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Saving energy of the biosensor nodes in WBSN by using Relay nodes using the saving Energy

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Abstract:

Wireless Body Area Network (WBAN) refers to a network on the human body. The energy consumption of biosensor nodes affects the performance of wireless body sensor networks (WBSNs). Vital nodes can be implanted or worn in the patient's body and vital signs monitored. A new design of a mathematical model for calculating the energy consumption of the front and rear WBSN of the human body is proposed. It was developed to enhance wireless body networks. Energy savings for biosensor nodes in WBSN is achieved by adding relay nodes to WBSN. The energy saved is calculated based on the approach proposed in this paper. This technique is the relationship between the biosensor nodes, the relay nodes, and the pelvis nodes on the front side of the body and on the back of the body. The performance of a wireless body area network, which uses relay nodes to reduce power consumption, has been studied. A new mathematical model is presented to provide energy consumption for the biosensor nodes. After testing this model, it was found that the percentage of energy consumption for the sensor nodes was reduced by up to 72%, which proves the efficiency of the model. The test was done with (MATLAB 2021B).

Keywords: WBAN, Energy consumption, network lifetime.

1. Introduction

An aging population and rising health care costs pose enormous challenges to the world's demographic growth. Sensor networks are designed to provide a highly efficient mechanism for transmitting information by detecting asymmetry in the body. As a result, patient parameters become more comfortable [1] [2]. WBAN is responsible for all this health-related activity. The potential domain of body area networks gives new meaning to the term 'sensitive' in the context of health monitoring. A person's health is very important and requires frequent and timely monitoring. WBAN belongs to a group of systems known as Healthcare External Monitoring (E-Health) systems. Long-term health monitoring is possible with the WBAN system, which does not interfere with normal activities. Low power and low bandwidth simultaneous WBANs are used. It is made up of a variety of smart, low-energy biosensors that may be attached to clothing, worn on the body or implanted in the skin. They can collect physiological data recorded by an electrode during muscle contraction, such as an electroencephalogram (EEG), electrocardiogram (ECG), arterial pressure, blood sugar, and temperature. In this paper, the energy consumption are presented in section 3, the proposed mathematical model is explained in Section 4, the results are shown in Section 5.

2. Related Works

Using relay node selection, several strategies have been developed to reduce power consumption and extend network life in WBAN. Chavva et al. [3] He proposed a strategy for providing power to wireless body area networks that uses an obscure method to reduce energy use. It detects data and sends it to the sink using a multi-hop routing approach. Huang et al. [4] Suggest a method

(opportunistic approach) to choose the optimal approach to enhance residual energy levels in the WBAN. Bhardwaj et al. [5] He proposed a health monitoring framework that is a combination of autonomic computing and queuing models that are more accessible to WBAN users. For example, K. Shashi Prabh et al. [6] introduce a mechanism for a collision-free body area network that analyzes and predicts channel changes. When multiple co-location BANs are implemented in the vicinity, There is a prediction-based dynamic relay transmission (PDRT) mechanism in the PDRT. Instead of using a variable interval assignment to improve performance, a fixed interval assignment was used. PDRT enhances energy efficiency while also increasing transmission reliability. For a technical social health surveillance system, Romero et al. [7] human data interactions and human-computer interaction have been suggested. [8] He studied future medical healthcare approaches to increase quality of life. It focuses on the Internet of Things, cloud computing, big data analytics, and WBAN-based applications to deliver eHealth services. Nadim et al. [9] proposed the Stable Increasing Throughput Link Efficiency (SIMPLE) strategy, which used a multi-hop architecture and eight sensor nodes on the human body. They define a cost function to specify the parent and redirector nodes. The original node was selected based on the minimum distance between the sensor node and the sink, as well as the largest residual power. During the first stage, the pelvis broadcasts a packet that provides its location to all other nodes, allowing them to store it. During the node propagation phase, each sensor node broadcasts a packet containing its data so that its neighbours can store it. SIMPLE aims to maximize network reliability and high packet delivery. [10] He proposed a multi-hop system based on thermal threshold-dependent adaptation that is energy-saving and energy-efficient. It is responsible for routing the data sent from the hotspot connection. All nodes update their neighbours, pelvic position, and potential pelvic node paths during the first phase. The optimal path was chosen based on the energy use of the routing phase. Data is sent directly to the trough node from nodes with a higher data rate. It uses the least amount of energy and ensures that packages are delivered reliably. Marshed Mohamed and others. [11] examination of the dynamic properties of a wireless body area network channel during walking, taking into account complex elements and body motion. Javid et al. [12] developed a mechanism based on the sensor node relay method. The authors used a linear mathematical programming approach to maximize network longevity and reduce end-to-end delays while minimizing costs. The communication distance between sensors inside the body has been reduced to a minimum. There was also no multiple hope among sensors inside the body. Relays have been attached to the patient's body for simple recharging in the event of a battery failure and replacement if the relay fails. In [13], a strategy is presented to reduce power consumption in wireless body area networks. This method is used to balance the energy of various signals and senses to the pelvis. Sharma and colleagues [14] Discuss the possibilities and limitations of using a soft computing algorithm to diagnose mental disorders. Based on the literature review, it was determined that WBAN has different methods of health monitoring. The main issue of power and routing is present in all physiological data relay strategies, as it is the primary concern in WBAN, and is addressed in this work using the idea of relay nodes.

3.The Energy Consumption

A sensor node is consumed the energy in the states which are the sensing, the processing data, the receiving, and the sending. There are two formulae for energy consumption in the communication (transmission energy and reception energy)

$$E_{tx}(k_{bio}, d) = E_{TXelect} \,.\, k_{bio} + E_{amp}(n) \,.\, k_{bio} . d^n \qquad (1)$$

$$E_{rx}(k_{bio}) = E_{RXelect} \,.\, k_{bio} \qquad (2)$$

Where

The E_{tx} represents the transmission energy,

$E_{TXelect}$ indicates the dissipated radio energy to run the circuit for transmission,

. k_{bio} represents the number of sent biomedical bits,

E_{amp} represents the energy consumption for the transmitter.
n is the route loss coefficient (there are two values: 3.38 and 5.9 for this parameter).

Non-line of sight propagation (NLOS) and line of sight propagation (LOS) are two different types of propagation. In the latter case, $E_{RXelect}$ represents the receiver energy,
while E_{rx} represents the receiver energy.
Radio energy that has been dissipated the total amount of energy used in transmitting and receiving data during the name of the node is:

$$E_{txr}(k_{bio}, d) = E_{tx}(k_{bio}, d) + E_{rx}(k_{bio}) \qquad (3)$$

$$E_{txr}(k_{bio}, d) = \left(E_{TXelect} \,.\, k_{bio} + E_{amp}(n) \,.\, k_{bio} . d^n\right) + E_{RXelect} \,.\, k_{bio} \qquad (4)$$

The Nordic nRF2401 is a low-power radio that runs at 2.4-2.45 GHz and is widely used in wireless sensor networks. The values of the various parameters for Nordic nRF2401[15] are shown in Table 1.

Parameter	nRF2401	Parameter	nRF2401
$E_{TXelect}$	16.7 nJ/bit	$E_{amp}(3.38)$	1.97e-9 J/bit
$E_{RXelect}$	36.1 nJ/bit	$E_{amp}(5.9)$	7.99e-6 J/bit

Table 1: specific parameters for Nordic nRF2401

The distance between the transmitting and receiving antennas is a factor in this model [16]. It is determined by (5). In the WBAN, there are two types of propagation models: line-of-sight (LOS) and non-line-of-sight (NLOS). For both models, the semi-empirical formula is as follows:

$$P_{dB} = P_{0,dB} + 10.n.\log(\frac{d}{d_0}) \quad (5)$$

The path loss at a reference distance of d_0 is denoted by $P_{0,dB}$, and the path loss exponent is denoted by n, which is equal to 2 in free space [17]. According to Table 2, there are two alternative path loss propagation models (5). For line of sight and non-line of sight, the route loss coefficient (n) is 3.38 and 5.9, respectively [15].

Table 2: The path loss model: values of parameters

Parameter	Value LOS	Value NLOS
d0	10 cm	10 cm
$P_{0,dB}$	35.7 dB	48.8 Db
σ	6.2 dB	5.0 dB
n	3.38	5.9

4. The proposed mathematical model:

In this section, a novel mathematical model is considered for the WBSN, it represented the energy consumption for the nodes in the front and back body. In the model, the energy consumption is calculated based on the relationship between sensor node, relay node, and sink node. we explained the model of a novel mathematical model as the following:

Total energy = Energy front side + Energy back side

$$E_T = E_F + E_B \quad (6)$$

Nodes of front side: 13 nodes
Nodes of back side: 4 nodes

$$E_F = E_{all\ front\ nodes}$$

$$= E_A + E_B + E_C + E_D + E_E + E_F + E_G + E_H + E_I + E_J + E_K + E_L + E_M \quad (7)$$

$$\text{Energy(A)} = Transmitting\ energy\ (A) + receiving\ energy\ (A) + sensing\ energy(A) + processing\ energy\ (A)$$

$$E_A = E_{TXelec_A} .\ k_A + E_{amp}(n)_A .\ k_A\ d_A{}^n + E_{RXelec_A} .\ k_A + E_{s_A} + E_{p_A} \quad (8)$$

$$\text{Energy(B)} = Transmitting\ energy\ (B) + receiving\ energy\ (B) + sensing\ energy(B) + processing\ energy\ (B)$$

$$E_B = E_{TXelec_B} .\ k_B + E_{amp}(n)_B .\ k_B\ d_B{}^n + E_{RXelec_B} .\ k_B + E_{s_B} + E_{p_B} \quad (9)$$

$$\text{Energy(C)} = Transmitting\ energy\ (C) + receiving\ energy\ (C) + sensing\ energy(C) + processing\ energy\ (C)$$

$$E_C = E_{TXelec_C} .\ k_C + E_{amp}(n)_C .\ k_C\ d_C{}^n + E_{RXelec_C} .\ k_C + E_{s_C} + E_{p_C} \quad (10)$$

$$\text{Energy(D)} = Transmitting\ energy\ (D) + receiving\ energy\ (D) + sensing\ energy(D) + processing\ energy\ (D)$$

$$E_D = E_{TXelec_D} \, . \, k_D + E_{amp}(n)_D \, . \, k_D \, {d_D}^n + E_{RXelec_D} \, . \, k_D + E_{s_D} + E_{p_D} \quad (11)$$

$$\text{Energy(E)} = Transmitting\ energy\ (E) + receiving\ energy\ (E) + sensing\ energy(E) + processing\ energy\ (E)$$

$$E_E = E_{TXelec_E} \, . \, k_E + E_{amp}(n)_E \, . \, k_E \, {d_E}^n + E_{RXelec_E} \, . \, k_E + E_{s_E} + E_{p_E} \quad (12)$$

$$\text{Energy(F)} = Transmitting\ energy\ (F) + receiving\ energy\ (F) + sensing\ energy(F) + processing\ energy\ (F)$$

$$E_F = E_{TXelec_F} \, . \, k_F + E_{amp}(n)_F \, . \, k_F \, {d_F}^n + E_{RXelec_F} \, . \, k_F + E_{s_F} + E_{p_F} \quad (13)$$

$$\text{Energy(G)} = Transmitting\ energy\ (G) + receiving\ energy\ (G) + sensing\ energy(G) + processing\ energy\ (G)$$

$$E_G = E_{TXelec_G} \, . \, k_G + E_{amp}(n)_G \, . \, k_G \, {d_G}^n + E_{RXelec_G} \, . \, k_G + E_{s_G} + E_{p_G} \quad (14)$$

$$\text{Energy(H)} = Transmitting\ energy\ (H) + receiving\ energy\ (H) + sensing\ energy(H) + processing\ energy\ (H)$$

$$E_H = E_{TXelec_H} \, . \, k_H + E_{amp}(n) \, . \, k_H \, {d_H}^n + E_{RXelec_H} \, . \, k_H + E_{s_H} + E_{p_H} \quad (15)$$

$$\text{Energy(J)} = Transmitting\ energy\ (J) + receiving\ energy\ (J) + sensing\ energy(J) + processing\ energy\ (J)$$

$$E_J = E_{TXelec_J} \, . \, k_J + E_{amp}(n)_J \, . \, k_J \, {d_J}^n + E_{RXelec_J} \, . \, k_J + E_{s_J} + E_{p_J} \quad (16)$$

$$\text{Energy(K)} = Transmitting\ energy\ (K) + receiving\ energy\ (K) + sensing\ energy(K) + processing\ energy\ (K)$$

$$E_K = E_{TXelec_K} \, . \, k_K + E_{amp}(n)_K . \, k_K \, {d_K}^n + E_{RXelec_K} \, . \, k_K + E_{s_K} + E_{p_K} \quad (17)$$

$$\text{Energy(L)} = Transmitting\ energy\ (L) + receiving\ energy\ (L) + sensing\ energy(L) + processing\ energy\ (L)$$

$$E_L = E_{TXelec_L} \, . \, k_L + E_{amp}(n)_L \, . \, k_L \, {d_L}^n + E_{RXelec_L} \, . \, k_L + E_{s_L} + E_{p_L} \quad (18)$$

$$\text{Energy(M)} = Transmitting\ energy\ (M) + receiving\ energy\ (M) + sensing\ energy(M) + processing\ energy\ (M)$$

$$E_M = E_{TXelec_M} \, . \, k_M + E_{amp}(n)_M \, . \, k_M \, {d_M}^n + E_{RXelec_M} \, . \, k_M + E_{s_M} + E_{p_M} \quad (19)$$

$$E_B = E_{all\ back\ nodes} = E_O + E_P + E_Q + E_T \quad (20)$$

$$\text{Energy(O)} = Transmitting\ energy\ (O) + receiving\ energy\ (O) + sensing\ energy(O) + processing\ energy\ (O)$$

$$E_O = E_{TXelec_O} \, . \, k_O + E_{amp}(n)_O \, . \, k_O \, {d_O}^n + E_{RXelec_O} \, . \, k_O + E_{s_O} + E_{p_O} \quad (21)$$

$$\text{Energy(P)} = Transmitting\ energy\ (P) + receiving\ energy\ (P) + sensing\ energy(P) + processing\ energy\ (P)$$

$$E_P = E_{TXelec_P} \cdot k_P + E_{amp}(n)_P \cdot k_P\, {d_P}^n + E_{RXelec_P} \cdot k_P + E_{s_P} + E_{p_P} \quad (22)$$

$$\text{Energy(Q)} = Transmitting\ energy\ (Q) + receiving\ energy\ (Q) + sensing\ energy(Q) + processing\ energy\ (Q)$$

$$E_Q = E_{TXelec_Q} \cdot k_Q + E_{amp}(n)_Q \cdot k_Q\, {d_Q}^n + E_{RXelec_Q} \cdot k_Q + E_{s_Q} + E_{p_Q} \quad (23)$$

$$\text{Energy(T)} = Transmitting\ energy\ (T) + receiving\ energy\ (T) + sensing\ energy(T) + processing\ energy\ (T)$$

$$E_T = E_{TXelec_T} \cdot k_T + E_{amp}(n)_T \cdot k_T\, {d_T}^n + E_{RXelec_T} \cdot k_T + E_{s_T} + E_{p_T} \quad (24)$$

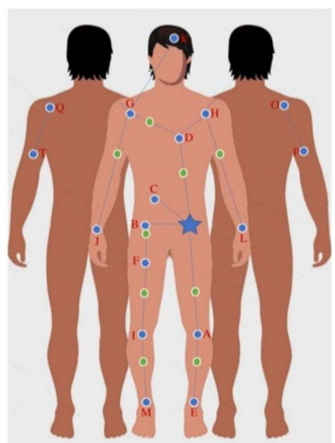

Figure 1: proposed nodes deployment topology

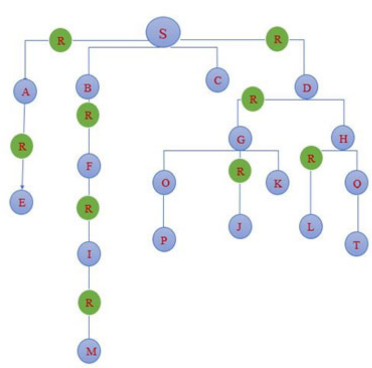

Figure 2: The tree of WBAN model

5. Wireless body sensor network performance

The performance of the proposed network is evaluated through two main factors the results of energy consumption and the network lifetime are below in the details.

5.1 Energy consumption results

The implementation of the proposed network is evaluated after examining the performance of the remaining power of the sensor nodes without a relay using a variety of metrics, the most important of which are the power consumption and the life of the network, which mainly depend on the distance between the sensor node and the sink node, as the greater the distance between the sensor node and the sink node, consumption and thus Reduce the life of the sensor in particular and the life Figures 3 and 4 show a comparison of the power consumption of the proposed schemes with and without relay nodes for the front and rear sides of the body. The mathematical model implemented in the proposed network ensures a large amount of power in the nodes, which results in the transmission of data from the transmitter to the receiver at the lowest possible power.

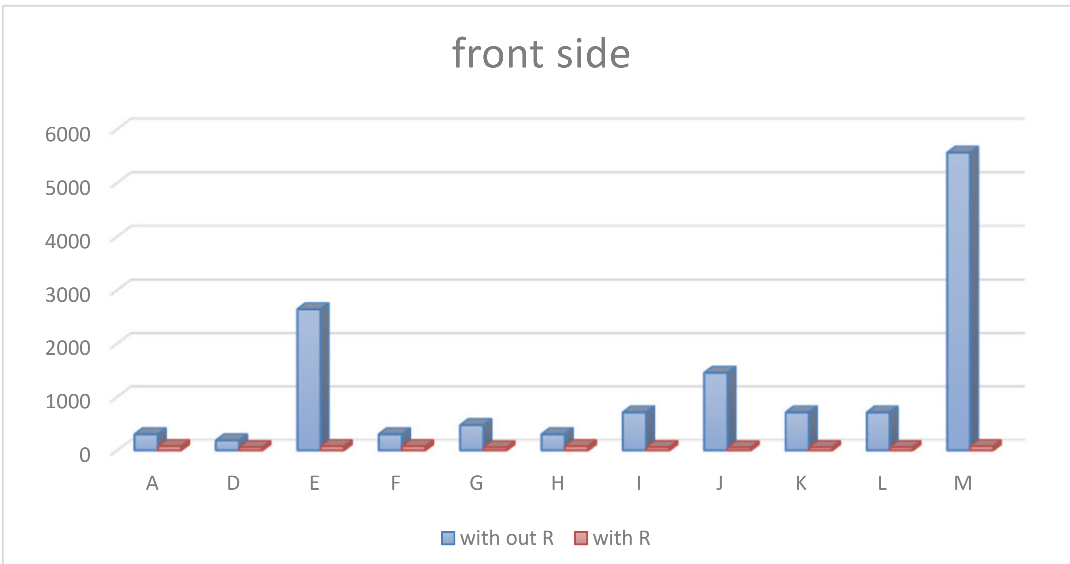

Figure 3: Energy consumption for front side

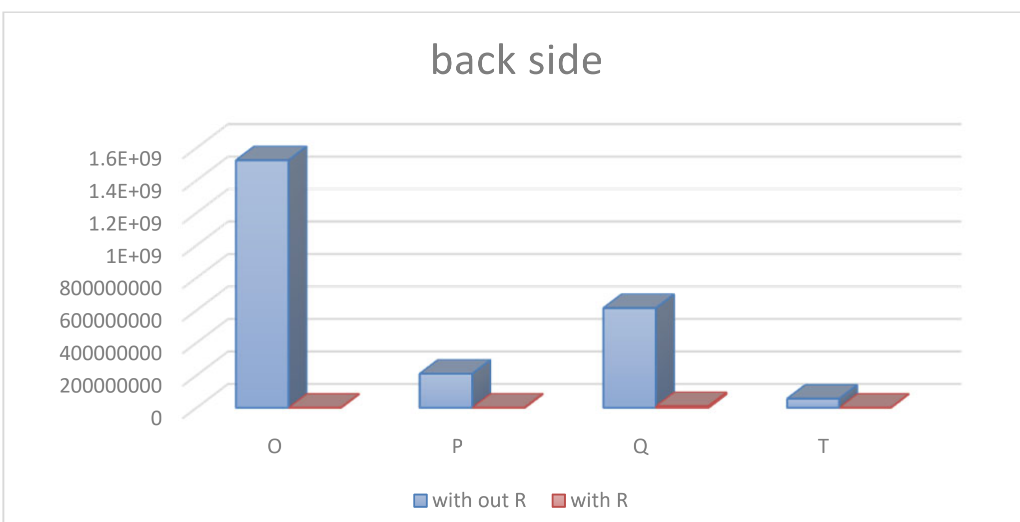

Figure4: Energy consumption for back side

5.2 The lifetime of Network results:

A network stability period is the amount of time network activities take before nodes die [18]. With regard to intermediate applications, the network should be tuned for long-term use. Most wireless sensor networks use a variety of energy-saving strategies to communicate between nodes and base stations. The proposed mathematical model of sensing nodes communicating with relay nodes has a longer stability period. It is necessary to strike a balance between energy use and extending the life of the network. The network must be maintained and operational as long as the physical indicators are measured.

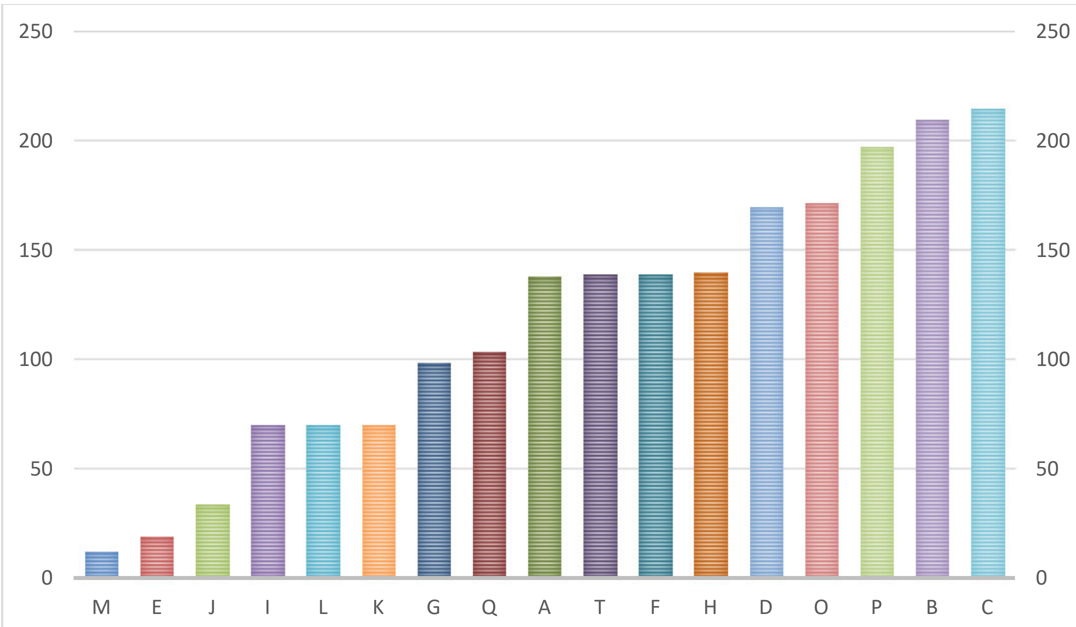

Figure 5: Network life time without relay nodes

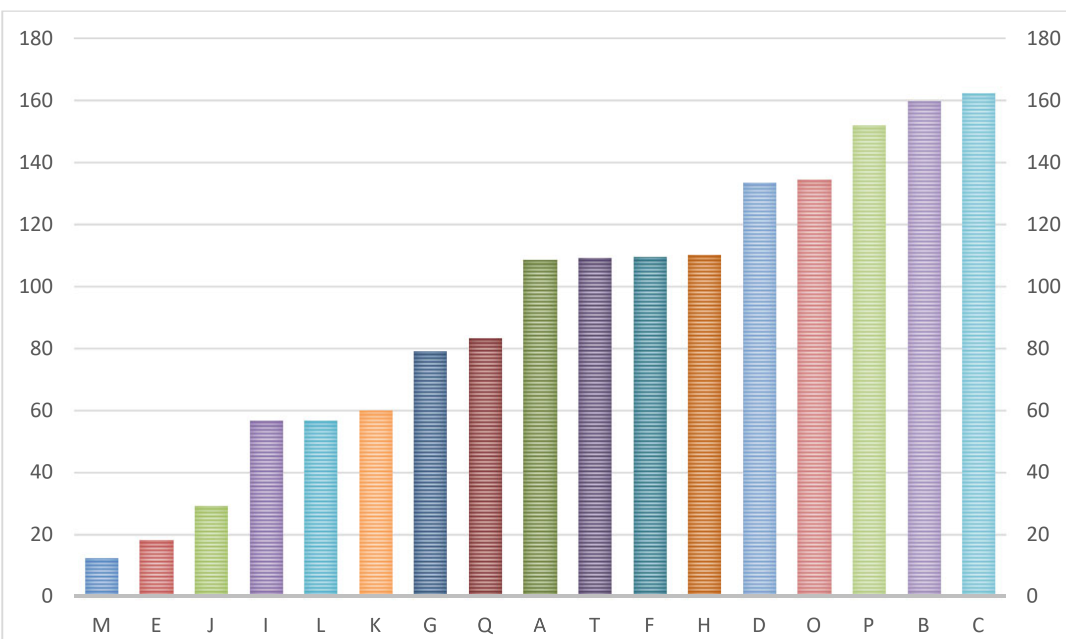

Figure 6: Network life time with relay nodes

6. Conclusions:

The energy efficiency of WBANs can be improved by relying on several mechanisms, including the mathematical model used in this paper, which considers the use of relay nodes to help sensor nodes transmit physiological data with the least amount of energy. We tested with (MATLAB 2021B), focusing on reducing sensor power consumption and increasing network life. The results indicate that the proposed mechanism achieves lower power consumption, higher throughput, and longer network life. Our future directions focus on more energy efficiency and contract collaboration for practical guidance. Since WBANs are an application-based technology, our goal is to implement the approach he proposed in any practical application.

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