANs. RTT, i.e., Restricted Tree Topology protocol, utilizes dual-hop topology of network through transitional relays which are utilized as forwarder among sensor and sink nodes. RTT procedure expands that to a tree topology from star topology by limiting the number of hops. This method assists for solving issues like excessive loss of propagation, energy limitation, as well as reliability limitation. The standard of channels among variety of nodes is looked over utilizing RSSI, i.e., Received Signal Strength Indicator. RTT technique is capable of managing energy as well as reliability, by using opportunistic as well as dynamic relays. Even so, it utilizes a big number of relays that show discomfort in patients. Harsharan et al. talked about the use of WBAN accompanied by a variety of sensor nodes inside the healthcare environment [28]. Conversation of computation of residual energy as well as cost function is over. For choosing top forwarder node, utilization of cost function occurs. Here, the suggested protocol attains additional stability period of energy by comparing its counterpart as well as its cost-effectivity. The author in [29] proposed a strategy for naming WBANs, RE-ATTEMPT

(Reliability Enhanced Adaptive Threshold-based Thermal Unaware Energy Efficient Multi-Hop Protocol). On the basis of amount of energy, wireless sensor nodes are employed at determined locations. Urgent sensed information is straightly transmitted to that sink node although usual information is transmitted utilizing multi-hop transmission. The protocol utilizes less hop count like cost function for choice of route. Co-LAEEBA (cooperative Link Aware Energy Efficient protocol) routing strategies are introduced with the help of Sheeraz et al. [30]. For choice of probable route toward the sink node, the cost function is utilized. It's dependent on the distance of node from residual energy and the sink. After simulation, the outcomes display enhancement in execution of suggested protocol, by comparing with other chosen protocols utilizing described perimeter. In [21] the authors suggested one routing strategy for WBAN named DARE (Distance Aware Relaying Energy efficient). Inside such investigation, eight patients inside the hospital were supplied by seven sensor nodes, all being observed for multiple physiological variables. This study uses mobile sink node that is located at multiple locations of hospitals' quarter to create multiple topologies. By mitigating the consumption of energy, one on-body relay node located at the patient's chest is utilized to gain information from further nodes as well as transmission toward the sink. The on-body relay node holds greater energy by comparing with further sensor nodes. SIMPLE [20] with efficient power and reliable high-throughput routing strategy for WBAN is introduced by Q. Nadeem et al. With lengthy duration of network as well as minimum consumption of energy, multi-hops topology is being pursued. For selecting forwarder node and cost function on the basis of low distance toward more residual energy and sink is utilized. Even so, because of the utilization of one and only sink, the detached among sensor nodes located at foots as well as hands can occur.

3 Fusion of IoT with WBAN

The WBAN architectural model is classified into four surfaces [7] shown in Fig. 2. The first surface (Surface 1) called BAN surface combines various wireless sensor nodes employed within one restricted physiographic region, so making one WPAN – Wireless Personal Area Network. It depends upon owned style by positioning sensor nodes at human anatomy within mode of wearable sensors stitched inside fabrics, tiny marks (on-anatomy sensor) else placed inside anatomy of human (inside body sensor). SNR (signal-to-noise ratio), RNF (Receive-Noise-Figure), and BPL (body path loss) are three important components that turn on the sensor node's power transmission. SNR is based on standard of transmission link. RNF component is based on gadget. Different devices give different results by it. This receiver affects BPL within utilization as well as radioactivity system [31, 32]. Various customer interactivity with gadgets on Surface 2 are there (interactivity surface customer) that importantly performs like access point (AP). The sensor nodes sense information which is sent toward the treated server like pharmaceutical server located on hospital by such surface. With the basis of utilized wireless

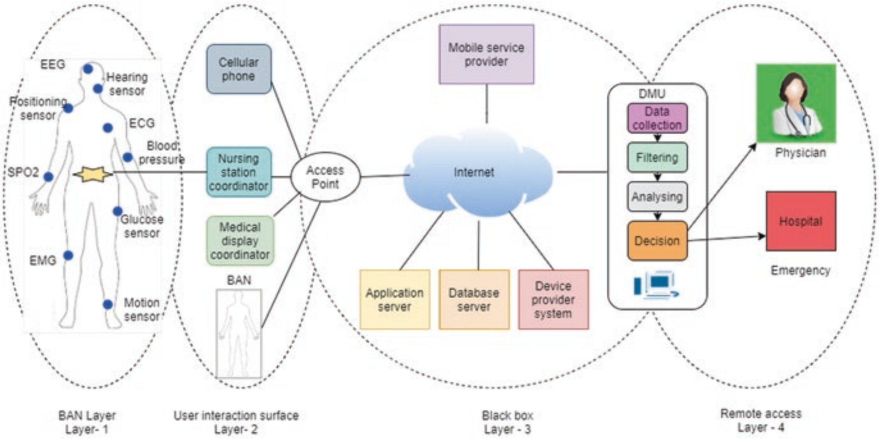

Fig. 2 Architecture of WBAN for e-health system

transmission protocol, surface 2 holds various gadgets like smart phones or PDAs which are based on Bluetooth. Those gadgets gain as well as send information toward surface 3. Due to observing of populous, by one AP equips various quarters inside home that is also attached with one wired else wireless network such as Wi-Fi [12]. Surface 3 carries the DMU – Decision Measuring Unit. This attaches with the back-end pharmaceutical server located inside the hospital by the World Wide Web. This consequently acts every main task of computation. The major task of the DMU is for collecting information, filtering, as well as analyzing to make decisions. Surface 4 is the end surface. This supplies medical management utilities toward staffs with monitoring. The processed information with the help of DMU is communicated with remote pharmaceutical server. Inside hospital it locates server, at which physician treated build correct conclusions at gained data. Such surface provides importantly dual various tasks called medical management services and urgent services.

Figure 3 describes about the DSBC routing protocol . The expanding duration of network focuses on DSBC protocol, enlarging throughput as well as association. Also, this stabilizes burden at a sink node. Afterwards, to sense information, every node sends this toward the sink node with straightly else by sender node. The sender node uses the CF (cost function) for selection. It is calculated for every nearer node calculates CF that is depended upon path from sink node, power of transmission as well as residual energy. By utilizing SNR, link standard is inspected too. The least CF of a nearer node is chosen for the sender. What we talk about in literature review, such larger part of suggested strategies utilize a sink node that gains information sensing from sensor nodes as well as sends this toward end server afterward accumulation. Moreover, nearly without protocol inside, WBAN utilizes clustering technology. For this, a few issues appear that don't possess awareness like:

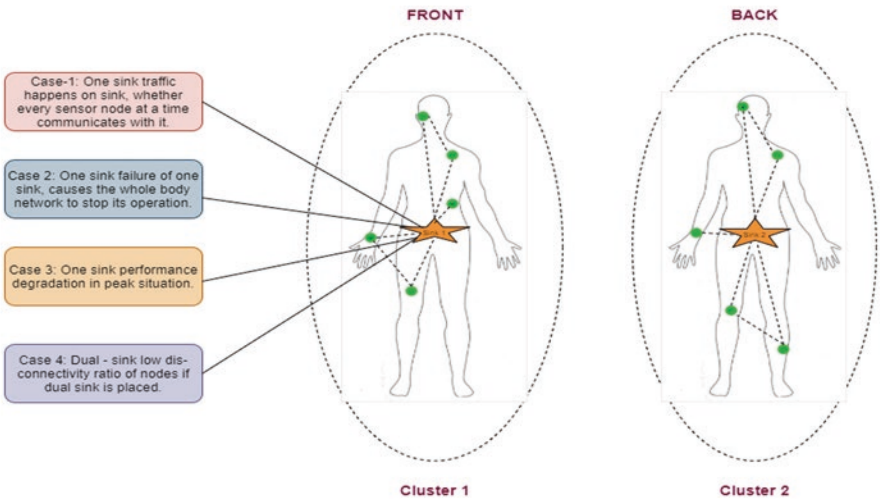

Fig. 3 Diagrammatic approach for DSBC protocol

- At first, there are many possibilities of traffic phenomenon on sink node while every sensor node forwards information at the same time, mostly on the condition of that censorious information.
- Secondly, WBAN' negligence of one sink node shows within absolute negligence while sink performs like the main hub.
- Third, degradation of action on sink node occurs while several sensor nodes forward information on time that shows for short transport ratio.
- Fourth, to maximize anatomy description, requirement of many sensor nodes occurs as well as whether a cluster proposal is utilized that may generate burden at one sink node.
- Fifth, LOS (Line of Sight) transmission is needed within several plots that can't be attained while anatomy is within movement.

Consequently, a routing strategy is presented by us known as DSCB that controls above-named lacks inside WBANs. Inside the DSCB protocol, path-loss consequences reduction, load of network leveling, as well as achievement of LOS transmission occurs.

The suggested routing strategy is presented by us in such part known as dual-sink software-defined networking proposal utilizing clustering inside BAN (DSCB) that improves WBAN execution by applying clustering strategy between both sinks. DSCB places both sinks nodes which are called S_1 and S_2 between ten sensor nodes at human anatomy. Sink nodes S_1 and S_2 are dissimilar with further distributed sensors at anatomy. The sink nodes possess superior assets by comparing with further sensor nodes like cell power, transmission power, memory, etc. Distribution of four sensor nodes occur at anterior part of human anatomy accompanied by S_1 like CH of them as well as four sensor nodes at behind of human anatomy accompanied by S_2 like CH of them. A node is located at right hand's anterior part when a node is

Table 1 Energy framework estimates

Parameters	Values
Initial energy ($E_{initial}$)	0.6 J
Minimum supply voltage	1.8 V
Frequency (f)	2.4 GHz
$E_{Tr\text{-}am}$	1.98nJ/bit
$E_{Tx\text{-}Cty}$	16.7nJ/bit
$E_{Re\text{-}Cty}$	36.3nJ/bit
DC current (Tr)	10.6 mA
DC current (re)	17 mA
Wavelength (λ)	0.138 m

located at behind of left hand. The waist locates S_1 as well as Lumbar S_2. With the movable part, these nodes which are connected toward the hands are attached to one of the two sink nodes utilizing LOS transmission. Figure 3 shows the suggested DSCB protocol's topology (Table 1 and 2).

3.1 Starting Stage

Inside such stage, two sink nodes (S_1 and S_2) telecasts packets i.e. "Hello" that carry IDs as well as places of them. On acceptance, every sensor node transmits "Reply" information that carries IDs, place as well as residual energy. With such procedure, every node plus two sink nodes gain data regarding every further node. To find nearer nodes this aids.

3.2 Cluster Evolution

Access point (AP) or cluster heads are used to receive messages from sensor nodes. Time period location follows cluster evolution toward every cluster participant, occurring with the help of CHs utilizing TDMA protocol.

3.3 Sensed Information Stage

Activation of sensor nodes occurs just within the assigned time period, or sensor nodes possess snooze way. As the sensor node turns agile, this initializes to sense information. That information sensing is inspected for cruciality firstly. Whether it is serious, it's transmitted straightly toward the sink node or sink node through multi-hop.

3.4 Choice of Forwarder Stage

DSCB calculates sender node with the help of link's SNR, distance (di) in distinction to sink, residual energy (E_{Rn}), as well as transmission power (T_{p}). The estimation of threshold considering SNR possesses default inside DSCB protocol that is same with "1". Whether one sensor node does sense little information as well as which isn't censorious, this chooses one node in distinction to its nearby table. After that, numerous hops to sink are added up for selecting nearby direct toward the sink. Whether numerous hops possess zero, such node is regarded by straightly attaching toward the sink, so this transmission occurs straightly with no sending node. Or SNR of link is computed whether less than 1, for becoming forwarder, it rejects such node as well as it records data of itself. Whether the SNR of link is greater than 1 after that node's Function of Cost (FC) be about is computed. To calculate the sensor node's residual energy (E_{Rn}), the following equation is used:

$$E_{\text{Rn}} = E_{\text{In}} - E_{\text{Cn}} \tag{1}$$

where n indicates numerous nodes utilized, E_{Rn} as residual energy, E_{In} as initial energy, and E_{Cn} as energy consumption node that computes the equation below:

$$E_{\text{Cn}} = E_{\text{Tr}} + E_{Re} + E_{\text{Cty}} \tag{2}$$

Here, E_{Tr} and E_{Re} are the amount of energy consumption with the help of node transceiver radio at the time of data transmission as well as reception. E_{Cty} is known as consumption of energy occurred with the help of electronic circuitry of node. The node n_j^i describes about the amount of energy absorbed at the time of setup period P_{su}, beginning on time 0 as well as consumption of energy which occurred in every round $E_{\text{Rnd}}{}_j^i$ (ti):

$$E_{\text{Rnd}}{}_j^i(\text{ti}) = \int_{ti+P_{\text{su}}}^{ti} E_{\text{Cn}_j}^i(t)\,dt \tag{3}$$

$$= \int_{ti+P_{\text{su}}}^{ti} \left(E_{\text{Tr}_j}^i(t) + E_{Re_j}^i(t) + E_{\text{Cty}_j}^i(t)\right)dt \tag{4}$$

where $E_{\text{Rnd}}{}_j^i$ = energy needed with the help of node n_j^i at time of period P_{su} also in every cycle.

For finding energy value needed considering the transmission as well as reception, we use these equations:

$$E_{\text{Tr}}(k,di) = E_{\text{Tr-Cty}} * k + E_{\text{Tr-am}}(k,di) \tag{5}$$

$$E_{\text{Tr}}(k,di) = E_{\text{Tr-Cty}} * k + \mathtt{T}_{\text{am}} k di^2 \tag{6}$$

$$E_{Re}\left(k\right)=E_{Re-\mathrm{Cty}}*k \tag{7}$$

where "di" = entire distance among receiver Re as well as transmitter Tr. E_{Re} as well as E_{Tr} = consumption of energy fares for every packet with help of receiver as well as transmitter accordingly. $E_{\mathrm{Re\text{-}Cty}}$ and $E_{\mathrm{Tr\text{-}Cty}}$ = consumption of energy estimates for every bit considering receiver as well as transmitter circuitries of electronics accordingly. k = length of packet at which $\in_{\mathrm{am}}$ = radio amplifier kind. Loss of coefficient = l_o that is distinct inside the human anatomy by comparing with earthly networks; thus, Eq. (6) is written as l_o:

$$E_{\mathrm{Tr}}\left(k,di,l_o\right)=E_{\mathrm{Tr-Cty}}\,k+\in_{\mathrm{am}}\,nkdi^{lo} \tag{8}$$

$$P_n.T=\frac{\mathrm{SNR}}{\beta} \tag{9}$$

where $P_n.T$ = power of transmission as wireless signal and β the path-loss parameter. To find the entire distance di among some sensor node as well as nearby sensor node or sink node of itself, below equation is used:

$$di\left(n,D\mathrm{ts}\right)=\sqrt{\left(P_n-P_{D_{ts}}\right)^2+\left(Q_n-Q_{D_{ts}}\right)^2} \tag{10}$$

$$Fn.C=\frac{di}{E_{Rn}*P_n.T} \tag{11}$$

where $F_n.C$ is function of cost of some node.

3.5 Consumed Energy as well as Routing Stage

An important edge with utilizing both sink nodes does which sink's more nodes undergo straight transmission span. Packets data goes straightly bring of short delay at utilizing single-hop transmission. Inside DSCB, straight transmission happens within various instances. For few instances, this protocol chooses sender node considering routing motive. Consumption of energy with the help of sensor nodes inside multi-hop transmission indicates [18]:

$$E_{\mathrm{Tr-Mu(k,di)}}=n*\left(E_{\mathrm{Cty}}+E_{\mathrm{am}}\right)*k*L_{\mathrm{EN}} \tag{12}$$

$$E_{Re-\mathrm{Mu(k)}}=\left(n-1\right)*\left(E_{\mathrm{Cty}}+E_{\mathrm{am}}\right)*k \tag{13}$$

$$E_{\mathrm{Tot-Mu}}=E_{\mathrm{Tr-M}}+E_{Re-\mathrm{Mu}} \tag{14}$$

where E_{Tr-Mu} as well as E_{Re-Mu} represents energy needed considering transmission as well as reception with help of transmitter as well as receiver accordingly inside multi-hop transmission. k = bits dimensions, di = distance among sink node as well as sensor nodes, E_{Cty} = energy needed considering the transmitters as well as receiver's electronic circuit, E_{am} = for amplifying k numerous bits toward distance di for this energy needed, n = numerous nodes, and L_{EN} = energy loss at a time of communication by medium of transmission.

Straight communication's consumption of energy is [5]:

$$E_{Tr-di(k,di)} = \left(E_{Cty} + E_{am}\right) * k * L_{En} \tag{15}$$

$$E_{Tot-di} = E_{Tr-di} \tag{16}$$

where $E_{Tr-di\ (k,di)}$ = transmission energy of straight transmission.

3.6 Model of Network

Here we use eight biosensor nodes (S_1, S_2, S_3, …, S_8) in the human body. At the midpoint of the human body is located the sink node. Every biosensor node inside such strategy does various works. S1 is utilized for BP, S2 on temperature, S3 on EEG, S4 lactic acid, S5 EMG, S6 for blood oxygen, S7 for ECG, as well as S8 for glucose with respect to Fig. 1.

With the biosensor nodes distributed inside the human body, below suppositions are being studied:

(i) Every node is fixed as well as utilized that bi directional link inside WBAN.
(ii) Energy deployed for every biosensor node is the same.
(iii) Every biosensor node can be acquainted with its separation from nearer nodes with also from the sink.

3.6.1 Model of Energy

Every node inside WBAN is operative every time; thus, every node requires energy toward processing, transmitting, and sensing information. For this protocol's somatic awareness, a model of energy suggested is utilized. Consumption of energy within communicating information may be evaluated by making use of Eq. (1):

$$E_{trans=} E_{T\_elect} * Pc + E_{amp} * Pc * Di^2 \tag{1}$$

Consumption of energy by getting information is evaluated using Eq. (2):

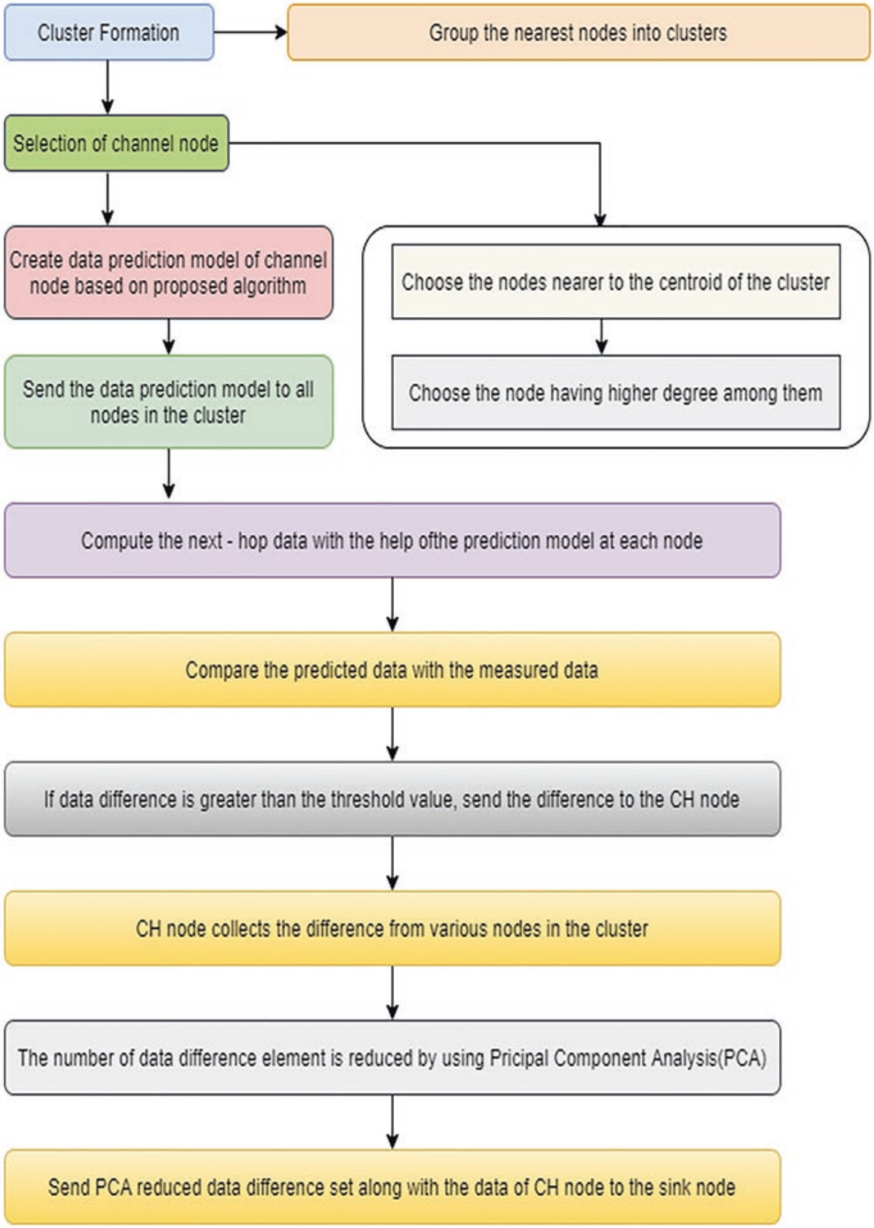

Fig. 4 Data transmission scheme in WBAN

$$E_{\text{recp}} = E_{\text{R\_elec}} * Pc \tag{2}$$

Inside WBAN, transmission of data occurs via the human anatomy, so few wastage may happen. So, overall consumption of energy for communicating the information later including path loss *m* can be evaluated by making use of Eq. (3) (Fig. 4):

$$E_{\text{trans}} = E_{\text{T\_elect}} * Pc + E_{\text{amp}} * m * Pc * Di^2 \tag{3}$$

where E_{trans} is transmission consumption of energy; E_{recp}, reception consumption of energy; $E_{\text{T\_elect}}$, energy needed by electronic transmitter circuitry; $E_{\text{R\_elec}}$, energy needed by the electronic receiver circuitry; E_{amp}, amplifier consumption of energy; *Pc*, size of packet; m, coefficient of path loss; and *Di*: distance to destination node from a source node (Fig. 2).

3.6.2 Model of Path Loss

This path loss turns on different elements like changeable opacity, attributive impedance, and constant dielectric of the human body. Such entire path loss throughout transmission of information is evaluated by making use of Eq. (4):

$$Ph_{\text{Loss}} = Ph_{\text{loss0}} + 10\log_{10}\left(Di_1 / Di_0\right) \tag{4}$$

where:

$$Ph_{\text{loss0}} = 10\log_{10}\left(4\pi Di_0 / \lambda\right) \tag{5}$$

Ph_{Loss} is the path loss, Di_1 distance of path, Di_0 distance of threshold (considered by 0.1) [20], and λ wavelength value (0.125 m) [16].

3.6.3 Particle Swarm Optimization Algorithm

James Kennedy and Russell Eberhart were introduced one metaheuristic on the basis of population optimization strategy called PSO, i.e., particle swarm optimization, in the year 1995. It's a much demanded metaheuristic optimization strategies which were persuaded from environment [34, 35]. Communal action of birds for hunting foodstuffs were prompted such optimization strategy. Inside the hunt area, every bird flaps toward that equal path. Below, we discuss about the PSO-based routing scheme.

Initialization

Firstly, along such hunt area, population being obtained candidly utilizing Eq. (6i) as well as starting speeds toward particles is allocated utilizing Eq. (6ii). Fitness value matches with place of particle inside hunt area that marks one feasible outcome toward issue. So direction as well as speed of particles is constituted with velocity as well as based at succeeding iteration also place is changed by particle.

$$Po^0{}_j = BL + rand(\ )x[BU - BL] \tag{6i}$$

$$vel^0{}_j = \text{zeros}(PN, N_o) \tag{6ii}$$

where $Po^v{}_j$ pertains to particle *j'* starting allotment; $vel^0{}_j$, particle *j'* starting velocity; *BU*, search variable' upper bound; *BL*, search variable' lower bound; *rand*(), random number across (0, 1); *PN*, population number (particles' size of population selected as 100); N_o, search space' total dimensions number; and x iterations chosen as 100.

Fitness Function's Evaluation

Each particle's fitness function can be found by using Eq. (7):

$$\text{Fit}_f : E_{\text{trans}} = E_{\text{T\_elect}} * Pc + E_{\text{amp}} * m * Pc * Di^2 \tag{7}$$

where Fit_f is fitness function and Fit_f ($\text{Loc}_\text{j}^\text{k}$) is fitness' estimate of particle *j* in *k*th iteration.

Hunting

Inside such hunting, hunt procedure carries where every particle hunts for their latest allocation as well as searches latest fitness estimate as per toward allocation. After that, particles are saved at the latest allocation.

Particles' Upgraded Velocity as well as Allocation

Each particle contains individual velocity as well as allocation. Every particle upgrades place as well as speed utilizing recent velocity as well as allocation of Pl_{bes} and Gl_{bes}. Here, these equations are used for upgrading velocity using Eq. 8 as well as allocation using Eq. 9:

$$Ve_\text{j}^{\text{k+1}} = \text{wt}Ve_{\text{j,k}} + \text{co}_1\text{rn}_1\left(Ps_{\text{j,k}}{}^{\text{loc}} - Ps_{\text{j,k}}{}^{\text{curr}}\right) + \text{co}_2\text{rn}_2\left(Ps_{\text{g,k}}{}^{\text{glob}} - Ps_{\text{j,k}}{}^{\text{curr}}\right) \tag{8}$$

$$Ps_{j,k+1}^{curr} = Ps_{j,k}^{curr} + wtVe_{j,k} \tag{9}$$

where $Ve_{j,k}$ is the *j-th* particle velocity at iteration *k-th*; $Ps_{j,k}^{curr}$, *j-th* particle's recent allocation at iteration *k-th*; $Ps_{j,k}^{loc}$ (Pl_{bes}), *j-th* particle's local finest allocation at iteration *k-th*; $Ps_{g,k}^{glob}$ (Gl_{bes}), *j-th* particle's global finest allocation at iteration *k-th*; co_1 and co_2, coefficients of acceleration of PSO technique; and rn_1 and rn_2, similarly diffused random numeral across (0, 1).

The coefficient of acceleration enhances probability for searching this global finest, at which one bigger coefficient of acceleration accelerates upward that crossway as well as make shorter calculation schedule, that aims PSO for effortlessly obtain confined toward local finest. By getting best results [40], puts co_1 as well as co_2 is determined as 2.0 estimates. Inside suggested protocol, estimates of elements co_1 as well as co_2 are 1.0 to achieve finest results.

This element weight be particles' weight of inertia as well as relies on below arithmetic correspondence:

$$wgt = wgt^{mx} - \frac{\left(wgt^{mx} - wgt^{mn}\right)itr}{itr_{mx}} \tag{10}$$

at which wgt^{mn} and wgt^{mx} are minimum as well as maximum estimates for weight of inertia. In this suggested technique, wgt^{mn} is 0.2, and wgt^{mx} is 0.9 [40].

Local Best as well as Global Best Upgrading

Here, we compare both local finest fitness estimate of particle and estimate of fitness searched as particle after iteration. The arithmetic representation of the equations are described below:

$$Ps_{j,k+1}^{loc} = \begin{cases} Ps_{j,k+1}^{curr}, Fit_f\left(Ps_{j,k+1}^{curr}\right) \le Fit_f\left(Ps_{j,k}^{loc}\right) \\ Ps_{j,k}^{loc}, Fit_f\left(Ps_{j,k+1}^{curr}\right) > Fit_f\left(Ps_{j,k}^{loc}\right) \end{cases} \tag{11}$$

$$Ps_{g,k+1}^{glob} = \begin{cases} Ps_{j,k+1}^{loc}, Fit_f\left(Ps_{j,k+1}^{loc}\right) \le Fit_f\left(Ps_{k}^{glob}\right) \\ Ps_{k}^{glob}, Fit_f\left(Ps_{j,k+1}^{loc}\right) > Fit_f\left(Ps_{k}^{glob}\right) \end{cases} \tag{12}$$

where $Ps_{j,k}^{loc}$ is the *j-th* particle's finest local location at *k-th* iteration; Ps_k^{glob}, finest global location at *k-th* iteration; $Ps_{g,k+1}^{glob}$, global finest location at *(k + 1)th* iteration; and $Ps_{j,k+1}^{loc}$, *j-th* particle's local finest location at (*k* + *1*)*th* iteration.

Algorithm (3.2.1) of Particle Swarm Optimization

Process i: Arrange those particles accompanied by arbitrary location Po_j^0 as well as velocity vel_j^0 by making use of Eqs. (6i) and (6ii).

Table 2 Distribution of biosensor nodes at the human body

Nodes	Position (X_1Y_1)
S_1	(0.55,1)
S_2	(0.25,1)
S_3	(0.28,0.2)
S_4	(0.48,0.25)
S_5	(0.3,0.5)
S_6	(0.5,0.5)
S_7	(0.45,0.13)
S_8	(0.35,0.9)
SINK	(0.4,1.1)

Process ii: Computation of fitness estimate utilizing function of fitness Fit ($Ps_{j,k}^{loc}$) by making use of Eq. (7) as well as search Ps_j^k local finest location as well as Ps_k^{glob} global finest location by making use of Eqs. (11) and (12).

Process iii: Searching of particle for recent position as well as velocity is upgraded utilizing Eqs. (8) and (9) with also recent location are stocked.

Process iv: Local finest as well as global finest fitness estimate as stated by finest outcome is upgraded.

Process v: Particles' recent location as well as velocity is upgraded.

3.7 Optimized Approaches

By developing WBAN, duration of network and consumption of energy are the most important factors. Each biosensor node transmits information toward the sink node by relay node. Biosensor nodes choose one route which has the smallest distance toward the sink node as well as absorbs small energy. The suggested task by us which has detected route to transfer information that's systematic as well as optimal. We are utilizing energy replicas for computing path loss as well as energy replicas for computing path loss within the chosen route. PSO technique is utilized to find the finest route for information transference inside WBAN. Such major procedures of suggested appeal for searching that finest route are found below. Inside Fig. 3. which is a flow chart of PSOBAN protocol also efficiency energy routing reveals.

3.7.1 System Model

Eight sensor nodes are used in the human body, and every node has the capability to sense as well as transmit information toward the sink to find the smallest path. Position of the biosensor nodes in the human body is listed in Table 2 (Fig. 5).

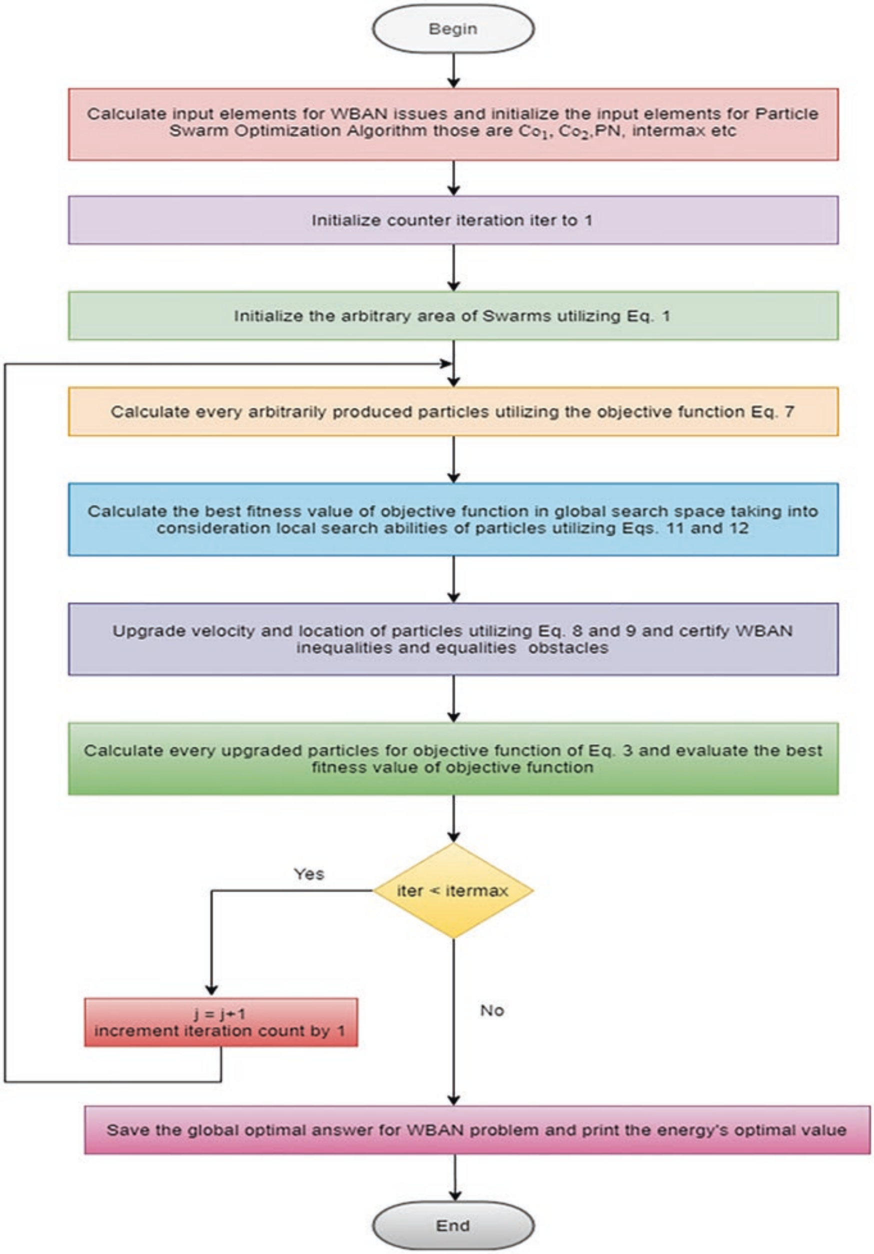

Fig. 5 Suggested PSOBAN protocol

3.7.2 Starting Stage

Inside suggested network for every biosensor nodes are distinctly set up. Preference 1 is put for S_1, S_2,…, S6 nodes, whereas preference 2 is put for S_7 and S_8 biosensor nodes. The important thing is to put various preferences toward S_7 as well as S_8 because of censorious information. Both nodes can transmit information straightly toward the sink node. Further nodes' preference 1 can forward information toward the sink node across the relay node. Here, S_3 node transmits information toward the sink; then information can be forwarded across 4, 5, as well as 6 nodes. Afterward, chosen protocol finds the finest path toward the sink from no. 3 node. Firstly, suggested protocol inspects of 3 no. node' residual energy. Calculation Stage

Within such stage, whether this chosen relay node is no. 5 node then utilized at most whether this has more abiding energy to transmit information. Let no. 5 node isn't one deceased node after that it is going to be chosen one relay node based on cost function that's computed with dividing that distance against no. 3 node accompanied by residual energy. Cost function (CF) is defined as the ratio of distance against the biosensor node toward the sink as well as sensor node's residual energy [20].

$$\mathrm{FC}(\mathrm{j}) = \frac{d(j)}{RE(j).}$$

Cost function estimation is computed with the use of PSO. Routing Stage

Afterward, such equal process is utilized to select the smallest route. In every stage, optimization protocol grants this optimum route within minimal interval. Then every stage matrix for cost function be given rise as well as upgraded as per abiding energy up to every node is announced deceased. These nodes that are chosen like relay nodes utilizing cost function will permit such smallest path. Furthermore, those characteristics of inducing routing protocols are matched by this suggested PSOBAN.

Transmission of Data Stage

At the last stage, transmission of data occurs from source node toward the sink by utilizing the smallest path chosen by the PSO. Every biosensor upon that path route accompanied by one minimal estimate of cost function is chosen to transmit data as computed by PSOBAN. The following flow chart (Fig. 4) is shown to handle different WBAN features inside PSOBAN. Such study suggests single efficient energy routing protocol being assorted WBAN on the basis of PSO Algorithm. This is obvious against name in which the protocol is conscious of path along the various biosensor nodes as well as is delicate toward biosensor nodes' energy. Those outcomes display which suggested protocol does well as regards residual energy. Such route

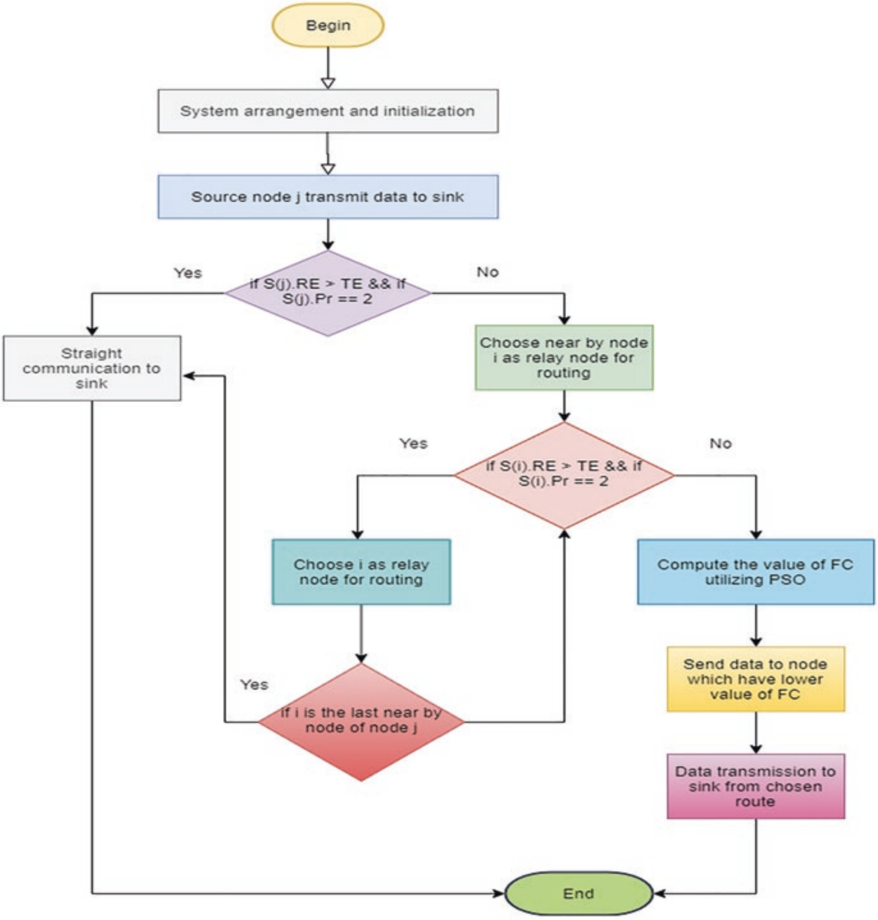

Fig. 6 Managing different WBAN obstacles

is chosen on the basis of numeral hops inside route as well as based on two important elements – distance and energy (Fig. 6).

4 MC-MAC Strategy for Interference Reduction Inside WBANs

In WBAN, sensor nodes are placed in or on the patient's body to monitor their vital signs. Figure 7 shows [42] the WBAN infrastructure for medical and non-medical applications. Personal server and medical server are the two main parts of the WBAN architecture. In WBAN, patient wears the sensor nodes on or inside the body that collect and transmit data to the personal server using communication

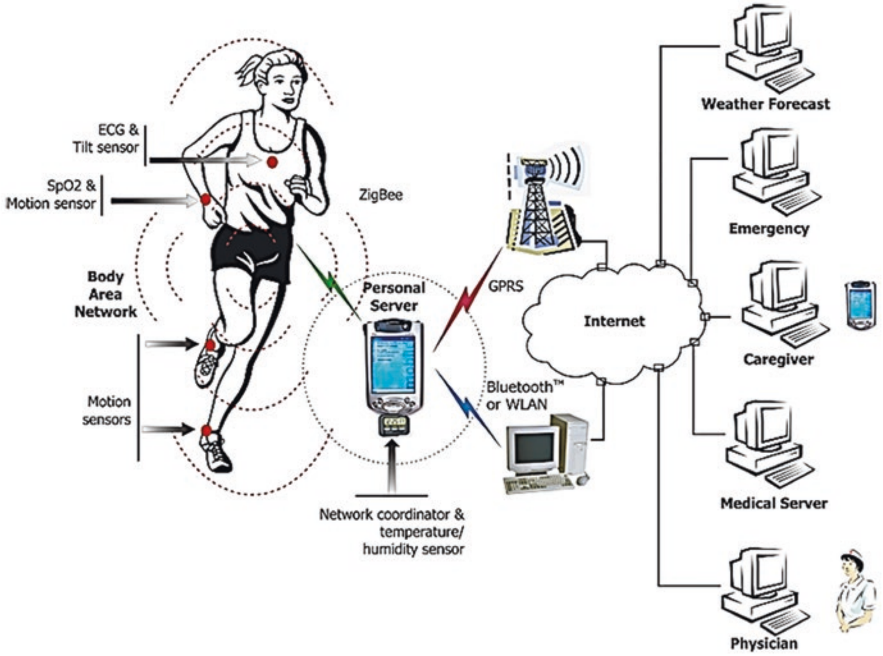

Fig. 7 WBAN architecture [42]

standards (Wi-Fi, Zigbee, etc.). Further data is transmitted to the medical server [41, 42]. The medical server then provides services to various users. The data is transmitted to the doctor from the medical server from where he can access the data from anywhere using the Internet. WBAN data is normally divided into three parts: normal data, emergency data, and on-demand data.

4.1 WBANs and Healthcare

Wireless body area network (WBAN) is a type of wireless sensor network (WSN) that has tremendous applications in the healthcare domain. Transmission of the critical health data must be prioritized over periodic ones to deliver it within the stipulated time. Further, as the spectrum is limited and fixed, there is a contention among users for its usage. The objective of this chapter is to maximize the system throughput by allocating the available bandwidth fairly based on the criticality of the data and mitigating inter-WBAN interference in a densely populated network by optimizing transmission power. We have mathematically modeled the problem as a Linear Programming Problem (LPP) and solved it using Particle Swarm Optimization (PSO). Simulation results show that the proposed solution converges quickly. It also outperforms 802.15.6 and other existing state-of-the-art algorithms in terms of throughput, packet delivery ratio, and retransmission of packets in high-mobility scenarios [2, 17]. Especially, defined from WSN, WBAN appears to be of much interest within these researchers [13–16]. The IEEE 802.15.6 standard gives a fast evolution of WBANs. WBANs constitute a broad scope of typologies of application accompanied by sensor nodes located on, near to, or inserted inside the body which calculate physiological symptoms. The developed small wireless sensors may help inhabitants as well as their stewards supply constant medical supervising, supervision of home applications, memory improvement, medical information retrieve, as well as urgent communication.

4.2 Protocols of Multi-channel

Various tasks inside productive protocols direct at featuring the issues of interference, huge traffic small utilization of channel, as well as inefficient energy, specifically in medical applications [18, 19]. To resolve issues, multiple access methods such as scheduling method or TDMA are introduced within particular modeled MAC protocols [20]. Even so, those are unsuitable for execution inside actual plot with proceeding within collisions at any time the WBAN topology replaces [33, 36–39]. Multi-channel perspective displays as a logical procedure to resolve the issues of interference as well as utilization of small channel. Also, within this outstanding evolution inside MEMS (micro-electromechanical systems) techniques and radio, sensor nodes are competent of accurately revolving their frequency above multiple channels. Generally, MC-MAC protocols are divided into four classifications at the basis of their concepts of action: common hopping [22], dedicated control channel [21], parallel rendezvous protocols, and split phase. SSCH (slotted seeded channel hopping) [20] is one protocol of scattered link layer Multi-channel Strategies Accurate for WBANs

After suggested MAC protocols observe one and only channel that emerges in interference issues, collision of channel and energy inefficiency. To solve these problems, various MAC protocols are raised inside WBANs. In [21], the author introduces an adaptive CSMA/CA MAC protocol for mitigating interference of inter-WBANs. The administrator begins an arbitrary back-off timer on the basis of its recognized interference level for mitigating collision probability. Viewing the multi-channel strategy is essential to reduce faults of one channel and suggests many MC-MAC protocols.

In [22], a multi-channel strategy is suggested for mitigation of coexistence for WBANs. This is reverse within small consumption of energy essential for sensors inside WBANs. [23] introduces one sole radio multi-channel TDMA MAC protocol in favor of WBANs utilizing one blend of mesh as well as star topology. Such actual sensor components prove that protocol may obtain a single small delay. The node accepts plenty of work. This will definitely speed up consumption of energy of nodes whose power is restricted as well as mitigate the entire network duration. According to the authors, the hub is accountable for coordinating those nodes that might be inculpated appropriately [25] explains a coherent method of management of multi-channel selected by one-to-one mapping among the beacon period as well as the data channel. Woefully, the channel allocation method is dull, and the access mechanism of coordination between the nodes is not supplied so far. In [26], Spectrum handoff strategy derived is for ignoring interference between concurrent WBAN with broadcasting as well as generating one table containing of nodes interfering. The dynamic resource assignment mechanism may certify the interference source for sustaining an interference tolerance level. Therefore, the strategy may reduce the interference of inter-tree, nodes on the basis of equal sub-tree have critical interference yet. In [27, 28], further multi-radio multi-channel mechanism introduces where each transmitting sensor node utilizes one specific channel whenever hub has multi-radio alliance. This enables for diminishing unusual loss of signal caused by immersion of electron beam waves inside interference, shadowing, fading and body fluid. Even so, this does not suggest some actual result for channel allocation scheme [33, 36, 39].

The faults regarding over-listening as well as restrictions of energy in CSMA/CA must be pulled inside deliberation. CSMA/CA is an allegation on the basis of MAC protocol. It attempts to mitigate collision; even so, it assists to problem of interminable inert hearing time as well as waste of energy [29]. The random access can propose a high detain whether load of traffic is long. Like the restriction of sensor battery capacity, more consumption of energy initiates an additional major problem.

5 Conclusion

Due to busy schedule, people do not have time to visit the doctor [41]. Sometimes, in case of emergency, doctors are not available. WBAN technology also helps the elderly population who are unable to visit the doctor regularly. An energy-efficient data routing protocol is of paramount importance for WBAN because biosensor nodes consume a considerable amount of assigned node energy for transmitting data to other nodes. A cluster-based protocol provides an energy-efficient data routing scheme with affordable data loss rates and network latency.

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