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Research Article

AHP–neutrosophic decision model for selection of relay node in wireless body area network

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Abstract: The medical health systems empowered by wireless body area networks (WBANs) are becoming a reliable technology with unmatched facilities for personalised health monitoring and managing real-time health issues. A WBAN is primarily composed of a miniature, and smart devices called sensors that are worn in, on, or around the human body. In recent years, research has been mainly centred towards the reduction of the energy consumption and stability of the network. The selection of the relay node is one of the foremost issues for balancing the energy consumption in WBAN. To overcome this issue, the authors propose a hybrid analytic hierarchy process–neutrosophic method for making the decision of the relay node selection, in which the analytic hierarchy process (AHP) technique calculates the weights for different criteria and forwards them to the neutrosophic technique which finds out the best alternative solution or choice which is closest to the ideal solution. A detailed analysis is carried out on multi-criteria decision-making techniques by comparing the proposed AHP–neutrosophic and AHP techniques taking into account various criteria and alternatives. The experimental outcomes of this research indicate a significant reduction in terms of energy consumption and enhanced overall network-stability.

1 Introduction

Over the years, lots of people have been suffering from many health problems such as cancer, diabetes, asthma, and chronic diseases due to which they die. If we diagnose or timely detect the disease, then we can save their lives. Wireless body area network (WBAN) sensors are placed inside or outside the patient's body [1]. WBAN used to generate communication connections between these sensors and give feedback to the users. There are two essential requirements for WBAN. First, WBAN has to provide stable communication as medical services protect human life from the risk of health issues. WBAN is designed to provide real-time health monitoring, and sending data to the server with ease. Second, sensor nodes need to operate using battery power to provide mobility. The various sensors used can be temperature, EEG, blood-pressure, glucose, insulin pump, motion detection, heart beat rate, etc. In the tier system, we can use relay node as an intermediate node for enhancing the network-lifetime. In WBAN, network conditions are regularly changed due to mobility factor and energy loss, due to posture body movements between sink and sensor nodes. Due to this, low energy consumption is the most critical issue in WBAN. Relay nodes can be attached to the WBAN to gather all the information from the sensors, then forward towards the sink, which will enhance the network lifetime and dependability [2]. Indeed, relay nodes assume a vital part in decreasing the transmission energy of biosensors, and in this manner have the preferred twofold standpoint of (i) securing human tissue from radiation and warming impacts and (ii) diminishing the energy utilisation of such devices. WBAN has been developed as a successful intend to give a few promising applications, such as sports and fitness monitoring, remote healthcare, security, gaming and entertainment, real-time streaming, emotion detection, etc. The relay node is an intermediate node between the parent node and the child node. In the relay node, a node and coordinator can use a multi-hop communication to exchange frames through another node.

In this paper, we proposed a hybrid analytic hierarchy process (AHP)–neutrosophic multi-criteria decision-making (MCDM) method for selecting the relay node to reduce energy consumption in WBAN. In the AHP method, the weights of different criteria are calculated and ranking according to the priorities of each alternative is done. In the neutrosophic method, the best alternative solution is found and also it evaluates the uncertainty, vagueness of the distance measure, or the priority of each component. Hence the relay node selection is made based on six different criteria, i.e. residual energy, traffic load, node density, signal-to-noise ratio (SNR), Euclidean distance, and node criticality.

2 Related work

The current techniques vary on the criteria for the selection of the relay node. For multi-hop, Kim *et al.* [3] used AHP MCDM techniques for a relay node selection. This system uses only three criteria and provides high communication reliability and low power consumption. An energy-conserving cluster head selecting technique in the wireless sensor area network (WSAN) has been recommended by Gao *et al*. [4]. To meet the desires of quality of requirements for distinct healthcare implementations, the geological multipath routing scheme for WSN has been proposed by Wu *et al.* [5]. The distance from the end position, left over batteries' strengths well as queuing capacity of the candidate-sensors are considered for relay node selection in upcoming hop, and then application of AHP is done for MCDM. Co-operative link aware routing protocol is given by Ahmed *et al.* [6] which reduces the loss of packet rates and link-failure rates. An objective function based upon distances and remaining energies are introduced for picking the most suitable path. Simulation results show the improved performance when compared with the existing routing protocols. Tauqir *et al.* [7] proposed distance-aware relaying routing technique to monitor the patient's health in multi-hop WBAN. The suggested scheme achieves increased network lifetime when compared with M-attempt [8]. Khan [9] defines a new set theory called a probabilistic simplified neutrosophic set (PSNS). They combined the concepts of probability and neutrosophic to retrieve more understandable information. A stable and reliable routing protocol has been suggested by Nadeem *et al.* in [10]. An objective function determines the node having higher remaining energies and least distances to sink. Elias and Mehaoua [11] proposed the WBAN model in realistic scenarios and compared the performance. By using the energy aware design model, total network installation cost, and the overall energy consumption is minimised. Feng *et al.* [12] proposed the prediction-based dynamic relay transmission scheme for WBAN. PDRT scheme is introduced, which decides 'when to relay' and 'whom to relay' in the best possible way based upon the known channel states. Senouci [13] gave a novel evaluation function is given in order to find out the weight of different alternative for selecting the finest. In [14], different applications in neutrosophic theory for the purpose of decision-making are discussed. Khan *et al.* [15] presented different WBAN design techniques for medical applications and performance evaluation of different protocols. Kaur and Singh [16] presented cost-effective energy-aware routing protocols for WBAN, i.e. OCER and Extended OCER, by considering different parameters. In [17], researchers put forward a new neutrosophic-based decision-making technique with multiple-parameter similarity combined with weight. In [18], a TDMA-based routing protocol is given for improving the performance in terms of energy in WBAN. An effective multi-hop routing strategy in [19] has been put forth that is helpful in detecting efficient routes among available routes while considering multiple significant criteria for making routing decisions, also providing balance in energy consumption across all the sensor nodes. In [20], the researchers gave a method for GSCM to create a strong ranking scheme by applying neutrosophic sets to dodge imprecise, indefinite opinion and concluded that GSCM practices could reduce waste, economic drops, etc. and offer effective resource utilisation. Nabeeh *et al.* [21] proposed a model which could be useful in estimating significant factors of enterprises related to IoT. Tey [22] proposed an MCDM technique called the neutrosophic data-AHP (NDAHP). Unlike all existing versions of AHP, fuzzy-AHP methods, handle actual datasets which use a subjective-weighting mechanism, the NDAHP technique uses an objective-weighting mechanism. Xia Liang *et al.* [23] created a new single-value trapezoidal-neutrosophic MCDM technique on the basis of SV-TNPR. Recently, various nature-inspired meta-heuristic approaches have been put forth, such as the Coyote optimisation algorithm. In [24], a neutrosophic AHP-SWOT model is proposed, and an actual case study of a company named Starbucks was utilised to authenticate their model. Freen *et al.* [25] defined a four-valued refined neutrosophic set and found the optimal solution of multi-objective non-linear optimisation model. Mohamed and co-authors [26] uses neutrosophic theory to form the AHP decision-making model for selection of the best alternative out of others. An innovative group-decisions creating technique is proposed in [27] on the basis of neutrosophic sets for diagnosing heart issues. In [28], an enhanced ELECTRE technique, along with multiple-valued neutrosophic data, is discussed. In order to study various trends in the stock market, a decision-making technique [29] based on neutrosophic sets is proposed. Smarandache [30] proved the distinction between neutrosophic set and all previous intuitionistic fuzzy set (IFS) and others.

3 Proposed approach

In the proposed system for relay node selection, sensor nodes arrange themselves according to the ranking of the index value obtained by using six criteria. An advertisement is broadcasted by the relay node to its adjacent node within its transmission range. Our technique focuses on increasing energy conservation.

The proposed technique is actualised using the following five phases:

- Initialisation phase.
- Relay candidate's discovery based on different criteria.
- AHP.
- Hybrid AHP–neutrosophic for selection of relay node.
- Data transmission

3.1 Initialisation phase

First, the sensor nodes are rested upon the body according to the x and y coordinates, as illustrated in Table 1. An aggregate of eight sensor nodes is used, and the sink is situated at the mid-section. The sensors transfer the information straight to the sink. Contrasting sensors take after their parent hub and send their data to drop through the forwarder hub. It provides vitality of centres, which allows the system to work for an elongated period of time.

3.2 Relay candidate's discovery based on different criteria

Relay candidate discovery is percolated using a control message called relay node exploration. Neighbour revelation is practiced in stage 2. A hello control bundle is communicated among all the sensor nodes by utilising carrier-sense-multiple-access (CSMA) method. The hello control bundle contains critical data, e.g. residual energy (criteria-1, C1); traffic load (C2); no of neighbours (C3); SNR (C4); hop distance (C5); node criticality (C6); and node location and ID data, which are illustrated in Fig. 1. All sensor nodes refresh their neighbourhood table in the wake of accepting the hello control parcel from neighbouring nodes. The selected blueprint works for the on-body sensors as relay nodes as in body sensors or devices have lesser battery holding capacity, which requires replacement after a certain period of time. So, it's inadequate using on-body sensors as relay nodes.

- *Residual energy (E_{resi}):* Residual energy is the left-over battery of sensors, and the initial energy of the sensor node is predefined. Sensor nodes have limited energy capacity. The estimated value of residual energy can be calculated by the following formula:

$$E_{\rm resi} = E - E_{\rm min}/E_{\rm max} - E_{\rm min} \tag{1}$$

where E = initial energy of the node; $E_{\rm min}$, $E_{\rm max}$ = minima, maxima $E_{\rm resi}$ in the neighbouring nodes.

- *Traffic load (TL):* The TL of the sensor is defined as the ratio of the reserved time slots of the sensor in a frame added by one to the number of the time slots of a frame.

It can be represented as

$$\text{TL} = (t+1) \times p/q \times p \tag{2}$$

$$\text{TL} = (t+1)/q \tag{3}$$

where p = maximum amount of data transmitted of a time slot; q = time slots; t = reserved time slots in a frame.

Table 1 Deployment of sensor nodes on patient's body

Node no.	1	2	3	4	5	6	7	8	Sink
x-coordinate, m	0.2	0.6	0.7	0.5	0.1	0.3	0.5	0.3	0.4
y-coordinate, m	1.2	1.1	0.8	0.6	0.8	0.5	0.3	0.1	0.9

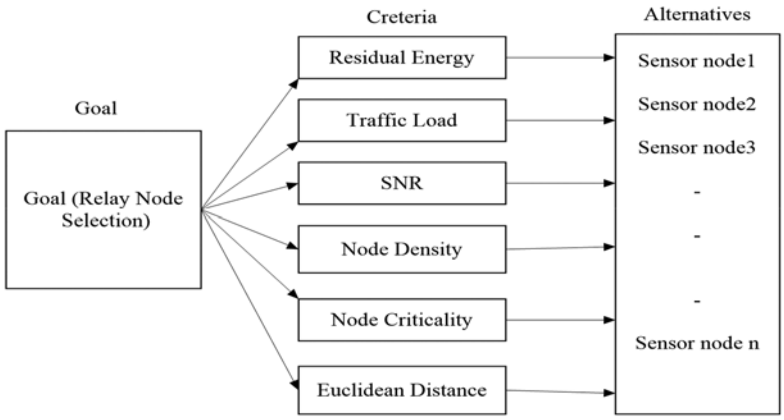

Fig. 1 *Proposed approach of AHP for WBAN problem*

- *Node density (ND):* There is an immediate connection between the number of neighbours and the relay node. In this way, the assessment estimation of the number of neighbours is estimated as

$$\mathrm{ND} = (\mathrm{ND}_i - \mathrm{ND}_0)/\mathrm{ND}_0 \quad (4)$$

where ND_i = number of neighbours of the sensor; ND_0 = ideal number of neighbours.

- *SNR:* It is defined as the ratio of the signal-power to noise-power in decibels (dB). A ratio higher than 1: 1 indicates more signal over noise. An SNR of zero indicates that the desired signal is virtually equivalent to the excessive noise

$$P_{\mathrm{rxv}} = P_{\mathrm{txv}} - P_{\mathrm{Ls}} - P_{\mathrm{Fs}} - G_{\mathrm{txv}} + G_{\mathrm{rxv}} \quad (5)$$

where P_{rxv} = received power; P_{txv} = transmitter power; P_{Ls} = path loss; P_{Fs} = loss due to the fading processes; G_{txv} = transmitter antenna gain; G_{rxv} = receiver antenna gain.

- *Euclidean distance (E_{dist}):* Here the distance of the sensor node with the sink node and neighbouring node is considered. Only one node with the maximum distance will exist that can be reached in a given number of hops, in a 2D network.

$$\mathrm{Dist} = (\mathrm{node}X - \mathrm{sink}x)^2 + (\mathrm{node}Y - \mathrm{sink}y)^2 \quad (6)$$

where node$X$, node$Y$ = x, y-coordinate of the particular sensor node; sink$X$, sink$Y$ = x, y-coordinate of the sink node.

- Node criticality (NC): The body area system is the intricate and specific type of sensor system in which nodes are characterised in particular positions. WBAN is characterised by observing the patient ailment status by setting the organ checked sensors. As per the malady and patients, the node criticality is characterised. To give successful correspondence, some improved routing methodology is required.

3.3 Analytic hierarchy process

The AHP [30] is a multi-criteria decision-making methodology that is used to review the complex decision-making problem based on calculation. First, decision problems are converted into sub-problems in the hierarchy, whether it is tangible or intangible. Then the evaluation of performance is done by comparing each element with the above elements in the hierarchy. Fig. 1 illustrates the proposed approach of AHP for WBAN problem. The phases for the AHP approach are mentioned as follows:

Step 1: Evaluating local weights – decide and calculate the local weights of choice components.
*Step 2:*Creating pair-wise compatibility – the pairwise comparison matrix is obtained by comparing each component to the highest component of the set in the hierarchy.
Step 3: Calculating weight vector – for the given matrix $\boldsymbol{A}_n$ compute its eigenvalue condition given as follows:

$$A\boldsymbol{W} = \lambda_{\max}\boldsymbol{W} \quad (7)$$

where $\boldsymbol{W}$ = non-zero vector known as eigenvector and $\lambda_{\max}$ = scalar eigenvalue.

For calculating the eigenvector $\boldsymbol{W}$, the vector component of $\boldsymbol{W}$ is taken as the nearby weight of every chosen variable around, given as follows:

$$W_j^T = \left\{W_\alpha, W_\beta, W\gamma, W_\delta, W_\lambda, W_\kappa\right\}$$

Step 4: Checking the consistency ratio – the consistency ratio can be measured as the proportion of consistency index (CI) to the random index (RI), it is checked whether the value is perfect or not.
Step 5: Calculating mean relative weights – the mean relative weights of each alternative node are calculated and the node with the most significant node is picked.

3.4 Hybrid AHP–neutrosophic for relay node selection

Neutrosophic is a handy technique for ranking several substitutes according to the closeness to the ideal solution. Neutrosophic MCDM method for calculating weights of criteria and choosing the best one. The uncertainty and inconsistency in data can be managed by neutrosophic sets. Neutrosophic sets [31] present truth membership for decision-making to achieve the ideal solution.

A hybrid AHP method with neutrosophic is applied by ranking the node for selection of the relay node in WBAN. A hybrid AHP–neutrosophic is presented to calculate weights of alternatives, for choosing the best one. Fig. 2 represents the structure of the methodology of AHP–neutrosophic method. The phases for the hybrid approach are mentioned as follows:

Step 1: Acquire expert information in AHP environment. Determine the criteria, alternative and collect expert perspective.
Step 2: Collect the weight of information from AHP and implement on neutrosophic
Step 3: Decomposition and construct the hierarchy. The hierarchy represents the overall main solution of problem, decision criteria and alternatives of final solution.

Create a pairwise matrix of decision-making judgments using the following form:

$$M^k = \begin{bmatrix} B_{11}^k & \cdots & B_{1z}^k \\ \vdots & \ddots & \vdots \\ B_{y1}^k & \cdots & B_{yz}^k \end{bmatrix}$$

where $B_{xy}^k = B_{yx}^{-k}$.

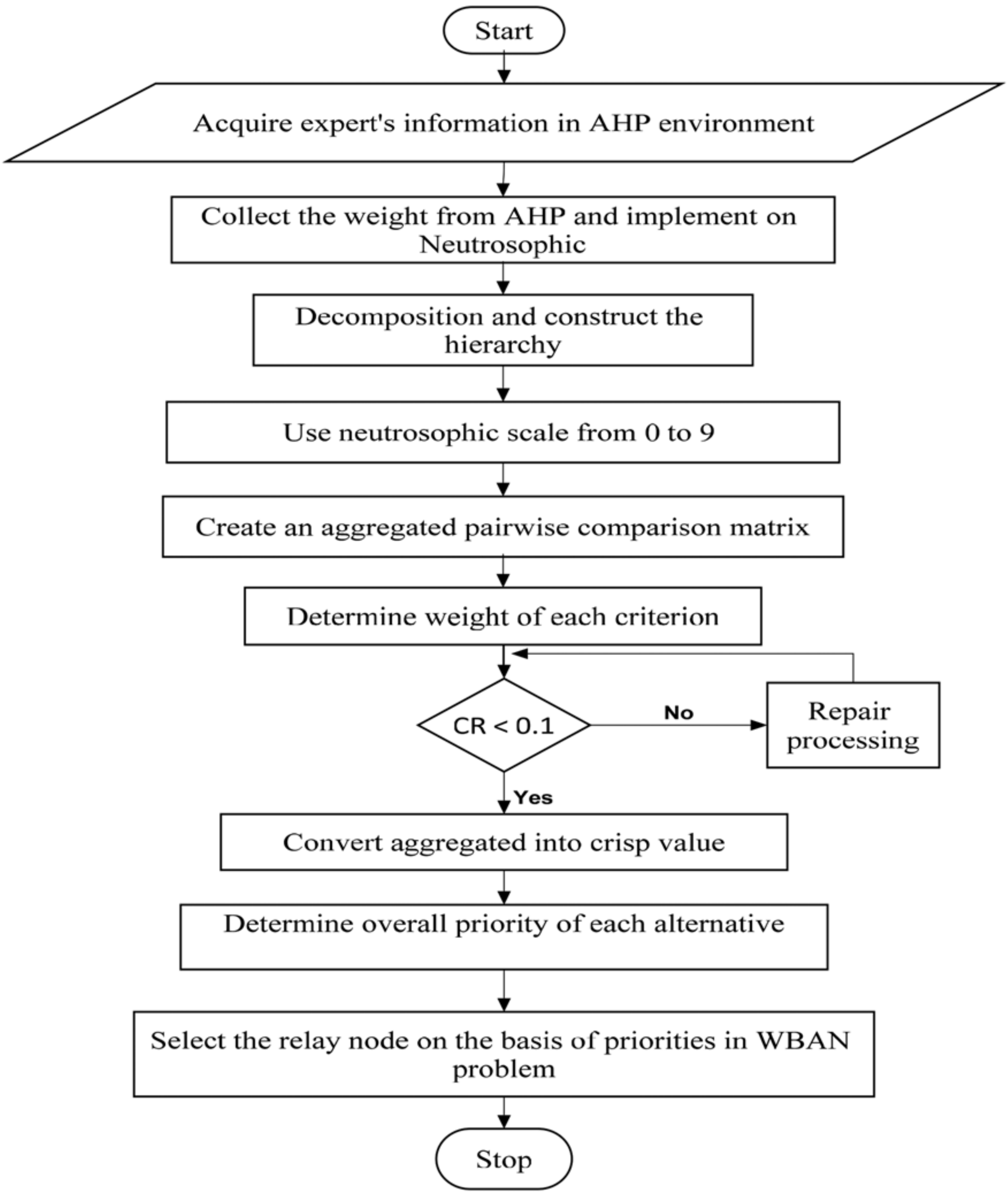

Fig. 2 *Proposed AHP–neutrosophic method for WBAN problem*

Step 4: Use the neutrosophic scale mentioned in Table 2. Pairwise comparison can be done according to the 1 to 9 neutrosophic scale and by using the random consistency index from Table 3.
Step 5: To determine the weights of each criterion for calculating the overall priority of each alternative and transform neutrosophic pair-wise comparison matrix to deterministic pair-wise comparison matrix and determine the final ranking of all alternatives, by using the following equations:

Let B^k_{xy} =($a1$, $b1$, $c1$), $\alpha^k a$, $\theta^k a$, β^k be a single-valued triangular neutrosophic number, then

$$S(B^k_{xy}) = 1/16[a1 + b1 + c1] \times (2 + \alpha^k a - \theta^k a - , \beta) \quad (8)$$

and

$$A(B^k_{xy}) = 1/16[a1 + b1 + c1] \times (2 + \tilde{\alpha} a - \tilde{\theta} a + \tilde{\beta} a) \quad (9)$$

A and S are called the accuracy degree and score degree of B^k_{xy}, respectively. To get a score and accuracy degree of B^k_{xy} we to use the following equation:

$$S(B^k_{yx}) = 1/S(B^k_{xy}) \quad (10)$$

$$A(B^k_{yx}) = 1/A(B^k_{xy}) \quad (11)$$

Step 6: Determine the weight of each criterion with compensation by score value of each triangular neutrosophic number in neutrosophic pair-wise comparison matrix and normalise the column entries by dividing each entry by the sum of the column and take the totality row averages.
Step 7: To compute an inconsistency within the judgments in each comparison matrix and for the entire hierarchy, we use the consistency index (CI) and the consistency ratio (CR) in the neutrosophic judgment matrix.

If CR <0.1, the judgments are untrustworthy because they are too near to randomness, and the experiment is incorrect or must be

Table 2 Neutrosophic triangular scale (linguistic terms)

Neutrosophic scale	Significance level	Neutrosophic range
1	evenly significant	$\tilde{1} = \langle 0.50, 0.50, 0.50\rangle$
3	little significant	$\tilde{3} = \langle 0.30, 0.75, 0.70\rangle$
5	powerfully significant	$\tilde{5} = \langle 0.80, 0.15, 0.20\rangle$
7	completely powerfully significant	$\tilde{7} = \langle 0.90, 0.10, 0.10\rangle$
9	absolutely significant	$\tilde{9} = \langle 1.00, 0.00, 0.00\rangle$
2	sporadic values between two cases	$\tilde{2} = \langle 0.40, 0.60, 0.65\rangle$
4		$\tilde{4} = \langle 0.35, 0.60, 0.40\rangle$
6		$\tilde{6} = \langle 0.70, 0.25, 0.30\rangle$
8		$\tilde{8} = \langle 0.85, 0.10, 0.15\rangle$

Table 3 Random consistency index for a pair-wise comparison matrix

Size of matrix	Random consistency
1	0.00
2	0.00
3	0.59
4	0.91
5	1.12
6	1.26
7	1.31
8	1.41
9	1.46
10	1.50

repeated. To calculate CI and CR do the following steps:

Compute the CI as follows:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{12}$$

where n is the number of items being compared.

Compute the CR, which is defined as follows:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{13}$$

Step 8: Convert aggregated into crisp value. From the previous pair-wise comparison matrix, normalise the column entries by dividing each criterion by sum of the column.

Step 9: Calculate the overall priority of each alternative and determine the final ranking of all alternatives.

As regards to accomplishing ranking, the proposed approach selects the node with the highest rank as a relay node in WBAN problem.

3.5 Data transmission

In this phase, data is gathered and information is sent by the member nodes to the relay nodes in scheduled time. Transmission can use the minimum amount of energy on the basis of received signal strength of the relay node advertisement and assumption of the radio channel. The relay node must keep a working state to get the data to originate from its individuals. At the point when an edge of information from every one of the individuals is received, the relay node applies information combination to aggregate the received information into a single bundle. At that point, the relay node sends the amassed information to the base station specifically. It uses hybrid AHP–neutrosophic to evaluate all the available nodes based on the criteria Information and transmit data to the destination.

4 Performance evaluation

4.1 Network model

In this paper, the network model is bifurcated of three levels as shown in Fig. 3. Level 1 manages 'intra-BAN communication,' which comprises of patient's information with different maladies analysed by an on-body sensor. The position of the biosensors is settled and has a similar transmission range. The change in values will be observed between the different biosensors with the body developments and movements in the body. Level 2 manages 'between BAN communication' that is between BANC and at least one PDD (Patient Data Display), which is one special gadget at this level. BAN information is transferred to a Level 3 special device that is CDD (Centralised Display Device) by the PDD. Level 3 manages' beyond BAN communication,' which empowers the approved medicinal services experts to get to the patient's information remotely utilising the Internet. This led to the improvement in the application and scope of the E-human services framework. All sensor nodes are fixed, homogenous, and synchronised in time.

4.2 Energy model

Entire sensor nodes within the WBAN remain dynamic for the whole period, so all the nodes require energy for detecting, dispensing, and transmitting of data. Energy spent on transmitting the data can be

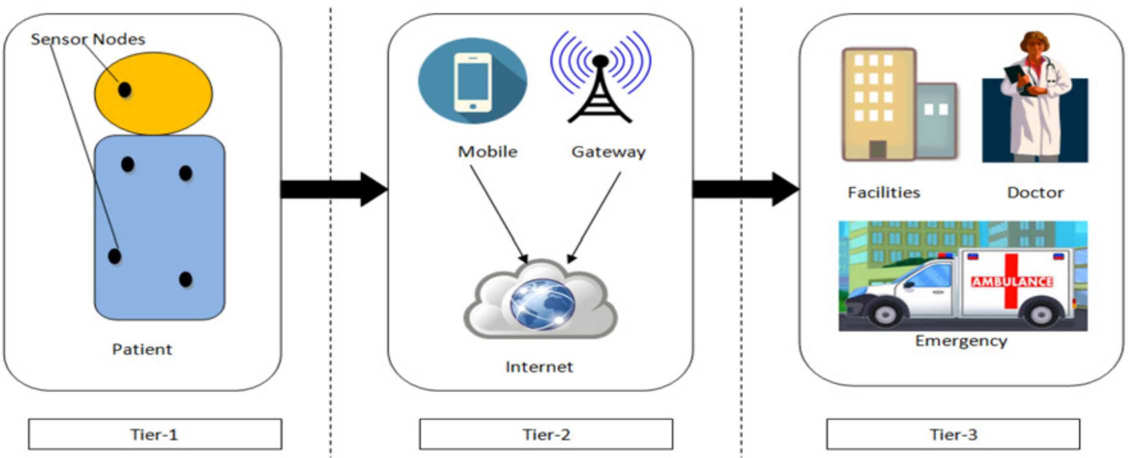

Fig. 3 *Three-tier system of WBAN*

evaluated by

$$En_{\text{trans}} = En_{T\_\text{elec}} \times p + En_{\text{amp}} \times p \times d^2 \tag{14}$$

Energy spent for receiving data is evaluated by

$$En_{\text{rec}} = p*EnR_{\_\text{elec}} \tag{15}$$

In WBAN, transmitting of data happens over the human body henceforth, and some loss ought to be there. Thus to accommodate that loss, an alteration co-efficient 'n' is involved in for calculating energy

$$En_{\text{trans}} = En_{T\_\text{elec}} \times p + En_{\text{amp}} \times n \times p \times d^2 \tag{16}$$

where En_{trans} = transmission-energy; En_{rec} = reception-energy, $En_{\text{T\_elec}}$ = energy needed by the transmitter circuit $En_{\text{R\_elec}}$ = energy needed by receiver circuit, En_{amp} = amplifier-energy.

4.3 Simulation scenarios

In this, several weighting criteria for every variable has been considered to research which situation gives the most ideal outcomes and their estimations. The medium for information transmission is uninterrupted from the crash as well as impedance. Advance, sensor nodes with the support of the relay node sends information to the sink by constantly keeping track of its surroundings. Table 4 illustrates the simulation parameters for the proposed approach. In order to access the proposed convention, a broad set of investigations has been done utilising MATLAB R2017a [32]. The execution of the proposed system is accessed by looking at the chosen execution measurements that are stability period, network lifetime, path loss, network throughput, network delay, and average energy consumption. The impacts of channel obstruction are overlooked on the proliferation of radio waves. The sensor nodes are placed at particular points on the human body. At first, all sensor nodes are prepared with constrained energy sources (0.5 J for each sensor node). At the point when the sensor nodes convey throughout the recreation, they exhaust and stop transmissions whenever the energy sources vanish.

5 Results and discussions

5.1 Network throughput

Throughput is defined as the number of packets received at the sink. It also implies the number of packets transported from one node to another in a particular time-period. AHP–neutrosophic handles inconsistency as well as indeterminacy effectively. Moreover, it deals with contradictions that are true and false at the same time. So, it gives flexible judgement for selecting the relay node in WBAN problem in comparison with AHP. Thus, AHP–neutrosophic produces higher amount of throughput than AHP as shown in Fig. 4.

Table 4 Simulation parameters for proposed approach

Parameters	Value
size of simulating area	3 m
no. of sensor nodes	10
the Primary energies of sensors	0.50 J
packet-size	4000
range of sensor nodes	3 m
transmission energy (ETX)	16.7 nJ/bit
reception energy (ERX)	36.1 nJ/bit
amplification energy (E_{amp})	1.97×10^{-9} J/bit
supply voltage, min	1.9 V
topology	multi-hop star topology

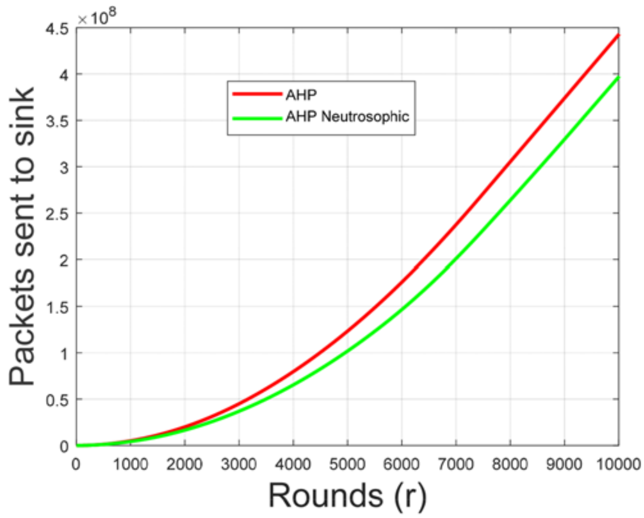

Fig. 4 *Analysis of network throughput*

5.2 Average energy consumption

The proposed protocol uses multi-hop node communication. A forwarder node is used to transfer the data from the node, which is farthest to the sink node. So, AHP–neutrosophic technique contributes to lesser energy consumption as compared to AHP. It is because AHP–neutrosophic method takes care of inconsistency and indeterminacy effectively, unlike AHP. Fig. 5 illustrates the analysis of the average energy consumption.

5.3 Stability period

First dead node contributes to the network stability period, and last dead node contributes to network Lifetime. AHP–neutrosophic technique improves both the stability period as well as the network lifespan of WBAN. The proposed method ensures more extended stability period. Since, it makes a flexible judgement for selection of the relay node in WBAN, unlike AHP. Thus, AHP–neutrosophic produces higher amount of throughput than AHP. Fig. 6 shows the results for stability period.

5.4 Average delay

Network delay is a vital design and performance characteristic of the telecommunication network. How much time a bit of data will take to travel from one node to another or endpoint to another is specified by the delay of the network. Depending upon the specific location of the communicating nodes, the delay may differ. Delay is the major

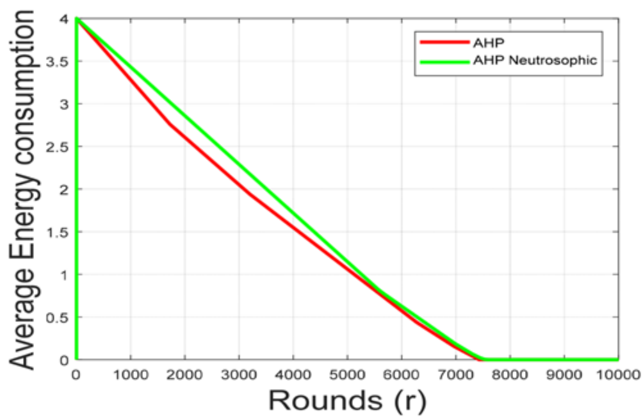

Fig. 5 *Analysis of average energy consumption*

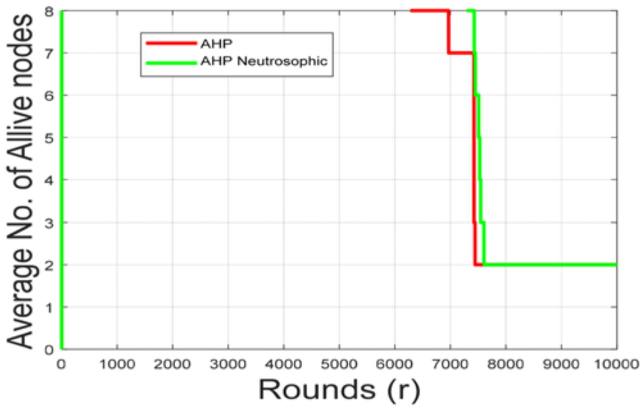

Fig. 6 *Analysis of number of alive nodes*

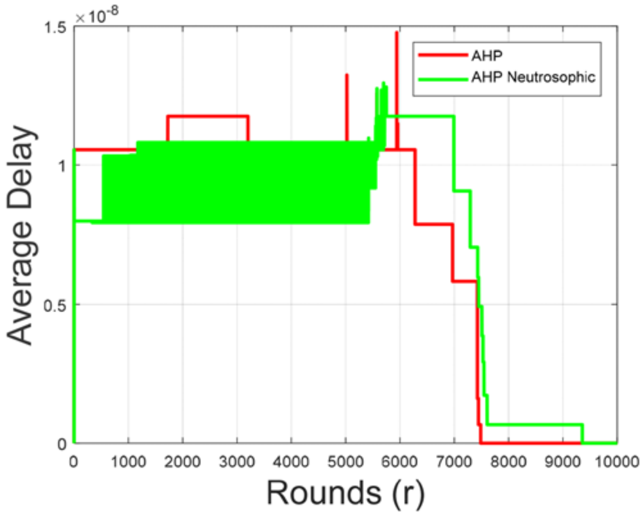

Fig. 7 *Analysis of network delay*

concern for the users as the patient's data should be transmitted at a proper time. Since, AHP–neutrosophic handles inconsistency as well as indeterminacy effectively. So, the proposed AHP–neutrosophic method ensures much lesser delay period than AHP. Fig. 7 represents the network delay.

5.5 Dead nodes

The stability period is a period of network operations from the beginning of the network until the first node dies. The period after the demise of the starting node until the death of the last node.

Since, unlike AHP, AHP–neutrosophic effectively handles inconsistency and indeterminacy. Also, it deals with contradictions which are true and false at the same time. So, AHP–neutrosophic method encounters first dead node much later within the network's lifespan in comparison with AHP. Fig. 8 represents the analysis of dead nodes.

5.6 Path loss

Path loss is defined as the reduction of power intensity of electromagnetic waves. A lesser path loss ensures the better propagation of the EM waves. Since, AHP–neutrosophic takes care of inconsistency as well as indeterminacy effectively.

Thus, AHP–neutrosophic method experiences comparatively lesser path loss than AHP. Fig. 9 illustrates the path loss of the network.

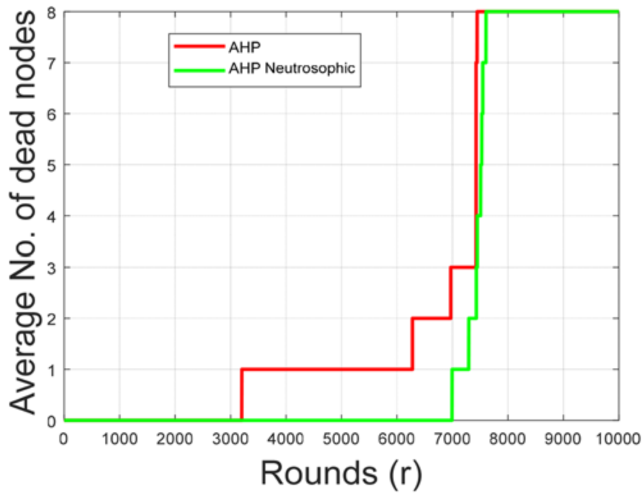

Fig. 8 *Analysis of number of dead nodes*

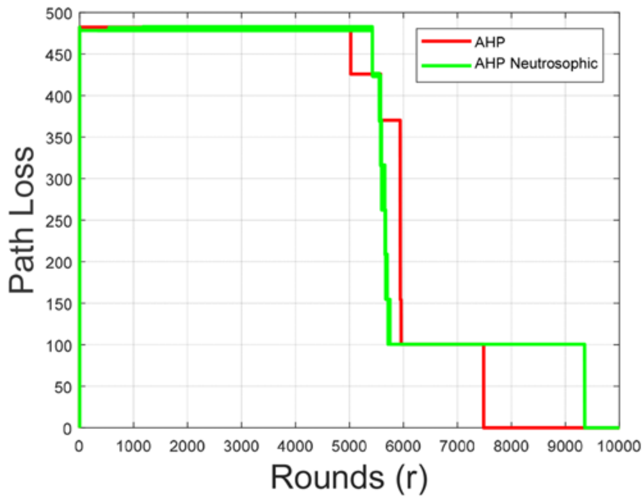

Fig. 9 *Path loss of AHP and AHP–neutrosophic*

6 Conclusions

In this paper, we proposed a new MCDM technique, i.e. hybrid AHP–neutrosophic method, for the selection of the relay node based on the priorities for WBAN problem. In the proposed method, AHP is used to calculate the weights of different criteria and neutrosophic method, find out the best alternative solution. The execution of the proposed method demonstrates lesser energy utilisation and enhanced network stability. The experimental results indicate that AHP–neutrosophic method outperforms AHP method in terms of throughput, energy consumption, delay, path loss, stability, and dead nodes. Our future work will be to compare various different techniques for further improvements in WBAN.

7 References

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