ISSN 2303-4521
Periodicals of Engineering and Natural Sciences *Original Research*
Vol. 11, No. 3, May 2023, pp.97-108

A novel nomadic people optimizer-based energy-efficient routing for WBAN

Adnan Yousif Dawod [1], Baqer A Hakim[2], Ahmed Dheyaa Radhi [3], Zinah S. Jabbar [4], Jamal Fadhil Tawfeq [5], Poh Soon JosephNg [6]

[1]Department of Computer Science and Information Technology, College of Computer Science and Information Technology, University of Kirkuk, Kirkuk, Iraq
[2] College of Dentistry, University of Al-Ameed, Karbala PO Box 198, Iraq
[3] College of Pharmacy, University of Al-Ameed, Karbala PO Box 198, Iraq
[4] Department of Communication Technology Engineering, College of Information Technology, Imam Ja'afar Al-Sadiq University, Baghdad, Iraq
[5] Department of Medical Instrumentation Technical Engineering, Medical Technical College, Al-Farahidi University, Baghdad, Iraq
[6] Faculty of Data Science & Information Technology, INTI International University, Persiaran Perdana BBN, 71800 Nilai, Negeri Sembilan, Malaysia

ABSTRACT

In response to user demand for wearable devices, several WBAN deployments now call for effective communication processes for remote data monitoring in real time. Using sensor networks, intelligent wearable devices have exchanged data that has benefited in the evaluation of possible security hazards. If smart wearables in sensor networks use an excessive amount of power during data transmission, both network lifetime and data transmission performance may suffer. Despite the network's effective data transmission, smart wearable patches include data that has been combined from several sources utilizing common aggregators. Data analysis requires careful network lifespan control throughout the aggregation phase. By using the Nomadic People Optimizer-based Energy-Efficient Routing (NPO-EER) approach, which effectively allows smart wearable patches by minimizing data aggregation time and eliminating routing loops, the network lifetime has been preserved in this research. The obtained findings showed that the NPO method had a great solution. Estimated Aggregation time, Energy consumption, Delay, and throughput have all been shown to be accurate indicators of the system's performance.

Keywords: Wireless Body Area Networks; Smart Wearable Systems ; Data transmission Network Lifetime; Nomadic People Optimizer-based Energy-Efficient Routing

Corresponding Author:

Poh Soon JosephNg
Faculty of Data Science and Information Technology, INTI International University
Persiaran Perdana BBN Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
Email: joseph.ng@newinti.edu.my

1. Introduction

One of the wireless sensor network applications used in the medical industry is a wireless body area network. Sensor nodes for the WBAN, a short-range network, are positioned inside a human body. These tiny, lightweight sensor nodes are used to measure vital indicators like blood pressure, oxygen saturation, and heart rate. To utilize the human body as the carrier of wireless signals, body sensors have been developed. Both intra- and inter-body communications are grouped under the WBAN energy-efficient routing protocol. While the interbody involves communication between coordinator nodes and sinks, the intra-body represents communication between sensors and sinks [1]. The physical characteristics of an area may be monitored and recorded by a wireless sensor network (WSN); a self-configured wireless network devoid of infrastructure. Due to their low price, compact size, and versatility, WSNs have attracted a lot of interest for a wide variety of uses, including healthcare, the military, and underwater surveillance. In recent times, the technologies utilized for handling WSN devices, networks, and data have been employed in various settings beyond their initial scope. As an illustration, sensor nodes are used in smart factories to gather data on the products and machinery to facilitate innovative factory operations [2]. “Wireless sensor networks” (WSNs) are a crucial part of technology that provide sensors the ability to collect a range of sensing data in an area they are monitoring and to carry out intelligent data processing & judgments. The sink is in charge of integrating, processing, and uploading the data that was first seen by the sensor nodes to the server in a typical WSN, which is made up of numerous sensor nodes that perceive and process data in self-organizing ways. As a result, electricity is the most valuable commodity in WSNs, and using energy-saving strategies is the best way to extend their useful lifespan. Making the most of the available resources, carrying out node load balancing, and keeping the network operational for as long as feasible are critical problems to address because energy-efficient routing algorithms might significantly lower energy use and increase the lifespan of WSNs [3]. Wireless body area network advancements have affected various real-time industries and fields, including defense, research, manufacturing, commerce, transportation, and healthcare. The wireless body area network sensors should be more precise, accurate, and noise resistant. In a WSN, the sensor nodes are spread far apart. Routing describes the process by which packets are transmitted from the WSN's sensor nodes to its base station using the network's wireless communication medium. Each sensor node's power consumption has a direct effect on the WSN network's longevity. Therefore, the routing protocol must guarantee longer WSN network life by effective node routing [4]. WBAN's creation has also improved and streamlined solutions for a wide range of nanotechnology-based fields, including medical, industry, agriculture, and the military. The medical field has been an important user of this technology. Systems that monitor a person's internal health typically use a plethora of Nanosensors implanted in the body, which are in constant contact with one another and the outside world to form the WBAN [5]. Consequently, a novel Nomadic People Optimizer (NPO)-based routing method for WBAN was developed in this study. The smaller size of the node is the source of the high energy usage. It has resource-constrained gadgets and needs more energy to transfer the data. The primary objective of energy efficiency is to improve a given quantity while abiding by a set of potential limitations by applying routing algorithms, commonly referred to as search techniques. This study's main contribution was the creation and use of a brand-new Energy-Efficient Routing method for resolving heuristic issues. Smart wearable patches are successfully enabled by the proposed Nomadic People Optimizer-based Energy-Efficient Routing (NPO-EER), which speeds up data gathering and avoids routing loops. The migration of nomads seeking food supplies in the desert served as the inspiration for NPO.

2. Related works

Reference [6] proposed a routing system with low energy consumption that effectively utilizes wired body area sensor network (WBASN) sensors for parameter monitoring. The forwarder node has made use of the multi-hopping idea. The forwarder node, which is some distance away from the sink, receives the sensor data. Once a forwarder node has accepted data, it will send that data to a sink node. Reference [7] offered a clear perspective on the many routing methods and issues surrounding data distribution and loss in a medical setting, hence achieving energy efficiency, low delay, and reliability. Reference [8] presented an evaluation of "reliable and energy-efficient routing methods" in the context of “wireless body area networks” (WBANs). They also conducted a theoretical investigation of how energy efficiency and dependability are related and how these aspects affect the durability and consistency of WBANs. The importance of link-aware energy-efficient communication between sensor nodes in the healthcare business is examined in reference [9], which sheds light on this subject. Medical care is one area where WBAN solutions are now being deployed successfully. Wearable WBAN & implantable WBAN are two types of WBAN use cases. Reference [10] applied machine learning to explain the infrastructure and architecture of WBANs, as well as transmission technologies of body area networks, constraints, and energy efficiency in various parts of the routing algorithm. In this research, they offer the WBAN routing protocol that minimizes energy consumption while maintaining throughput. This study suggests a novel "Energy Efficient Reliable Routing System" (ERRS) for resource-constrained WBAN. Reference [11] enhances stability and dependability. The two novel techniques used in ERRS are transponder node rotation and transponder node selection. Reference [12] developed an “Intelligent-Routing Algorithm for WBANs” (I-RAW) to extend the useful lifetime of such sensor nodes. Data is gathered from the sensor nodes that make up a cluster via two sinks, one on the patient's front and one on their back and sent to the cluster head (CH). Reference [13] presented a thorough analysis of several protocols and strategies for handling security, privacy, fault tolerance, and energy efficiency. A study in the article also indicates difficulties that must be considered before designing and creating any WBAN protocol. Reference [14] examined the natural trade-off between the sensors' power usage and the potential for erroneous health diagnoses. To acquire noisy evaluations of the patient's health, they frame the trade-off as a dynamical problem where each step enables us to choose which of a collection of sensors to activate. Reference [15] demonstrated a “wireless body area network” (WBAN) communication obligation. The protocol consists of several fundamental components, including cluster creation, random node placement, designating nodes with high SNR as "cluster heads," random CH rotation within each cluster, and so forth. The routing protocol "TLD-RP" (Temperature, Link Reliability, and Delay-Aware Routing Mechanism) is presented as one that monitors the Quality of Service (QoS) of a Wireless Body Sensor Network (WBSN), according to reference [16]. Almost all recommended temperature aware WBSN routing solutions (temperature, hop count, or energy) employ one or more routing metrics. In the context of WBAN, it was suggested in sources [17-21] to use a technique called "Minimum Edge-shared Vertex Paths Selections" (MEVPS). This requires updating knowledge of surrounding nodes using an ant colony algorithm. A path with the fewest edges might be created between the source and the BS. Clustering is useful for energy optimization since it reduces the number of duplicate requests and increases the quality of directed broadcasts in WBAN. Before the routing process, which involves choosing a cluster leader, clustering requires two separate steps. Routing loops, packet duplication, and transmission delays all rise when the cluster head is frequently replaced. When there are loops, repetition, or delayed transmissions in a WSN, network sustainability & network output suffer. As the number of reconnection attempts rises, energy consumption rises despite a decrease in transmission overhead. The Nomadic People Optimizer-based Energy-Efficient Routing (NPO-EER) algorithm is presented to address the issues with communication and power consumption [22-25]. Real-time medical data interchange using wireless body area networks is a practical solution to enhance medical services. It provides several opportunities in the medical and health fields. This is ineffective and attackable, which allows user private information to leak [26]. Data collection, data gathering, and error checking are the three categories under which B FFS is divided. It discussed some crucial security aspects of WBAN communication. In addition, it has revealed several security assaults that might be conducted in WBAN while messages are being sent [27]. To cluster data, an FLC is employed that considers crucial factors like CH temperature, comparable and total neighbors, remaining energy, and route loss. Maintaining an appropriate temperature of these sensors is imperative when dealing with large amounts of data and prolonged missions [28]. Information is gathered by a sensor node, and communication is enabled by a gateway node that links the sensor node. The use of energy efficient WBANs is hampered by other issues [29]. To classify the schemes, a taxonomy is offered. Smart grids, smart automobiles, and fog-assisted smart cities are also taken into consideration for secure, effective, and trustworthy data collecting with minimal computational cost [30]. The public wireless network environment of a WBAN presents a serious security risk in terms of ensuring that only authorized parties have access to patient's sensitive health information. A patient's life may be in danger if sensitive data were intercepted, interrupted, or modified because of unauthorized access. To construct a session key and accomplish safe authentication, several authentication algorithms have been put forward. The session key is then used to encrypt the sensitive data transferred over the insecure channel. But there are also performance constraints and security issues, such as impersonation attacks, desynchronization assaults, and other potential attacks via unprotected channels. A routing strategy for secure data transfer in WBAN is suggested in this work. The technique lowers energy consumption by direct connections using two-hop or multi-hop communication. A multi-parameter maximum gain function is created to choose the optimal next-hop node, and the weights are changed based on the significance of the inputs. Additionally, dynamic route modification is utilized to guarantee efficient and reliable data transfer. The paper provides a detailed explanation of the maximum benefit function creation and routing mechanism.

2.1. Development of the Function that Maximizes Benefits

The sum of the weighted coefficients for the hops to the sink, normalized residual energy, available bandwidth, and transmission efficiency indicates the maximum benefit functions. The node with the highest functional value is, thus, the optimum next hop. Because the energy supply for nodes is constrained, increasing energy efficiency is essential. To maintain a healthy balance in the network's total energy consumption, this study prioritizes the nodes' leftover energy. The optimal next hop is then determined to be the node with the maximum remaining energy. The percentage of packets a node can broadcast successfully serves as a gauge of its transmission efficiency. How many packets the node can deliver in a specific amount of time without experiencing any faults determines its efficiency. The optimum next hop must be chosen from the node with the highest transmission rate to enable reliable data delivery across nodes. The entire bandwidth at any time available to a node is its bandwidth. Better data transmission is made possible by a more considerable bandwidth, which speeds up the network. By considering the bandwidth that nodes have available, which results in constant, uninterrupted, and timely data transmission between nodes, the secure flow of data may be further secured. The number of hops needed for the nodes to reach the sink is determined once the network is created.

The transmission latency may be considerably decreased by choosing the best next hop node, resulting in smooth and timely data flow across nodes. The best next-hop node is chosen, and then the data is forwarded through the three stages of the proposed routing protocol.

2.2. Initialization of the Network

According to the suggested protocol, each node in the network, including the aggregation node, sends a Welcome message. After receiving this message, the node relocates the receiver to the new position and broadcasts another Welcome message to the network. The nodes' IDs, locations, remaining energy, transmission efficiency, bandwidth, number of hops to the recipient, and other data are all included in this message about the nodes. The receiver's and adjacent nodes' precise position is now known to all nodes. Following the initial phase, each node will offer a data table about its nearby nodes, known as NT. The best next hope will be determined using this table.

2.3. Choosing the Next Hop Node by Maximizing the Benefit Function

To meet the various QoS requirements for different types of data in WBAN, it is necessary to categorize and process them accordingly. P1 priority data may have low traffic and random creation, but it requires strict real-time and reliability criteria. When emergency data comprises anomalous physiological data that may risk people's lives and health, any delay might result in disastrous occurrences. As a result, issues like node transmission efficiency, available bandwidth, and the number of hops to the sink require extra consideration. To ensure the prompt and accurate delivery of emergency data, we can assign weights of 0.1, 0.3, 0.4, and 0.2 respectively. On the other hand, we require the fundamental premise of decreasing energy usage to successfully improve the weight values of other energy metrics for P2 priority data. An example of balancing the energy usage of nodes and ensuring reliable data transfer is by setting the weights to 0.5, 0.2, 0.2, and 0.1. By selecting a next-hop node with larger available bandwidth, better transmission efficiency, and fewer hops, node energy consumption can be balanced, extending the network lifetime while maintaining low latency and consistent communication between nodes. The protocol mandates that multi-hop routing use a maximum of three hops. The Eminth protocol establishes a minimum energy threshold for each network node to guarantee that it has sufficient energy to function. When a node's residual energy reaches this threshold, it may become a contender for the following hop by entering the NT. If a network device's remaining energy falls below this threshold, it will stop serving as the next hop and leave the NT. Currently, nodes only communicate their own packets and not information about other nodes in the network. Prior to sending the data, the best next-hop node is chosen. Data is obtained from the source node and sent to the sink by the chosen next-hop node. To ensure prompt urgent data transmission, the P1 data is processed first if two other nodes choose the same next-hop node simultaneously. If a node's remaining energy falls below Eminth, it only transmits its own data, assuming that its initial energy level was the same.

2.4. Network model

Consider a system of n sensor nodes, n sink nodes, and n source nodes made up of intelligent wearing patches. Under the “random waypoint” (RWP) paradigm, the nodes are distributed in the X*Y area in random order and with reduced mobility. Several sensor nodes also serve as monitoring nodes (MNs). The physical management of the transmission zone and network region determines the MN count. As principal aggregators, we classify intermediate nodes with higher energy (PAs). Secondary aggregators (SAs) are nodes with the second-highest energy that are idle. Backup aggregators (BAs) are intermediate nodes that act as aggregators after multipath. The major aggregator node seeks data from the active source nodes and initiates the broadcast. MNs are used as a buffer, to measure the flow rate after transmission, and to monitor the energy of the nodes during the initial stages of transmission. A wearable patch that is integrated with the WBAN model is shown in figure 1. In addition, MNs offer recommendations for modifying the aggregator node. A typical WBAN consists of several sensor nodes, a controller node, a mobile phone, or PDA. On a WLAN or mobile network, the central node serves as both a network sink and a public network gateway. The wearer's smartphone can be the interface for tracking health indicators if preferred. The sensor nodes contain WBAN models for usage by practitioners who adhere to standard operating procedures and gather data on anthropometric markers such as EGG, CGG, pulse, temperature, and blood glucose, as well as on-body movements and GPS wearable patches.

2.5. Nomadic People Optimizer

The description of nomads and their manner of existence, which serves as the foundation for the suggested algorithm, is the first stage in this section's explanation of the fundamentals of NPO. A mathematical model of

NPO is also provided. A nomad is a person who spends his or her whole life traveling from one region to another with flocks of camels, cattle, and sheep in search of food and fresh water. These herds graze on the grass near water sources, providing their owners with food and other necessities like skin and wool for clothing and tent construction. The nomads get their protein and calcium from the milk of the herd. Since nomads seldom stay in one spot for an extended period, it is generally known that they do not get used to their surroundings or develop the ground around their village. In truth, there are various sorts of nomads, including Berbers, Gypsies, and Bedouins. The new algorithm, NPO, was influenced by Bedouin categorization and lifestyle. The Sheikh family and regular families make up the Bedouins' families. The clan's head, the sheikh, decides the sites necessary for each family's survival as well as their distribution strategy. The family would be sent in search of a new appropriate place by the sheikh. The chosen families would travel at random distances and directions. The distribution of the families is shown in figure 2. The Sheikh's tent is in the middle of a semicircular dispersion of the family tents. The sheikh is the key player, having control over the clan's movement as well as the destiny of the families and their futures.

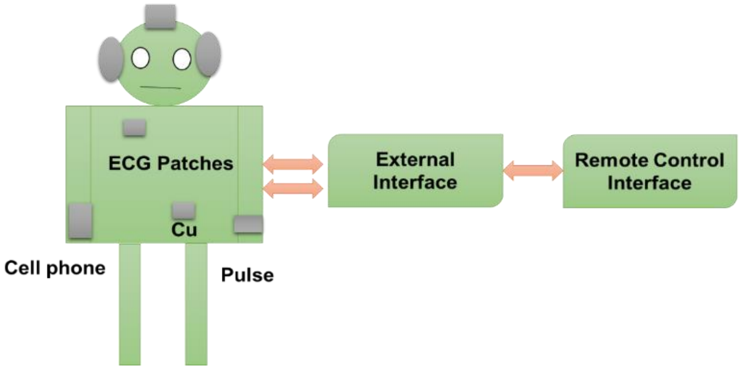

Figure 1. Wearable patches combined with the WBAN model

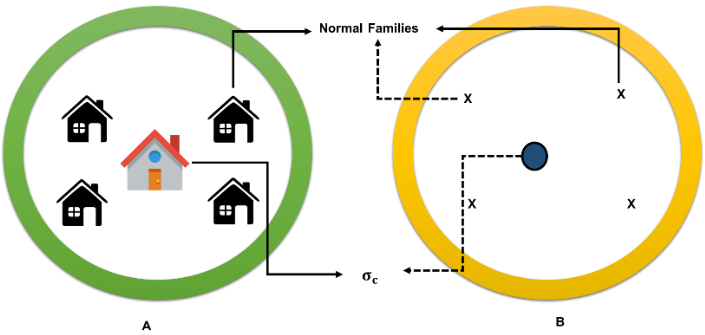

Figure 3: Semicircular distribution of the families

The following is a discussion of the terms used to describe NPOs:

- Leader (σ): One person in the swarm represents the current local best option.
- Best Leader (σ^E): The meeting room strategy uses a person to represent the overall best answer in all swarms.
- Normal Leader (σ^N): A person who stands in for all other leaders outside the Best Leader (σ^E). Family (x) refers to an individual who represents a member of a group or community whose physical abilities are not as strong as the leader.
- Clan (c) is a group of families (x) that are led by a single leader (σ). Each clan in the NPO consists of several households and one leader.
- To determine the worth of a particular place in the search space, the phrase "fitness" or "objective function" (f(x)) is employed.
- The function links the physical issue and the optimization approach by returning a value after receiving the coordinates of the solution space.

Direction (Ψ) is a variable that guides average leaders towards superior leaders.

Five key operators the Initial meeting, semicircular distribution, family search, leadership changeover, and finally, periodic meeting make up the NPO algorithm.

Initial meeting (initialization):
A group of chiefs (σ) is randomly initialized as $\sigma_i = \{\sigma_1, \sigma_2, \ldots \#Clans\}$ using equation (1).

$$\overrightarrow{\sigma_c} = (UB - LB) \times Rand + LB \quad (1)$$

LB and UB refer to the minimum and maximum limits, while $\overrightarrow{\sigma_c}$ indicates the position of the leader of clan c. Rand represents a randomly generated number within the range of 0 to 1.

Exploiting Local Search with a Semicircular Distribution:
A group of families (x), where $X_i = \{X_1, X_2, \ldots \#Families\}$, are arranged around the matching leader (r). Using the 2D circle equations, it is mathematically feasible to randomly distribute points inside of a specified circle with a defined radius. According to the angle's value and the following equations, a circle is drawn around these locations and the origin (the circle's center):

$$X = \left(Rd \times \sqrt{R_1}\right) \times \cos(\theta) + X_0 \quad (2)$$

$$Y = \left(Rd \times \sqrt{R_2}\right) \times \sin(\theta) + Y_0 \quad (3)$$

Where R_1 and R_2 stand for the randomly generated coordinates of a point on the circle's edge, and X_0 and Y_0 stand for the origin point's (circle's) coordinates. While θ is a random number between [0,2π], it corresponds to the angle value of that point. When the produced points are in the form of a 2D circle, equations 2 and 3 are applied (i.e., X, Y; and θ). The issues, however, do not need the use of X and Y coordinates if the answers are represented inside the search area. As a result, rather than being represented in two dimensions, the solutions are shown in the unary form. As a result, the leader's tent must be distributed randomly, and thus needs an X location, but not a Y position. Considering this, an equation was created to account for this situation, as shown in Equation (4) in the following:

$$\overrightarrow{X_c} = \overrightarrow{\sigma_c} \times \sqrt{R} \times COS(\theta) \quad (4)$$

In Equation (4), the position of a family is represented by $\overrightarrow{X_c}$, while the position of the leader of the same swarm or clan is represented by $\overrightarrow{\sigma_c}$. Additionally, R is a random integer between [0, 1]. When LB is 0 or positive, the equation may be multiplied by |COS(θ)|. It's important to note that the location of each family is entirely dependent on their leader's placement decisions. Therefore, the leader has full control over where each family is situated around their tent.

Families seeking (worldwide exploration): The following search space is based on arbitrary directions and steps produced by the Le'vy Flight equation:

$$\overrightarrow{X_i^{new}} = \overrightarrow{X_i^{old}} + a_c * \overrightarrow{\left(\sigma_c - X_i^{old}\right)} \oplus Levy \quad (5)$$

Where the variables $\overrightarrow{X_i^{new}}$ and $\overrightarrow{X_i^{old}}$ stand for the current family's new and old locations. The distance between all other normal families, a_c, which represents the area of the clan and can be determined using the following equation, is equal to a_c*a_b.

The symbols $\overrightarrow{X_i^{new}}$ and $\overrightarrow{X_i^{old}}$ represent the present positions of the family, both new and old, while a_c represents the size of the group, which is equivalent to the mean distance between all other typical families and $\sigma_c. a_c$. To determine $\sigma_c. a_c$, you can use this formula:

$$a_c = \frac{\sum_{i=1}^{\Phi} \sqrt{\left(\overrightarrow{\sigma_c} - \overrightarrow{X_i^{old}}\right)^2}}{\Phi} \quad (6)$$

In this case, the leader's function is denoted via (σ_c), and the role of the standard household is denoted via X_c^i. Φ represents the wide variety of households in every clan. When households are organized in a semicircular distribution round σ_c, x_(c) will be nearer to σ_c, motivating small-step exploration of the search region. The massive distance between all x_(c) and σ_c improves the capability of households to discover the search area a ways from the cutting-edge σ_c. This permits the fee of a_c to influence the search process tremendously. These households go randomly in exceptional instructions with the step dimension decided using the Le'vy flight (λ_c) equation.

$$Levy \backsim u = t^{-\lambda} \quad (1 < \lambda \leq 3) \qquad (7)$$

The random step duration is typically calculated using the Le'vy flight equation and the Le'vy distribution with an infinite mean and variance. Figure 5 is a common illustration of the stochastic equation for a random walk. A random walk's future state or location is often defined by its current position (the first component of the equation) and the transfer probability (the second term). ⊕ represents the product of term-by-term multiplication. The random walk using Le'vy flight is more successful while traversing the search space since its step length increases significantly with time.

Leadership transition (exploitation): Determine if a new family has a greater level of adaptability than the clan's present head for each clan. In such cases, both families will have leadership roles.
The periodical meetings (exploitation–exploration): All save the relocation of Leaders in the desert distinguish the recurring gatherings from the first gathering. The Leaders work to settle any external issues and explore the ideal areas for migration during these frequent sessions. The goal of this gathering is to give each Leader power over his domain without igniting the aspirations of those around him, but rather by drawing them closer to himself. For the other Chiefs to obtain a solution to update their positions during the first portion of the meeting, it is necessary to choose the most decisive or best-positioned Leader. This update is produced by the difference between the average most essential Leader position and the average Leader position, as shown in the following equation.

$$\Delta Pos = \Psi(\frac{\sqrt{\sum_i^D(\sigma^E - \sigma_c^N)^2}}{\#D}) \qquad (8)$$

Where σ^E stands for the greatest Leader's position and σ_{Ni} stands for the position of average Leader. In the meanwhile, $\#D$ stands for the problem's number of dimensions, Ψ for the problem's direction, and ΔPos for the normalized gap between the best Leader and the usual Leader. Ψ guides regular Leaders to better areas based on the fitness value of the top sheikh:

$$\Psi = \begin{cases} 1 & if\ f(\sigma^E) \geq 0 \\ -1 & otherwise \end{cases} \qquad (9)$$

By using Equation 10, the regular Leaders revise their positions. A portion of the NPO discovery stage is represented by this equation.

$$\overrightarrow{\sigma_c^{new}} = \overrightarrow{\sigma_c^N} + \Delta Pos\ (\sigma^E - \sigma_c^N) * \frac{IT}{c} \qquad (10)$$

Where IT and IT stand for the current iteration and the total number of iterations, respectively, and σ_c^{new} and σ_c^N stand for the new and old positions of the normal Leader. This algorithm is based on evolutionary computation and is designed to optimize a given objective function by simulating the natural selection process that occurs in nomadic populations. Many optimization issues, including those requiring intricate, nonlinear functions or numerous goals, can be resolved using the NPO method. A meta-heuristic optimization technique called the Nomadic People Optimizer was developed in response to observations of nomadic people. This algorithm is used to solve complex optimization problems, such as those found in engineering, finance, and logistics. To write the Nomadic People Optimizer algorithm, we first need to define the basic principles of nomadic behavior. Nomads are known for their ability to adapt to changing environments and their willingness to explore new territories. They are also highly social and rely on cooperation and communication to survive. Overall, the Nomadic People Optimizer algorithm combines elements of randomness, cooperation, and exploration to efficiently search for optimal solutions in complex optimization problems [19].

3. Simulation setup

The simulation is done using Qualnet 5.0.2. Performance metrics include throughput, delay, energy consumption, and aggregated time. Table 1 lists the specified simulation parameters.

Table 1. Simulation parameters

Simulation Parameter	Corresponding values
Channel frequency	2.4 GHz
Radio Type	Radio Type IEEE 802.15.4
Simulation time	300s
Data rate	15 kbps
Packet reception model	PHY 802.15.4
Data rate	15 kbps
MAC protocol	IEEE 802.15.4
Average end-to-end delay	< 350ms
Antenna type	Omni directional
CCA mode	Carrier-sense
Network Protocol	IPv4
Routing Protocol	Bellman ford
Beacon order	5,4,3
Application	CBR
Superframe order	3(fixed)
Packet rate (packet per second)	10,20,30
Energy Model	MICAZ

4. Result and discussion

The “Distributed Energy-Efficient Adaptive Clustering” (DEEAC) and “Distributed Energy-efficient Adaptive Clustering Protocol with Data Gathering” (DEACP) techniques, “Ad-hoc on-demand Multipath distance vector” (AOMDV) techniques are used to build the Nomadic People Optimizer-based Energy-Efficient Routing (NPO-EER) algorithm, and their performance is compared. Figure 4 shows the throughput plotted versus time. The throughput rises as time goes on. In N, it is guaranteed that nodes will remain operational even after energy depletion and that data will continue to be continuously collected and sent to the sink node through seamless aggregation. The proposed method's likelihood of data transmission rises since the duty cycle technique extends the node's life.

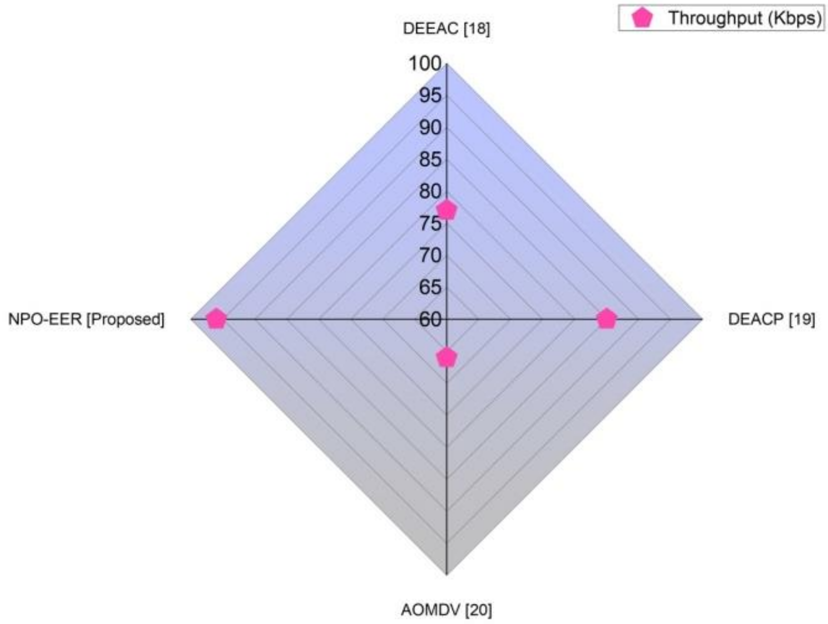

Figure 4. A comparative analysis of throughput (Kbps)

Figure 5 demonstrates the aggregation latency to flow rate. Throughput rises because of the flow rate, which also causes the aggregation delay to rise. When cluster re-election occurs, a pause time is recorded, and as that time passes, the latency in NEEMA, Improved SEAR, MGWOQL, and ICMP increases. NPO-EER enables concurrent multipath aggregation and eliminates the technique, which reduces aggregation latency. Figure 6 shows the comparative analysis of energy consumption (J)

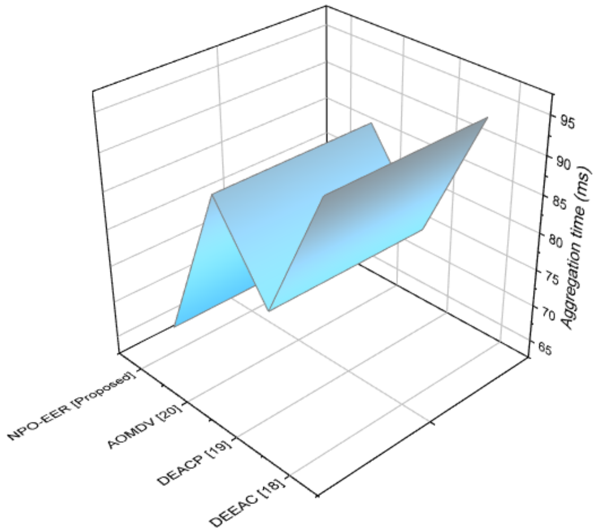

Figure 5. A comparative analysis of aggregation time (ms)

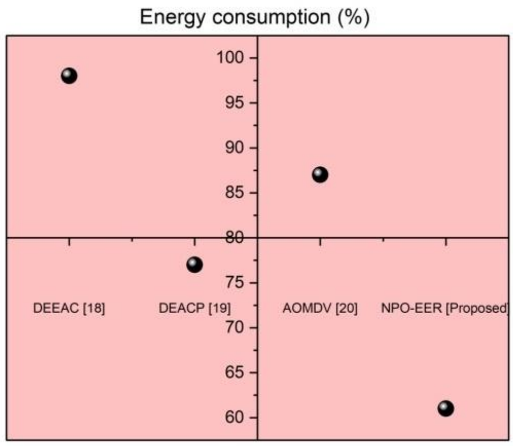

Figure 6. A comparative analysis of energy consumption (J)

The network's energy use over time is shown in Figure 7. Early consumption is less common in NPO-EER because the nodes often rotate between active and sleep phases to maintain energy balance. Due to node switching and load sharing, the network maintains a low single-node energy consumption. The suggested technique is contrasted with the current approaches in Table 2.

Table 2: Comparison of the many characteristics of the proposed and current techniques

	DEEAC	**DEACP**	**AOMDV**	**NPO-EER (Proposed)**
Throughput	78	86	68	97
Delay	89	85	72	60
Aggregation time	91	75	84	66
Energy consumption	94	77	86	62

For heterogeneous wireless sensor networks, an enhanced Distributed Energy-Efficient Adaptive Clustering (DEEAC) is presented; it assumes that the various node types are dispersed across the various zones. The transmission overhead decreases, and energy consumption increases as more attempts are made to reconnect [18]. The Distributed Energy Efficient Adaptive Clustering Protocol (DEACP) with data collection has been used to optimize the distance between cluster heads to generate well-distributed clustered WSNs with a suitable cluster size. The network's life cycle is the operation period after its founding node's demise [19]. For ad hoc networks, Ad-hoc On-Demand Multipath Distance Vector (AOMDV) is the loop-free routing approach. It begins on its own in a network configuration with moving nodes and can withstand a variety of network traits, including node mobility, connection errors, and packet loss. A lot of control packets are produced when a connection fails, using up bandwidth on the network, and the degree of QoS declines as network density rises [20-25]. For all the nodes in a network, whether they are source nodes or nodes transmitting user data, flat routing methods maintain the same requirements. The routing protocols in this group provide a path for every sensor node to take to reach the sink. Compared to other existing algorithms, this NPO-EER technique is superior [26-40].

5. Conclusion

This paper offers a WBAN load balancing, and Nomadic People Optimizer integrated energy-efficient routing approach. By using forehand updates from monitoring nodes, the NPO-EER employs adaptive routing.Internal node state switching, external neighbor selection, and transmission sequence updating activities prevent energy failures caused by overload and delayed data propagation caused by loops. The system uses an adaptive neighbor selection technique to maintain communication speeds based on the energy availability and data processing capability of each user. With a low energy use of 62% and a high number of active nodes, the integrated approach maintains a throughput of 97% while aggregation time is reduced to 66% and end-to-end latency is reduced to 60%. To address the problem of aggregator nodes not knowing the position of sink nodes, the technique may be further integrated by using the adaptive localization approach. This would aid in optimizing the smart wearable patch's energy usage and neighbor selection after aggregation with fewer travels to the destination.

Acknowledgements

The authors are grateful to the Iraqi Ministry of Higher Education and Scientific Research (MOHESR) for technically supporting the current research.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] T. O. Barayyan, A. Kaur, and S. Shilpa, “A MULTISINK ENERGY-EFFICIENT ROUTING PROTOCOL FOR WIRELESS BODY AREA NETWORK,” Yanbu Journal of Engineering and Science, vol. 13, no. 1, May 2021, doi: 10.53370/001c.24323.

[2] W.-K. Yun and S.-J. Yoo, “Q-Learning-Based Data-Aggregation-Aware Energy-Efficient Routing Protocol for Wireless Sensor Networks,” IEEE Access, vol. 9, pp. 10737–10750, 2021, doi: 10.1109/access.2021.3051360.

[3] Q. Ding, R. Zhu, H. Liu, and M. Ma, “An Overview of Machine Learning-Based Energy-Efficient Routing Algorithms in Wireless Sensor Networks,” Electronics, vol. 10, no. 13, p. 1539, Jun. 2021, doi: 10.3390/electronics10131539.

[4] M. H. Ali, A. Ibrahim, H. Wahbah, and I. Al_Barazanchi, “Survey on encode biometric data for transmission in wireless communication networks,” Period. Eng. Nat. Sci., vol. 9, no. 4, pp. 1038–1055, 2021, doi: 10.21533/pen.v9i4.2570.

[5] A. Attir, “Cryptanalysis of an Anonymous Mutual Authentication Protocol for Wireless Body Area Network,” Proceedings of the 11th International Conference on Sensor Networks, 2022, doi: 10.5220/0010829000003118.

[6] R. A. Khan, Q. Xin, and N. Roshan, “RK-Energy Efficient Routing Protocol for Wireless Body Area Sensor Networks,” Wireless Personal Communications, vol. 116, no. 1, pp. 709–721, Aug. 2020, doi: 10.1007/s11277-020-07734-z.

[7] I. Al-Barazanchi, H. R. Abdulshaheed, and M. S. Binti Sidek, “A survey: Issues and challenges of communication technologies in WBAN,” Sustainable Engineering and Innovation, vol. 1, no. 2, pp. 84–97, Dec. 2019, doi: 10.37868/sei.v1i2.85.

[8] F. Ullah, M. Z. Khan, G. Mehmood, M. S. Qureshi, and M. Fayaz, “Energy Efficiency and Reliability Considerations in Wireless Body Area Networks: A Survey,” Computational and Mathematical Methods in Medicine, vol. 2022, pp. 1–15, Jan. 2022, doi: 10.1155/2022/1090131.

[9] N. Ahmad, B. Shahzad, M. Arif, D. Izdrui, I. Ungurean, and O. Geman, "An Energy-Efficient Framework for WBAN in Health Care Domain," Journal of Sensors, vol. 2022, pp. 1–11, Feb. 2022, doi: 10.1155/2022/5823461.

[10] A. Malik et al., "Pan Evaporation Estimation in Uttarakhand and Uttar Pradesh States, India: Validity of an Integrative Data Intelligence Model," Atmosphere (Basel)., vol. 11, no. 6, p. 553, May 2020, doi: 10.3390/atmos11060553.

[11] H. Tao, S. M. Awadh, S. Q. Salih, S. S. Shafik, and Z. M. Yaseen, "Integration of extreme gradient boosting feature selection approach with machine learning models: application of weather relative humidity prediction," Neural Comput. Appl., 2022, doi: 10.1007/s00521-021-06362-3

[12] A. Malik, A. Kumar, O. Kisi, N. Khan, S. Q. Salih, and Z. M. Yaseen, "Analysis of dry and wet climate characteristics at Uttarakhand (India) using effective drought index," Nat. Hazards, 2021, doi: 10.1007/s11069-020-04370-5.

[13] H. Tao et al., "Training and Testing Data Division Influence on Hybrid Machine Learning Model Process: Application of River Flow Forecasting," Complexity, vol. 2020, pp. 1–22, Oct. 2020, doi: 10.1155/2020/8844367.

[14] B. Karimi, P. Mohammadi, H. Sanikhani, S. Q. Salih, and Z. M. Yaseen, "Modeling wetted areas of moisture bulb for drip irrigation systems: An enhanced empirical model and artificial neural network," Comput. Electron. Agric., 2020, doi: 10.1016/j.compag.2020.105767.

[15] Y. K. Salih, O. H. See, S. Yussof, A. Iqbal, and S. Q. Mohammad Salih, "A proactive fuzzy-guided link labeling algorithm based on MIH framework in heterogeneous wireless networks," Wirel. Pers. Commun., vol. 75, no. 4, pp. 2495–2511, 2014, doi: 10.1007/s11277-013-1479-z.

[16] F. Ullah, M. Zahid Khan, M. Faisal, H. U. Rehman, S. Abbas, and F. S. Mubarek, "An Energy Efficient and Reliable Routing Scheme to enhance the stability period in Wireless Body Area Networks," Computer Communications, vol. 165, pp. 20–32, Jan. 2021, doi: 10.1016/j.comcom.2020.10.017.

[17] A. Malik et al., "The implementation of a hybrid model for hilly sub-watershed prioritization using morphometric variables: Case study in India," Water (Switzerland), vol. 11, no. 6, 2019, doi: 10.3390/w11061138.

[18] H. Tao et al., "A Newly Developed Integrative Bio-Inspired Artificial Intelligence Model for Wind Speed Prediction," IEEE Access, vol. 8, pp. 83347–83358, 2020, doi: 10.1109/ACCESS.2020.2990439.

[19] Y. B. David, T. Geller, I. Bistritz, I. Ben-Gal, N. Bambos, and E. Khmelnitsky, "Wireless Body Area Network Control Policies for Energy-Efficient Health Monitoring," Sensors, vol. 21, no. 12, p. 4245, Jun. 2021, doi: 10.3390/s21124245.

[20] Y. K. Salih, O. H. See, S. Yussof, A. Iqbal, and S. Q. Mohammad Salih, "A proactive fuzzy-guided link labeling algorithm based on MIH framework in heterogeneous wireless networks," Wirel. Pers. Commun., vol. 75, no. 4, pp. 2495–2511, 2014, doi: 10.1007/s11277-013-1479-z.

[21] S. Memon et al., "Temperature and Reliability-Aware Routing Protocol for Wireless Body Area Networks," IEEE Access, vol. 9, pp. 140413–140423, 2021, doi: 10.1109/access.2021.3117928.

[22] A. M. Ali, M. A. Ngadi, R. Sham, and I. I. Al Barazanchi, "Enhanced QoS Routing Protocol for an Unmanned Ground Vehicle, Based on the ACO Approach," Sensors (Basel)., vol. 23, no. 3, 2023, doi: 10.3390/s23031431.

[23] A. Sundar Raj and M. Chinnadurai, "Energy efficient routing algorithm in wireless body area networks for smart wearable

[24] patches," Computer Communications, vol. 153, pp. 85–94, Mar. 2020, doi: 10.1016/j.comcom.2020.01.069.

[25] S. Q. Salih and A. R. A. Alsewari, "A new algorithm for normal and large-scale optimization problems: Nomadic People Optimizer," Neural Comput. Appl., vol. 32, no. 14, pp. 10359–10386, 2020, doi: 10.1007/s00521-019-04575-1.

[26] N. Bilandi, H. Verma, and R. Dhir, "An Energy Efficient Health Monitoring System using Relay Node in Wireless Body Area Networks," EAI Endorsed Transactions on Pervasive Health and Technology, vol. 5, no. 20, p. 164098, May 2020, doi: 10.4108/eai.13-7-2018.164098.

[27] I. Al-Barazanchi et al., "Remote Monitoring of COVID-19 Patients Using Multisensor Body Area Network Innovative System," Comput. Intell. Neurosci., vol. 2022, pp. 1–14, Sep. 2022, doi: 10.1155/2022/9879259.

[28] F. Cui, S. Q. Salih, B. Choubin, S. K. Bhagat, P. Samui, and Z. M. Yaseen, "Newly explored machine learning model for river flow time series forecasting at Mary River, Australia," Environ. Monit.

Assess., 2020, doi: 10.1007/s10661-020-08724-1.
[29] T. Hai et al., “DependData: Data collection dependability through three-layer decision-making in BSNs for healthcare monitoring,” Inf. Fusion, vol. 62, pp. 32–46, Oct. 2020, doi: 10.1016/j.inffus.2020.03.004.
[30] S. Q. Salih, M. Habib, I. Aljarah, H. Faris, and Z. M. Yaseen, “An evolutionary optimized artificial intelligence model for modeling scouring depth of submerged weir,” Eng. Appl. Artif. Intell., vol. 96, p. 104012, Nov. 2020, doi: 10.1016/j.engappai.2020.104012
[31] S. A. M. Al-Juboori, F. Hazzaa, S. Salih, Z. S. Jabbar, and H. M. Gheni, “Man-in-the-middle and denial of service attacks detection using machine learning algorithms,” Bull. Electr. Eng. Informatics, vol. 12, no. 1, pp. 418–426, Feb. 2023, doi: 10.11591/eei.v12i1.4555.
[32] Z. A. Jaaz, M. E. Rusli, N. A. Rahmat, I. Y. Khudhair, I. Al Barazanchi, and H. S. Mehdy, “A Review on Energy-Efficient Smart Home Load Forecasting Techniques,” Int. Conf. Electr. Eng. Comput. Sci. Informatics, vol. 2021-Octob, no. October, pp. 233–240, 2021, doi: 10.23919/EECSI53397.2021.9624274.
[33] S. A. Shawkat and I. Al-Barazanchi, “A proposed model for text and image encryption using different techniques,” TELKOMNIKA (Telecommunication Comput. Electron. Control., vol. 20, no. 4, p. 858, Aug. 2022, doi: 10.12928/telkomnika.v20i4.23367.
[34] Y. Niu, S. I. Kadhem, I. A. M. Al Sayed, Z. A. Jaaz, H. M. Gheni, and I. Al Barazanchi, “Energy-Saving Analysis of Wireless Body Area Network Based on Structural Analysis,” in 2022 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA), Jun. 2022, pp. 1–6, doi: 10.1109/HORA55278.2022.9799972.
[35] I. Al Barazanchi, W. Hashim, A. A. Alkahtani, H. H. Abbas, and H. R. Abdulshaheed, “Overview of WBAN from Literature Survey to Application Implementation,” 2021 8th Int. Conf. Electr. Eng. Comput. Sci. Informatics, no. October, pp. 16–21, 2021, doi: 10.23919/eecsi53397.2021.9624301.
[36] A. A. AlRababah, “Neural Networks Precision in Technical Vision Systems,” Int. J. Comput. Sci. Netw. Secur., vol. 20, no. 3, pp. 29–36, 2020.
[37] A. A. Alrababah, A. Alshahrani, and B. Al-Kasasbeh, “Efficiency Model of Information Systems as an Implementation of Key Performance Indicators,” IJCSNS Int. J. Comput. Sci. Netw. Secur., vol. 16, no. 12, pp. 139–143, 2016, [Online]. Available: http://paper.ijcsns.org/07_book/201612/20161219.pdf.
[38] A. A. Q. AlRababah, “Watermarking implementation on digital images and electronic signatures,” Int. J. Adv. Appl. Sci., vol. 4, no. 10, pp. 160–164, Oct. 2017, doi: 10.21833/ijaas.2017.010.022.
[39] A. AbdulQadir, “Lempel - Ziv Implementation for a Compression System Model with Sliding Window Buffer,” Int. J. Adv. Comput. Sci. Appl., vol. 6, no. 10, pp. 101–104, 2015, doi: 10.14569/ijacsa.2015.061014.
[40] A. A. Al-Rababa and M. A. Al-Rababah, “Module Management Tool in Software Development Organizations,” J. Comput. Sci., vol. 3, no. 5, pp. 318–322, May 2007, doi: 10.3844/jcssp.2007.318.322.