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A Critical Evaluation for the Energy Efficient Routing Protocols in Wireless Body Area Sensor Networks (WBAN)

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Wireless Body Area Network (WBAN) is a promising technology for providing intelligent healthcare services in remote locations. A review of the literature shows that researchers have primarily focused on Quality of Service (QoS)-aware energy-efficient routing techniques, network topology, and Medium Access Control (MAC) layers in WBANs. QoS-aware routing techniques are based on a set of protocols that efficiently maintain routes and effectively facilitate data exchange between sensor nodes. This research introduces WBAN and discusses its medical applications in detail. It provides a classification of routing protocols in WBAN and addresses the challenges researchers face in QoS-aware routing. Additionally, a framework for an energy-efficient routing protocol in WBAN is developed, aimed at healthcare authorities for use in emergency rescue operations.

Keywords. Energy Aware Routing, Quality of Service, Body Area Network, Energy-Efficient Cooperative QoS Aware Routing Protocol, Priority Based Energy Efficient, Delay and Temperature Aware Routing Protocol, Energy Efficient Routing Protocol for WBAN.

Introduction.

Healthcare applications related to WBAN focus on improving medical facilities, particularly for older adults living at home. The role of sensors in healthcare monitoring includes providing emergency rescue services for elders. WBAN applications are primarily designed for monitoring elderly health using lightweight sensors. These portable tools are frequently used to monitor organ function, diabetes, asthma, cancer, and cardiovascular illnesses. For example, biofeedback sensors are used to monitor heartbeat, pulse rate, oxygen saturation level, muscle activity, and brainwaves [1].

WBAN-based medical applications leverage wireless communication networks, cellular networks, or the Internet to enhance the performance and dependability of remote patient healthcare monitoring. WBAN uses wireless devices to facilitate communication across the human body [2]. Figure 1 illustrates the three-tier architecture of a wireless body area network designed for healthcare systems.

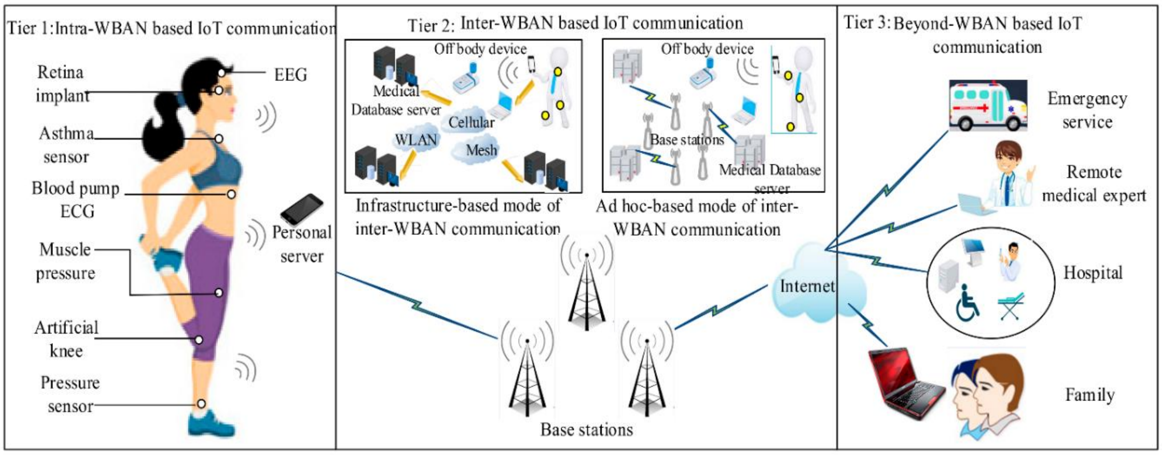

Figure 1. Three-Tier Body Area Sensor Network Architecture [2]

Research Challenges in WBAN.

Wireless Body Area Networks (WBANs) and the Internet of Things (IoT) are increasingly integral to modern technological advancements, revolutionizing how we monitor, manage, and interact with our health, environments, and daily lives. However, this integration has introduced a unique set of challenges that must be addressed to ensure the efficacy, security, and reliability of these systems.

As digital infrastructures, including emerging 6G networks, become more prevalent, their influence on sustainability and environmental impact must also be considered. While these networks enable digital applications that improve sustainability in other sectors, the networks themselves must be designed with a focus on energy efficiency and environmental factors. The Research Challenges which had been identified in this research study based on their significance are mentioned as follows.

- Power consumption overhead related to wireless sensor nodes [2][3][4][5][6][7][8]
- Because sensor nodes have a limited battery life, power consumption is a significant concern in wireless sensor networks. Various tactics are used to extend the lifespan of networks, which affects how they are designed and run.
- Optimal Routing technique to be used [4]
- The human body's dynamic nature and the urgent necessity for dependable data transmission make routing in WBANs more difficult than in other networks.
- Clustering technique to be used[4]
- The formation of clusters from nodes enables localized communication. To preserve the battery life of individual sensors, aggregated data only needs to be transmitted over larger distances by the cluster head.
- Localization and mobility issues [9]
- WBANs function on the human body, which is a continually moving platform, in contrast to static sensor networks. This presents serious difficulties for Precise Node Localization. Movement, shifting postures, and the possibility of sensor displacement make it challenging to pinpoint the exact location of sensors on the body. Sustaining Stable Connections. Wireless links between nodes can be disrupted by movement, which can cause data loss and communication problems.

- Quality of service [9]
- The ability of a network to guarantee different performance indicators and thus a particular level of service is known as quality of service (QoS). Because of the potentially life-critical applications and sensitive nature of the data, QoS is crucial in the context of WBANs.
- Network communication Range and Node density [10][11]
- Restricted Range. WBANs often use low-power wireless technologies (usually within a few meters) such as Bluetooth Low Energy or Zigbee, which have limited communication ranges. The regulatory limitations on transmission power to guarantee user safety are partially to blame for this. Effect of the Human Body. Wireless signals are attenuated by the human body, which functions as an impediment. The position of the sensor, body tissue, and posture all affect this attenuation.
- Fault Tolerant communication between wireless sensor nodes [12]
- Node Failure. Environmental variables, hardware malfunctions, or low battery levels might cause a sensor node to malfunction. Link Failure. Movement of the body, obstructions, interference, and signal fading can all cause problems with wireless communication links.
- Security issues related to WBANS [9]

Sensitive Data.

Sensitive data is a hot target for hackers. Robust security methods are challenging to implement on WBAN nodes due to their limited memory, processing capacity, and energy budget. Wireless communication is susceptible to jamming, interception, and eavesdropping by nature.

The objective of this research study is to examine the role of energy-efficient sensors in the healthcare domain. Our proposed framework is based on an optimal clustering technique for energy-efficient routing in medical healthcare systems.

Literature Review.

In healthcare and personal monitoring, Wireless Body Area Networks (WBANs) represent a crucial technological advancement. WBANs enable the seamless integration of wearable and implanted sensors to collect and transmit physiological data for prompt analysis. These networks offer significant benefits in terms of financial savings and enhanced care quality for both patients and healthcare providers due to their independence and adaptability.

One of the main challenges in WBAN architecture is selecting suitable routing protocols to transfer data effectively from sensor nodes to the central coordinator or gateway. While various routing protocols have been proposed for Wireless Mesh Networks (WMNs), which share similarities with WBANs in requiring dynamic topologies, self-organization, and self-healing, the development of specific routing systems for WBAN applications is essential due to the unique characteristics of the human body and the resource constraints of wearable sensors.

Developing routing protocols for WBANs involves considering several factors, including reliability, energy efficiency, scalability, and latency. Given the limited battery life of wearable sensors, energy efficiency is critical. Routing protocols must minimize energy consumption while ensuring reliable data delivery, as missing important physiological data can have severe consequences for a patient's health. Latency is also crucial since many WBAN systems rely on real-time monitoring and emergency response capabilities. Additionally, WBAN routing protocols need to be scalable to accommodate the growing number of connected devices and increasingly complex healthcare applications.

Researchers have proposed various routing strategies for WBANs, such as cluster-based protocols, multi-hop routing, and energy-harvesting-enabled solutions, to address these challenges. To enhance the functionality and performance of WBAN systems, further research is needed to optimize these protocols and integrate advanced technologies like cognitive IoT and non-orthogonal multiple access. Techniques such as ant colony optimization have been used to deploy wireless sensor networks, including Zigbee-based sensor nodes, on the human body for healthcare applications. Figure 2 is about the OMNeT++ discrete event simulator that has been used for communication purposes [13].

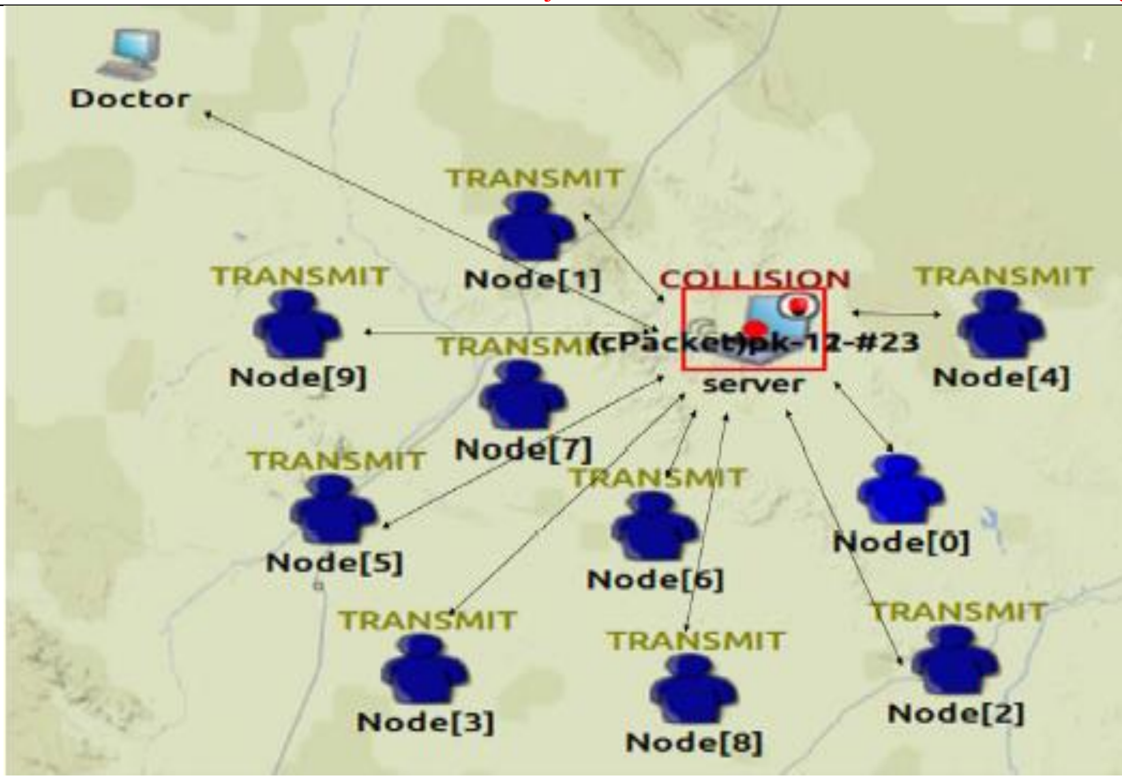

Figure 2. OMNet++ discreet event simulator to be used in WBAN [13]

Routing Protocol has been used for Multipath mobility management in the case of energy-efficient wireless sensors and Actor Networks [14]. Nowadays RFID devices are most commonly integrated with WSN in the case of health care systems [15]. Elliptic Curve Cryptography has been used for secure medical data transmission based on mutual Authentication [10]. A free space management Energy model has been designed which is based on multipath channel fading between transmitter and receiver. N nodes are randomly distributed uniformly in M*Mfreespace. The energy utilized to transmit 1- a bit message over a distance d is mentioned as follows.

$$E_{TX}(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 & d \geqslant d_0 \end{cases} \quad (1)$$

$$E_{RX}(l) = lE_{elec} \quad (2)$$

Whered2isfree-space power loss and d4 is multi-path fading. Eelec is energy based on electronics, efs, and amplifier energies in different radio models [16]. The particle swarm optimization technique has been used in WSN in reliable cluster formation [17]. The first-order Sugeno fuzzy model can be mathematically expressed as follows.

$$Rule1: IfXisA_1 andYisB_1, thenf_1 = p_1x + q_1y + r_1 \quad (3)$$

$$Rule2: IfXisA_2 andYisB_2, thenf_2 = p2x + q_2y + r_2 \quad (4)$$

The above-mentioned Rule-based equations depend on the output function f corresponding to the input vector value x and y. The values p, q, and r represent the constant quantities. K-means clustering algorithm is used in data mining systems which are used nowadays in real-time applications. The objective function is mentioned as follows.

$$J = \sum_{j=1}^{k}\sum_{i=1}^{x}\left\| x_i^{(j)} - c_j \right\|^2 \quad (5)$$

||xi-cj||is distance measured between the two different points. Xi iscluster center, cjis distance of n points from the cluster center [18]. Agent based Architecture for wireless body area sensor networks had also being designed. Agents are processes that are running over the Internet. The Flow diagram of Methodology in WBAN is mentioned as follows [19] [20].

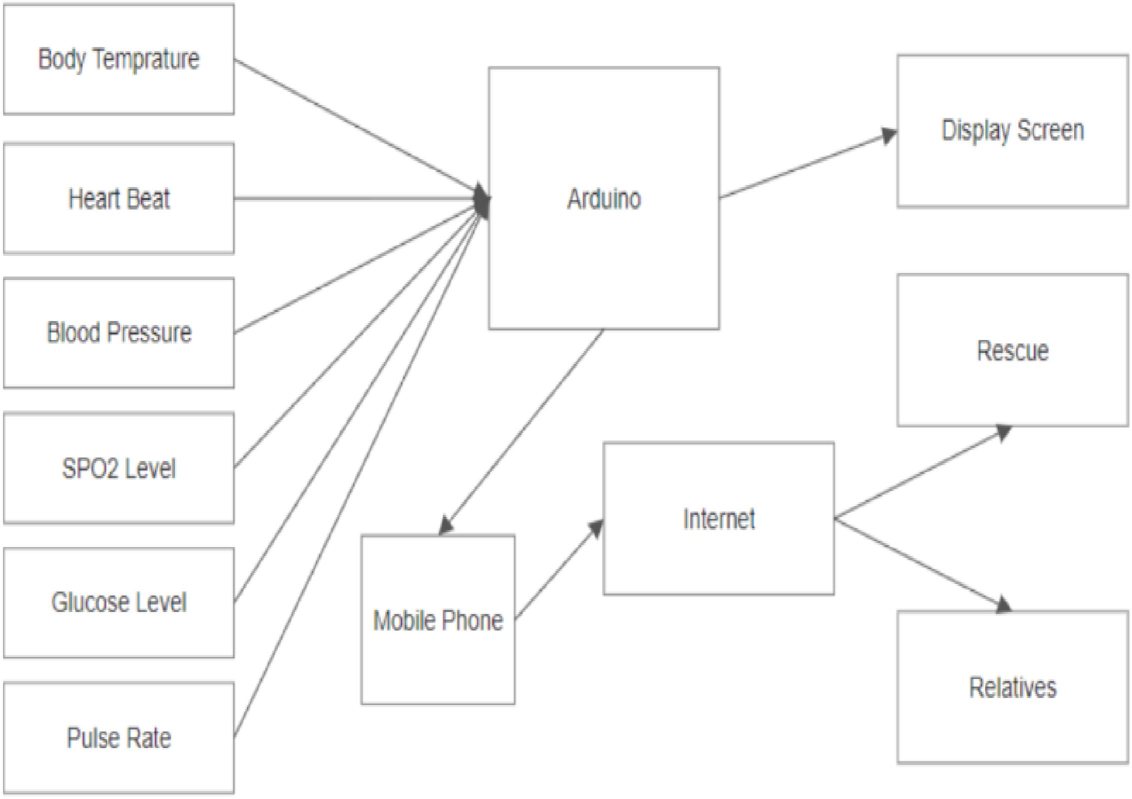

Figure 3. Flow diagram of Methodology in WBAN [19] [20]

The Critical thinking factors that are to be considered related to energy efficiency bottleneck during pre-hospital WBAN are mentioned as follows [21].

- Improper data transfer between the wireless sensor nodes.
- Storage resources include memory and flash storage.
- Maximum use of battery power supply.
- Maximum utilization of data traffic video and audio communication in real-time
- Interference between data transmissions and retransmissions.
- Non-optimal design of the network which utilized maximum power during routing.
- Power utilization of sensor nodes as per environmental conditions.

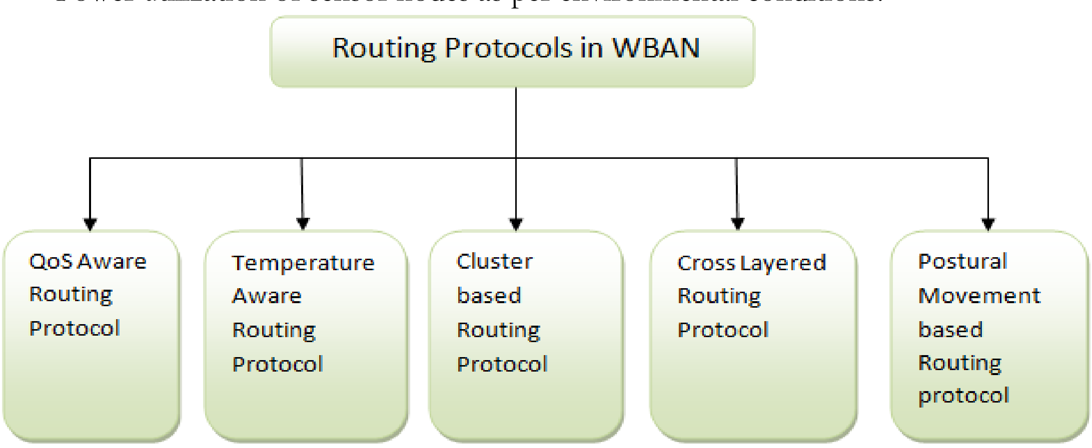

Figure 4. Classification of WBANs Routing Protocols [22]

The research challenges identified during the literature review are presented as a comparative analysis in a tabular format, highlighting Wireless Sensor Networks (WSN) and Wireless Body Area Networks (WBAN) [23]. The taxonomy of WSN-based routing protocols is classified in the following table, along with their strengths and limitations [24]. Table 1 describes the comparative analysis Methodology of the cluster-based routing protocols based on parameters such as Energy efficiency, communication delay, cluster stability, and Load balancing [24]. The terminologies abbreviated as L=Low, H=High, M=Medium, G=Good, B=Bad, S=Small, V.L=Very Low, V.H=Very High.

Table 1. Comparative Analysis Methodology of cluster-based routing protocols

Scheme Name	Energy Efficiency	Communication Delay	Cluster Stability	Scalability	Load Balancing

LEACH [2]	V.L	V.S	M	V.L	M
HEED [4]	M	M	H	M	M
UCS [25]	V.L	S	H	L	B
EECS [24]	M	S	H	L	M
CCM [24]	V.L	S	H	V.L	M
LEACH-VF [2][4]	M	S	H	V.L	M
TEEN [4]	V.H	S	H	L	G
GAF [24]	M	S	M	H	M
PANEL [24]	V.L	M	L	L	G
TTDD [24]	V.L	S	V.H	L	G
SLGC[24]	M	S	M	V.L	M
PEGASIS [24]	L1	L	L	V.L	M
CCS [24]	L1	H	L	L	V.B
TSC [24]	M	M	M	M	B

Table 2 describes the research challenges between Wireless sensor networks and wireless body area sensor networks [22], [23].

Table 2. Research challenges between WSN and WBAN

Research Challenges	Wireless Sensor Networks (WSN)	Wireless body area Sensor Networks (WBAN)
Node Deployment	Homogenous	Heterogeneous
Mobility Range	Meters (M) and kilometers (KM)	Centimeters (CM) and meters (M)
Max no of nodes in the network field	Maximum coverage	Limited coverage
Network Topology	Static	Dynamic (due to movement of the body)
Wireless Network Technology	Blue tooth, zigbee, GPRS	Blue tooth, zigbee, GPRS
Biosensor compatibility	Nil	Implanted inside the human body
Energy utilization	High	Low
Replacement of Node	Easy to replace	Difficult to replace
Size of Node	Large	Small
Life Time of Node	Months-years	Days-months
Source of Energy	Solar powered	Body temperature

Table 3 describes in detail the tabular representation of WBAN protocols based on parameters including the Functionality of WBAN protocols, Delay, Temperature rise, address schemes, and packet data ratio [22], [23].

Table 3. Tabular representation of WBAN protocols

Protocols	Functionality	Delay	Temperature	PDR
TARA	Overheating functionality minimized	High	High	Low
LTR	Reduce energy utilization and high-temperature	High	High	Low
ALTER	End to End delay minimized	Medium	Low	High
LTRT	Establish a route with a temp	Low	Low	High
HPR	End to End delay minimized	Low	Low	High
RAIN	Temp increase, average delay minimized	Low	Low	High
TSHR	Medium Energy consumption	Low	Low	Average
M-ATTEMPT	Low Energy consumption	Low	Low	Average

Proposed Model for Energy efficient framework for wireless body area Sensor Networks (WBAN).

The foundation of the proposed healthcare system structure is the Wireless Body Area Network (WBAN). The suggested framework, illustrated in Figure 5, consists of four clusters. Each cluster in Tier 1 comprises ad hoc relay stations (ARS), energy-efficient relay nodes (RN), and sensor nodes attached to the human body, monitoring parameters such as blood pressure, body temperature, glucose level, pulse rate, and heartbeat. Tier 2 comprises the Secure Home Area Network (HAN). Within the HAN, we are implementing WSN solutions. The HAN is specifically designed for older adults who are relocating and living alone in their homes, providing them with enhanced healthcare monitoring and support.

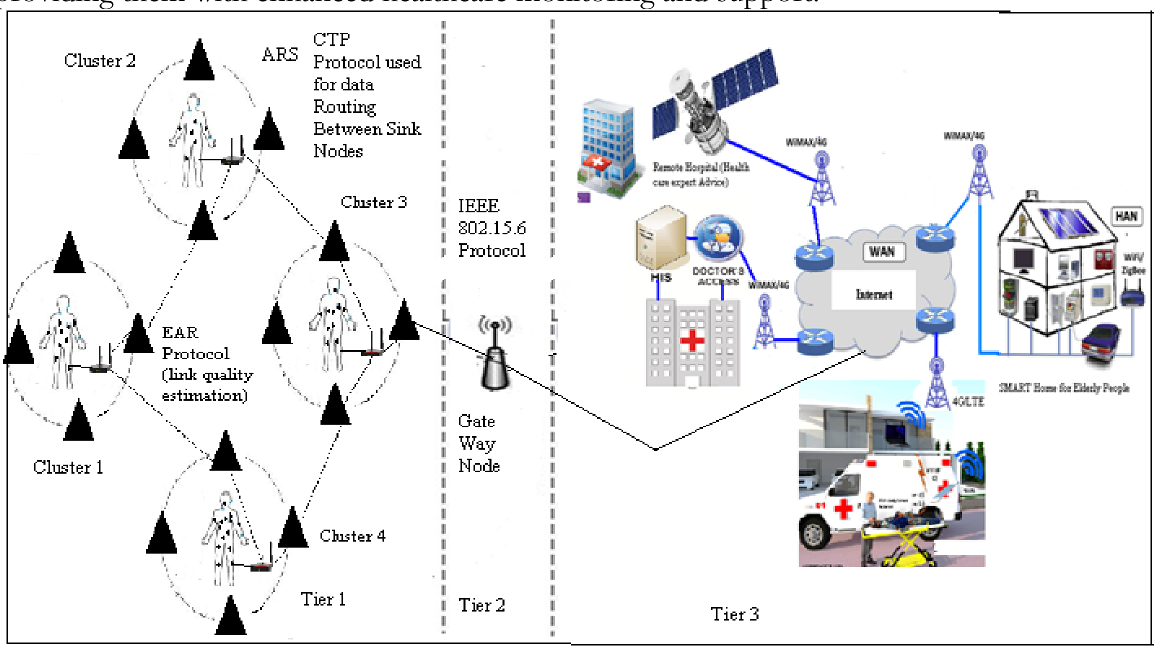

Figure 5. Proposed Framework for WBAN Application

Tier 3 is composed of the Base Station (BS) and Access Point (AS). Real-time routing is typically employed for transmitting data to these base stations or access points, offering minimal average end-to-end latency and robust communication reliability [26]. Tier 3 also includes the Health Information Systems (HIS) module, which is responsible for collecting, processing, and analyzing data to facilitate informed decision-making. Finally, the Medical Emergency Server at Tier 3 can access patient health status data from Tier 2 through the Internet.

Comparison and Evaluation Framework for Energy Efficient Routing Protocols.

Section 3 describes in deep detail the comparison and evaluation framework.

Table 4. Evaluation Parameters and Criteria

Evaluation Framework Parameters	Sub Parameter 1	Sub Parameter 2	Sub Parameter 3	Sub Parameter 4
Energy Efficiency (Score=10)	Single/Multi-hop routing (Score=4)	Quality of service (Score=3)	RT Delay (Score=2)	Radio Optimization (Score=1)
Routing (Score =6)	Location-based Routing (Score=2)	Multipath based Routing (Score=2)	QoS based Routing (Score=2)	----------------------------
Clustering (Score=6)	Cluster Topology (Single Hop) Score=2)	Cluster Topology (Multi-Hop) Score=2)	CH Selection (Score=2)	
Communication/ Network Infrastructure (Score=6)	Coverage Area-Triangle/square/ Hexagon (Score=2)	Energy Consumption (Score=2)	Medical WSN deployment (Score=2)	------------------
Delay/ Packet loss Ratio (Score=6)	RSSI (Score=2)	Hop count (Score=2)	Per-hop Round Trip Time RTT (Score=2)	-----------------------

Security (Score=4)	Confidentiality (Score=1)	Integrity (Score=1)	Authentication (Score=1)	Access Control/Non-repudiation (Score=1)
WSN Types (Score=4)	Homogenous WSN(Score=2)	Heterogeneous WSN (Score=2)	--------------------	---------------

Table 5 describes the Routing information sub-parameter classification table.

Table 5. Energy Efficiency Evaluation parameters

Evaluation Sub Parameter / Author Name	Single Hop (Score=2)	Multi-Hop (Score=2)	QoS (Score=2)	R.T Delay (Score=2)	Radio Optimization (Score=2)	Total Score (10)
Z.Khan et al [7]	Yes	No	No	No	No	2
M.Sahndhu et al [5]	Yes	No	No	Yes	No	4
L.Liang et al [27]	No	Yes	No	Yes	No	4
A.Ahmad et al [6]	Yes	Yes	No	Yes	Yes	8
N.Javaid et al [7]	No	Yes	No	No	No	2
C.Abreu et al [8]	Yes	No	No	No	No	2
N.Bradai et al [28]	No	No	Yes	No	No	2
J.Elias et al [29]	Yes	Yes	No	Yes	No	6
S.Ahmed et al [30]	Yes	Yes	Yes	Yes	Yes	10
k.Haseeb et al [12]	Yes	Yes	No	Yes	No	6
N.K.Mangali et al [30]	No	Yes	No	No	Yes	4
M.Sabet et al [31]	No	Yes	No	No	No	2
T.Mukhtar et al [32]	Yes	No	No	No	No	2
J.K.Murthy et al [33]	Yes	Yes	No	Yes	No	6
K.S.Raja et al [34]	No	Yes	No	Yes	No	4
D.R.Chen et al [35]	No	Yes	Yes	Yes	No	6
B.Zeng et al [36]	No	No	No	Yes	No	2
N.Javaid et al [26]	No	Yes	No	No	No	2
F.Hu et al [24]	No	No	No	Yes	No	2
I.Ha et al [25]	No	Yes	Yes	Yes	No	6
N.Javaid et al [26]	Yes	No	Yes	Yes	No	6
N.Javaid et al [27]	Yes	No	No	No	No	2
Y.Kim et al [37]	Yes	No	No	No	No	2
M.Aslam et al [38]	Yes	Yes	Yes	No	No	6
A.H.Sodhro et al [39]	No	No	No	Yes	No	2
Z.A.khan et al [31]	No	No	Yes	No	No	2
D.Rathee et al [40]	No	No	No	Yes	No	2
k.jinhuyk et al [41]	No	No	No	Yes	No	2
X.Meng et al [42]	No	No	No	No	No	0
J.Y.Chang et al [43]	Yes	Yes	Yes	No	No	6

Table 6 describes the Routing Table evaluation parameter sub-classification. The sub-classification is based on Location-based Routing, multipath-based routing, Quality of service achieved, and their total score achieved. The total score achieved in the case of the Routing table parameter is based on the sub-parameter classification. The sub-parameter classification is obtained from the Literature review.

Table 6. Routing information parameters

Evaluation Sub Parameter / Author Name	Location-based Routing (Score=2)	Multipath based routing (Score=2)	QoS-based Routing (Score=2)	Total Score (6)
Z.Khan et al [6]	No	Yes	No	2
M.Sahndhu et al [7]	Yes	No	No	2
L.Liang et al [27]	No	Yes	No	2
A.Ahmad et al [6]	No	Yes	Yes	4
N.Javaid et al [7]	Yes	Yes	No	4
C.Abreu et al [8]	Yes	No	No	2
N.Bradai et al [28]	No	No	No	0

J.Elias et al [29]	Yes	No	No	2
S.Ahmed et al [30]	Yes	Yes	Yes	6
k.Haseeb et al [12]	Yes	Yes	Yes	6
N.K.Mangali et al [30]	Yes	No	No	2
M.Sabet et al [31]	Yes	No	No	2
T.Mukhtar et al [32]	Yes	No	No	2
J.K.Murthy et al [33]	Yes	No	No	2
K.S.Raja et al [34]	No	No	No	0
D.R.Chen et al [35]	Yes	Yes	Yes	6
B.Zeng et al [36]	Yes	No	No	2
N.Javaid et al [23]	No	Yes	No	2
F.Hu et al [24]	No	No	No	0
I.Ha et al [25]	Yes	Yes	Yes	6
N.Javaid et al [26]	Yes	Yes	No	4
N.Javaid et al [27]	Yes	No	No	2
Y.Kim et al [37]	Yes	No	No	2
M.Aslam et al [38]	Yes	No	No	2
A.H.Sodhro et al [39]	No	No	No	0
Z.A.khan et al [44]	Yes	Yes	No	4
D.Rathee et al [40]	No	No	No	0
k.jinhuyk et al [41]	No	No	No	0
X.Meng et al [42]	Yes	No	No	2
J.Y.Chang et al [43]	Yes	No	No	2

Table 7 describes the Clustering evaluation parameter sub-classification. The sub-classification is based on Cluster Topology single hop-multi hop, cluster head selection, and their total score achieved. The total score achieved in the case of the Routing table parameter is based on the sub-parameter classification. The sub-parameter classification is obtained from the Literature review.

Table 7. Clustering evaluation parameters

Evaluation Sub Parameter / Author Name	Cluster Topology (Single Hop) (Score=2)	Cluster Topology (Multi-Hop) (Score=2)	CH Selection (Score=2)	Total Score (6)
Z.Khan et al [25]	No	No	No	0
M.Sahndhu et al [5]	No	No	No	0
L.Liang et al [27]	No	No	No	0
A.Ahmad et al [6]	Yes	Yes	Yes	6
N.Javaid et al [7]	No	No	No	0
C.Abreu et al [8]	No	No	No	0
N.Bradai et al [28]	No	No	No	0

J.Elias et al [29]	No	No	No	0
S.Ahmed et al [30]	No	No	No	0
k.Haseeb et al [12]	No	Yes	No	2
N.K.Mangali et al [30]	No	Yes	Yes	4
M.Sabet et al [31]	No	No	No	0
T.Mukhtar et al [32]	Yes	No	Yes	4
J.K.Murthy et al [33]	No	No	No	0
K.S.Raja et al [34]	No	No	No	0
D.R.Chen et al [35]	No	Yes	No	2
B.Zeng et al [36]	No	No	No	0
N.Javaid et al [45]	No	No	No	0
F.Hu et al [44]	No	No	No	0
I.Ha et al [46]	Yes	Yes	No	4
N.Javaid et al [6]	No	No	No	0
N.Javaid et al [6]	No	No	No	0
Y.Kim et al [37]	No	No	Yes	2
M.Aslam et al [38]	Yes	No	No	2
A.H.Sodhro et al [39]	No	No	No	0
Z.A.khan et al [47]	No	No	No	0
D.Rathee et al [40]	No	No	No	0
k.jinhuyk et al [41]	No	No	No	0
X.Meng et al [42]	Yes	Yes	No	4
J.Y.**Chang** et al [13]	Yes	No	No	2
R.Lata et al [13]	Yes	Yes	No	4
c.v.villada et al [14]	No	No	No	0
T.adame et al [15]	No	No	No	0
S.K.Shankar et al [10]	No	No	No	0
S.Yanjing et al [16]	Yes	Yes	No	4
R.S.Y.Elhabyan et al [17]	Yes	No	No	2
S.B.Tambe et al [18]	No	No	Yes	2
V.Vaidehi et al [19]	No	No	No	0
E.Gonzalez et al [21]	No	No	No	0
K.Awan et al [22]	No	No	Yes	2

Table 8 describes the communication and Network subparameter classification. The sub-parameter classification is based on coverage area which may be triangular, square, or Hexagon. The next sub-parameter classification is based on Energy consumption, medical wireless sensor network deployment, and the total score achieved. The total score achieved in the case of communication and Network Infrastructure is based on the sub-parameter classification. The sub-parameter classification is obtained from the Literature review.

Table 8. Communication and Network Infrastructure parameters

Evaluation Sub Parameter / Author Name	Coverage Area-Triangle/square /Hexagon (Score=2)	Energy Consumption (Score=2)	Medical WSN Deployment (Score=2)	Total Score (6)
Z.Khan et al [25]	Yes	Yes	Yes	6
M.Sahndhu et al [5]	Yes	Yes	Yes	6
L.Liang et al [27]	No	Yes	Yes	4
A.Ahmad et al [6]	No	Yes	Yes	2
N.Javaid et al [7]	No	Yes	No	2
C.Abreu et al [8]	No	Yes	Yes	4
N.Bradai et al [28]	No	No	Yes	2
J.Elias et al [29]	Yes	Yes	Yes	6
S.Ahmed et al [30]	No	Yes	Yes	4
k.Haseeb et al [12]	No	Yes	No	2
N.K.Mangali et al [30]	Yes	Yes	No	4
M.Sabet et al [31]	Yes	Yes	Yes	6
T.Mukhtar et al [32]	Yes	No	No	2

J.K.Murthy et al [33]	No	Yes	No	2
K.S.Raja et al [34]	Yes	No	No	2
D.R.Chen et al [35]	Yes	Yes	No	4
B.Zeng et al [36]	Yes	Yes	No	4
N.Javaid et al [45]	No	Yes	Yes	4
F.Hu et al [44]	No	No	No	0
I.Ha et al [46]	No	Yes	Yes	4
N.Javaid et al [6]	No	Yes	Yes	4
N.Javaid et al [6]	No	Yes	Yes	4
Y.Kim et al [37]	Yes	Yes	Yes	6
M.Aslam et al [38]	Yes	Yes	No	4
A.H.Sodhro et al [39]	No	Yes	No	2
Z.A.khan et al [47]	No	No	No	0
D.Rathee et al [40]	No	Yes	Yes	4
k.jinhuyk et al [41]	No	No	Yes	2
X.Meng et al [42]	No	No	No	0
J.Y.Chang et al [13]	Yes	No	No	2
R.Lata et al [13]	No	Yes	Yes	4
c.v.villada et al [14]	No	Yes	No	2
T.adame et al [15]	No	Yes	Yes	4
S.K.Shankar et al [10]	No	No	No	0
S.Yanjing et al [16]	No	Yes	No	2
R.S.Y.Elhabyan et al [17]	No	No	Yes	2
S.B.Tambe et al [18]	No	No	No	0
V.Vaidehi et al [19]	No	No	Yes	2
E.Gonzalez et al [21]	No	Yes	No	2
K.Awan et al [22]	No	Yes	No	2

Table 9 describes the Delay Packet Ratio subparameter classification. The sub-parameter classification is based on Received Signal Strength Intensity (RSSI), Hop count, Per Hop Round Trip Time, and the total score achieved. The total score achieved in the case of delay packet loss ratio is based on the sub-parameter classification.

Table 9. Delay Packet Loss Ratio classification

Evaluation Sub Parameter / Author Name	RSSI (Score=2)	Hop count (Score=2)	Per-hop Round Trip Time RTT (Score=2)	Total Score (6)
Z.Khan et al [25]	No	No	No	0
M.Sahndhu et al [5]	Yes	No	No	2
L.Liang et al [27]	Yes	Yes	No	4
A.Ahmad et al [6]	Yes	No	No	2
N.Javaid et al [7]	Yes	Yes	No	4
C.Abreu et al [8]	No	No	No	0
N.Bradai et al [28]	Yes	Yes	No	4
J.Elias et al [29]	Yes	Yes	No	4
S.Ahmed et al [30]	Yes	No	No	2
k.Haseeb et al [12]	Yes	Yes	No	4
N.K.Mangali et al [30]	No	No	No	0
M.Sabet et al [31]	Yes	No	No	2
T.Mukhtar et al [32]	Yes	No	No	2
J.K.Murthy et al [33]	Yes	No	No	2
K.S.Raja et al [34]	Yes	No	No	2
D.R.Chen et al [35]	No	Yes	No	2
B.Zeng et al [36]	No	Yes	Yes	4
N.Javaid et al [45]	No	No	No	0
F.Hu et al [44]	No	No	No	0
I.Ha et al [46]	Yes	No	No	2
N.Javaid et al [6]	Yes	Yes	No	4
N.Javaid et al [6]	Yes	Yes	No	4

Y.Kim et al [37]	Yes	No	No	2
M.Aslam et al [38]	Yes	No	No	2
A.H.Sodhro et al [39]	Yes	No	No	2
Z.A.khan et al [47]	Yes	No	No	2
D.Rathee et al [40]	No	No	No	0
k.jinhuyk et al [41]	Yes	No	No	2
X.Meng et al [42]	No	No	Yes	2
J.Y.Chang et al [13]	Yes	No	No	2
R.Lata et al [13]	No	No	No	0
c.v.villada et al [14]	Yes	No	No	2
T.adame et al [15]	No	No	No	0
S.K.Shankar et al [10]	No	No	No	0
S.Yanjing et al [16]	No	No	No	0
R.S.Y.Elhabyan et al [17]	No	No	No	0
S.B.Tambe et al [18]	No	No	No	0
V.Vaidehi et al [19]	Yes	No	No	2
E.Gonzalez et al [21]	No	No	No	0
K.Awan et al [22]	Yes	No	No	2

Table 10 describes the Security subparameter classification. The sub-parameter classification is based on confidentiality, Integrity, Authentication, Access Control/Nonrepudiation, and their total score achieved. The total score achieved in the case of security is based on the sub-parameter classification. The sub-parameter classification is obtained from the Literature review.

Table 10. Security evaluation parameters

Evaluation Sub Parameter / Author Name	Confidentiality (Score=1)	Integrity (Score=1)	Authentication (Score=1)	Access Control/Non-repudiation (Score=1)	Total Score (4)
Z.Khan et al [25]	No	No	No	No	0
M.Sahndhu et al [5]	No	No	No	No	0
L.Liang et al [27]	No	No	No	No	0
A.Ahmad et al [6]	No	No	No	No	0
N.Javaid et al [7]	No	No	No	No	0
C.Abreu et al [8]	No	No	No	No	0
N.Bradai et al [28]	No	No	No	No	0
J.Elias et al [29]	Yes	No	Yes	No	2
S.Ahmed et al [30]	No	No	No	Yes	1
k.Haseeb et al [12]	No	No	No	No	0
N.K.Mangali et al [30]	No	No	Yes	No	1
M.Sabet et al [31]	No	No	Yes	No	1
T.Mukhtar et al [32]	Yes	No	Yes	Yes	3
J.K.Murthy et al [33]	No	No	No	No	0
K.S.Raja et al [34]	Yes	Yes	Yes	Yes	4
D.R.Chen et al [35]	No	No	No	No	0
B.Zeng et al [36]	No	No	No	No	0
N.Javaid et al [45]	No	No	No	No	0
F.Hu et al [44]	No	No	No	No	0
I.Ha et al [46]	No	No	No	No	0
N.Javaid et al [6]	No	No	No	No	0
N.Javaid et al [6]	No	No	No	No	0
Y.Kim et al [37]	No	No	No	No	0
M.Aslam et al [38]	No	No	No	No	0
A.H.Sodhro et al [39]	No	No	No	No	0
Z.A.khan et al [47]	No	No	No	No	0
D.Rathee et al [40]	No	No	No	No	0
k.jinhuyk et al [41]	No	No	No	No	0
X.Meng et al [42]	No	No	No	No	0
J.Y.Chang et al [13]	No	No	No	No	0

R.Lata et al [13]	No	No	No	No	0
c.v.villada et al [14]	No	No	No	No	0
T.adame et al [15]	No	No	No	No	0
S.K.Shankar et al [10]	Yes	Yes	Yes	No	3
S.Yanjing et al [16]	No	No	No	No	0
R.S.Y.Elhabyan et al [17]	No	No	No	No	0
S.B.Tambe et al [18]	No	No	No	No	0
V.Vaidehi et al [19]	No	No	No	No	0
E.Gonzalez et al [21]	No	No	No	No	0
K.Awan et al [22]	No	No	No	No	0

Figure 6 describes in deep detail the Graphical Representation of Evaluation framework parameters total score versus references.

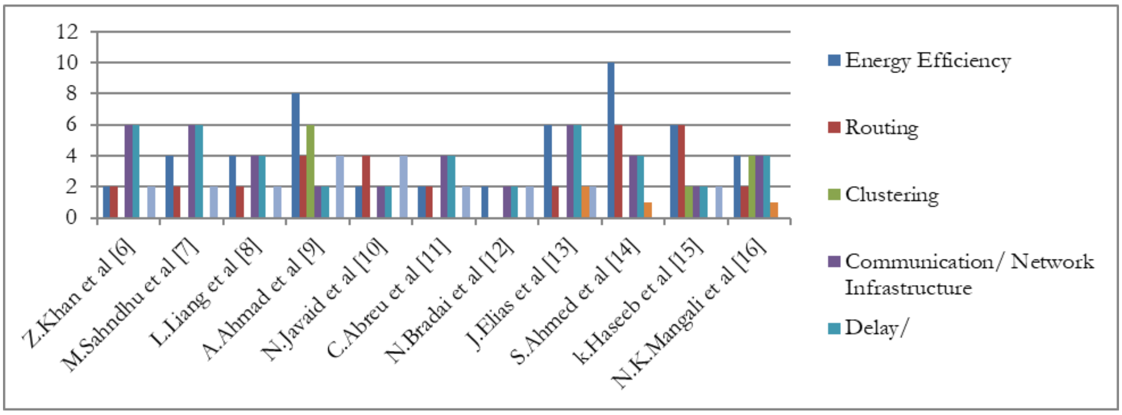

Figure 6. Graphical Representation of Evaluation Framework Parameters Total Score versus reference

Figure 7 describes in deep detail the Graphical Representation of Evaluation framework parameters total score versus references.

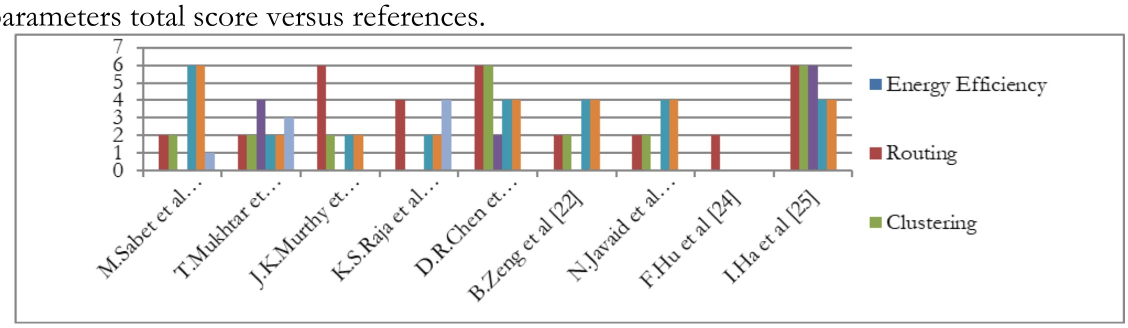

Figure 7. Graphical Representation of Evaluation Framework Parameters Total Score versus reference

Figure 8 describes the Graphical Representation of Evaluation framework parameters total score versus references.

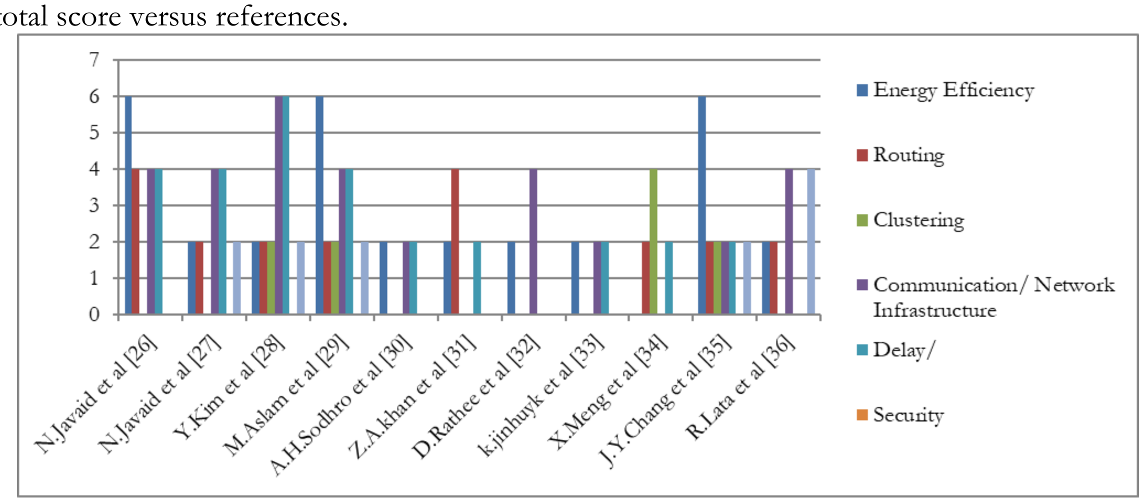

Figure 8. Graphical Representation of Evaluation Framework Parameters Total Score versus reference

Figure 9 describes in deep detail the Graphical Representation of Evaluation framework parameters total score versus references.

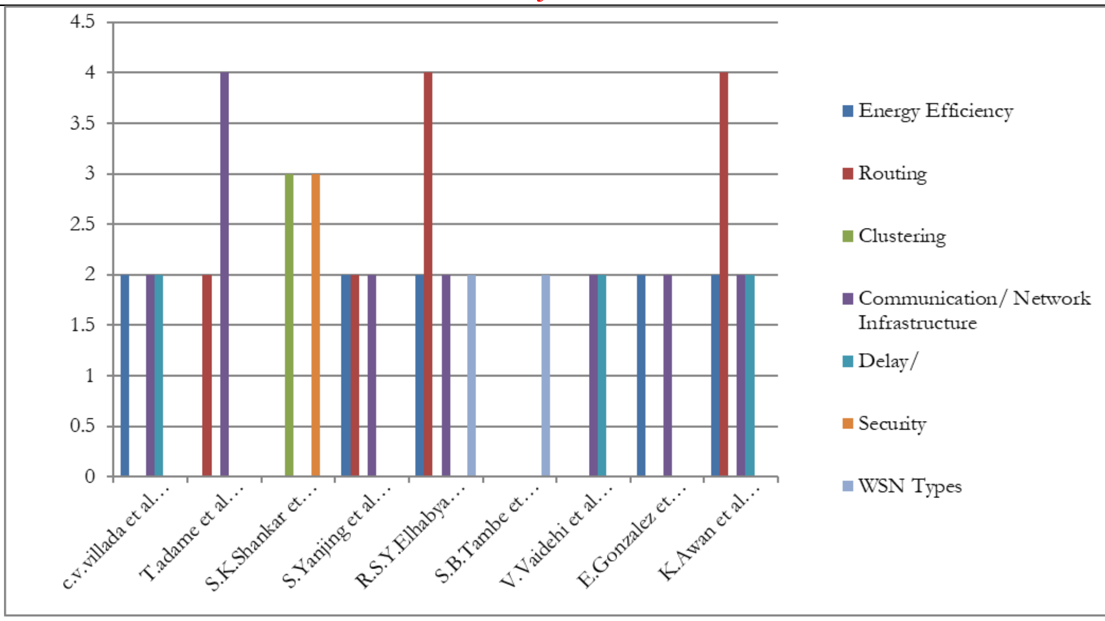

Figure 9. Graphical Representation of Evaluation Framework Parameters Total Score versus reference

Conclusions & Future Works.

Future research should enable the seamless integration of WBANs within larger healthcare IoT ecosystems so that they are interoperable with electronic health records (EHR), hospital networks, and remote patient monitoring systems.

AI and Machine Learning: By leveraging AI/ML on WBAN data, new vistas of personalized health predictions or prognostic insights can be gauged along with the ability to predict diseases well in advance that fall under tacts broader frameworks within the IoT analytics landscape.

In this research study, we have proposed an energy-efficient routing framework in wireless body area sensor networks based on the following open research challenges and motivational factors.

- Continuous Monitoring of Human Physiological Data by using sensors at remote locations
- In cooperating with WBAN solutions in smart homes for elderly and chronically ill patients.
- Transmission of the selected data by using an optimal routing technique
- Proposed protocol to improve the communication mechanism by reducing packet drop ratio and minimizing energy consumption factor
- A Wireless Communication Model is to be designed that is capable of effectively communicating between sensor nodes and Actor nodes (RN) for centralized decisions in routing mechanism
- Classification of selected data by using the machine learning technique

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