International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Design and Analysis of an Efficient and Load-Balanced Multipath Routing Algorithm for Energy-Effective Wireless Sensor Networks

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Submitted: 26/05/2023 **Revised**: 06/07/2023 **Accepted**: 24/07/2023

Abstract: In the recent advancement of an effective and efficient multipath routing technique, energy has become an emerging constraint in the architectural requirement for wireless sensor networks, which are widely being considered due to their versatile services. Our main goal in considering energy as a prime constraint in multipath routing is to reduce the data traffic during the structural and maintenance steps of a wireless sensor network and select the best route that uses the least energy. Today's energy constraint is successfully used in most multipath routing protocols to increase network life, decrease energy quantity in every packet to be transmitted, reduce battery cost, and maintain the highest level of battery capacity throughout the network. Though energy is the most important constraint in this routing scheme, researchers have faced some vital problems like energy hole complications, energy consumption issues, and so on in this type of routing system. This paper conducts a thorough investigation into the energy-enabled multipath routing process of wireless sensor networks. An energy effective and load balanced multipath routing algorithm along with performance analysis of the proposed algorithm are introduced in this paper. Additionally, we have tried to highlight some specific sensor network routing challenges and have recommend some guiding principles for overcoming those challenges in terms of energy constraints. The significant variations between our research paper and existing research work can be identified the comparative analysis part of this paper.

Keyword**:** *Challenges, Wireless sensor network, Energy, Clarification, Multipath routing.*

1. Introduction:

A multiple number of sensor nodes that can perform sensing, calculation, and data transmission and are connected in a wireless manner throughout a network are termed a "wireless sensor network (WSN)"[1]. Out of the number of constraints, energy is the most common and frequently considered constraint in the multipath routing technique of this type of network [2][3]. In terms of energy efficiency, routing system is categorized into three categories: unicast routing, broadcast routing, and multicast routing [2]. Network lifetime, energy quantity, battery capability, battery cost, and variation in the power level are the remarkable issues in energy-efficient unicast routing [3]. On the other hand, bandwidth, quality of service, scheduling technique, distance, and time are the vital issues in energy-enabled multicast routing [4]. But in both cases, effective data transmission with optimal bandwidth utilization is the common objective. Web surfing and file transfers are famous examples of unicast routing, whereas multimedia data broadcasting systems are examples of multicast routing systems [5]. There is a special type of routing system called broadcast routing. It may be mentioned here that there are some important parameters like quality of service, latency, network architecture, protocol, and distance that are directly related to energy constraints for the design of the multipath routing method in this network [6].

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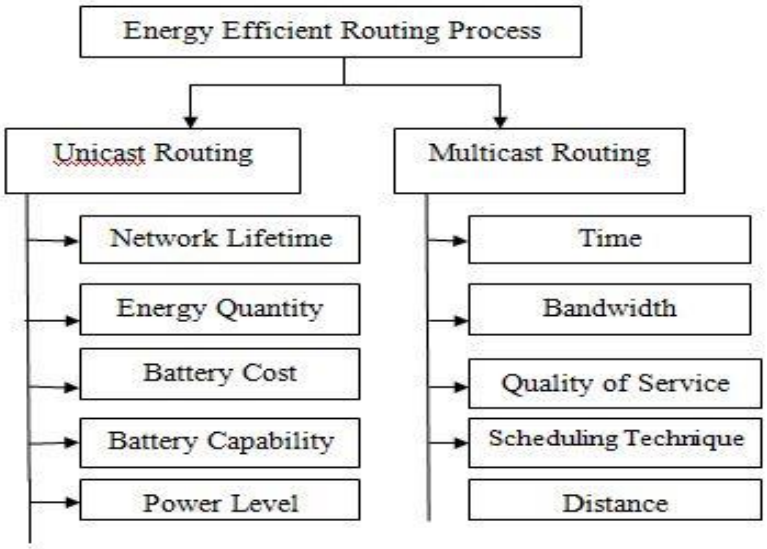

Fig. 1: Classification of Energy Efficient Routing Technique

In unicast routing, the communication mapping pattern is one to one, i.e., only one sender and one receiver system; in multicast routing, the communication mapping pattern is one to many, i.e., one sender and many receiver systems [7]. On the other hand, in broadcast routing, the communication mapping is a one-to-all pattern, i.e., one sender and all possible receivers in the sensor network [8]. It may be mentioned that broadcast routing is a special type of multicast routing system [9]. The basic difference between unicast, multicast, and broadcast routing is that in unicast and multicast routing, bandwidth is properly utilized, whereas in broadcast routing, bandwidth is wasted in the network [10].

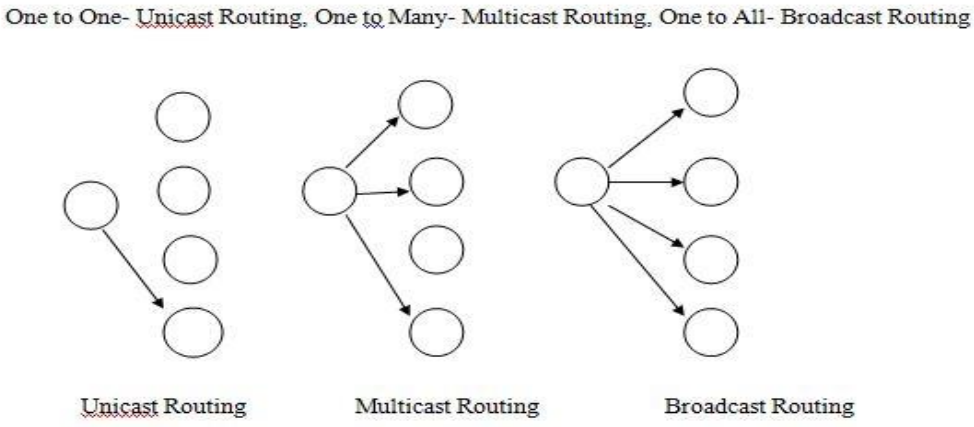

Fig. 2: Unicast, Multicast and Broadcast Routing

In order to enhance the network longevity period, energy and bandwidth should be properly distributed during the data transmission mechanism of multiple number of path in this network. For balanced load distribution among various participating node from source to sink throughout the network, distance is another significant factor to be handled. In case of multiple number of packet transmission simultaneously, proper scheduling algorithm need to be chosen for effective information transmission through multiple path. In this various distance vector routing system, RIP, BGP are already proposed. Basically, energy oriented routing is such type of flat routing mechanism in which power utilization and latency of data are reduced to ensure the scalability of the sensor network. Energy efficiency means the requirement of fewer amount of energy which is to be used in the routing process commendably in the network.

This paper presents energy constraint based and load balanced effective multiple path routing technique for wireless sensor network. In the introduction section, the theoretical overview and classification of multipath routing are explained. The working procedure of multipath routing system, its application and different components are discussed in the background study part.

In the literature genesis overview part, analysis of existing research work in this field is mentioned carefully. In the commercial application of multipath routing technique part, we have tried to depict a clear scenario of the used key technology, protocol and its limitation in various commercial fields like agriculture, environment, healthcare, and road traffic management etc. Several existing multiple paths routing protocol for WSN are discussed in the protocol analysis section. We have identified some prime challenges of this type of existing proposed protocol in the key challenges part. In the comparative analysis part, a clear dissimilarity between our work and existing research are presented. Different tool/parameters are considered in different proposed protocols which are presented in the empirical analysis section. In the result and discussion part, we have proposed some concrete guidelines to handle the identified challenges of the type of protocol and the proposed protocol's configuration constraint table.

Background Study:

As the life expectancy of the total sensor network system depends on every sensor node's longevity, we have to consider energy as an important parameter when designing the multipath routing system for this network [11][12]. For example, tier oriented routing system and cluster oriented routing system are proposed for multipath routing, which are basically energy-oriented [13]. Apart from this, in order to provide balanced sensor nodes for effective data transmission from source to sink node in terms of residual energy, we have to use and distribute energy equally among all participating sensor nodes throughout the wireless sensor network [14] [15]. So the load balancing parameter is closely related to energy constraints in multipath routing systems [16]. The basic components of an energy-efficient multipath routing system are: source, transmitter, transmission system, receiver, and destination [17].

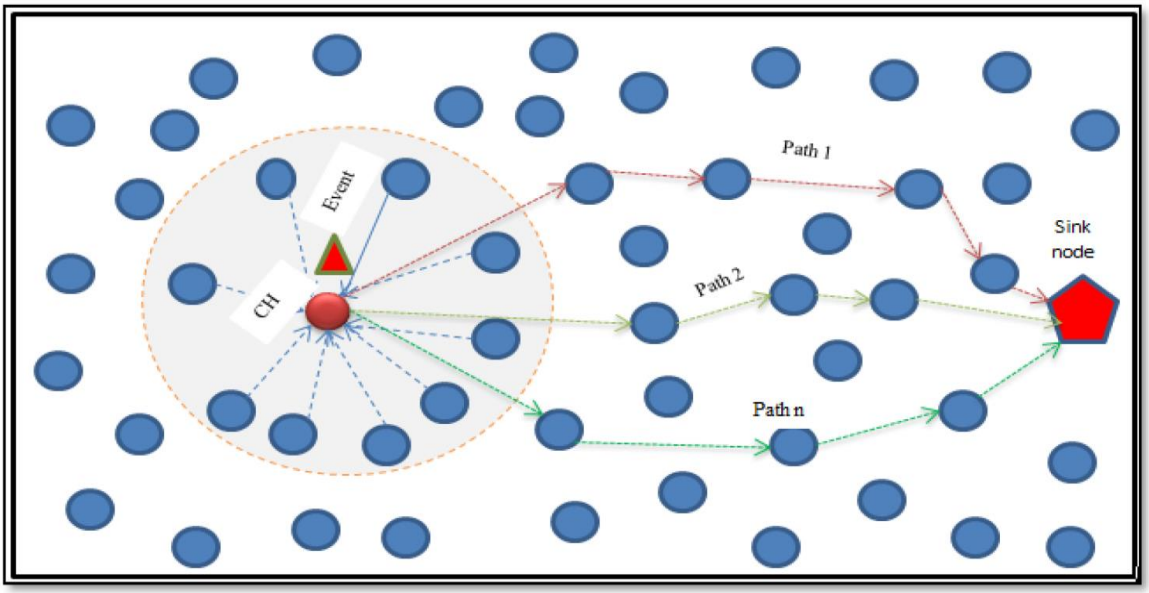

Fig. 3: Energy Efficient Multipath Routing Technique

Energy-oriented multipath routing techniques can be implemented in mobile sensor networks, ad hoc networks, etc [18]. Traffic management systems in transportation, medical image analysis, solar systems, and satellite networks are the best examples of implementing energy-oriented multipath routing systems in wireless sensor networks [19]. Apart from this, it can be applied in defense system applications, various smart home appliances, and agriculture as well. In fact, this energy-oriented routing technique is becoming more popular day by day for its versatile applications using wireless sensor networks [20][21][22].

In order to ensure sensor network's effectivity, reliability, and durability, energy oriented constraints like battery capability, battery cost, and battery longevity should be handled carefully. In this case, cluster base networking concept is the best solution in multipath routing. Cellular networks, internet of things (IoT), underwater WSN (UWSN) are the various modern applications of WSN which are implemented in different commercial sectors. There are several algorithmic methods like genetic algorithm, bellman-ford technique; ant-colony optimization technique implemented in energy based multipath routing system of wireless network to enhance the performance and lifetime.

Outcome of the Literature Genesis Overview:

In order to analyze the research on the energy-efficient multipath routing process of wireless sensor networks effectively, we have to consider some recent remarkable research work that is taken from the Google Scholar database. The key purpose of considering energy

constraints in the multipath routing technique in this network is to provide secure and trustworthy data broadcasting in a load-balancing manner that is effective and efficient [23][24]. Despite significant improvements in the multipath routing process, consumption remains a major issue in this area, which is addressed by introducing cluster network distribution-based optimized routing techniques [25]. According to research, there is a power dependency on battery life span when using energy constraints in this field [26]. Similarly, without losing accuracy, energy conservation is an important challenge in this area, which is handled by implementing flat routing and gradient-based routing [27].

It is observed that already some of the mechanisms, like traditional energy harvesting and the piezoelectric nano-generator concept of energy harvesting, have been introduced to improve the performance of energy-oriented multipath routing, but there are still some challenges, like the high installation charge and low energy quantity [28] [29]. For this reason, these mechanisms need to be reviewed. We have noticed that restricted energy accessibility and lower processing power are two energy-related problems in this type of routing that are eliminated by proposing an ant colony optimization routing process that is meta-heuristic in nature [30][31]. Additionally, we can mention that in IoT-based sensor networks, energy quantity is a key challenge for multipath routing systems, which are maintained by introducing neuro-fuzzy and cluster-oriented routing techniques [32][33]. In fact, out of the various parameters in this type of network, energy is the most vital issue to ensure successful multipath routing [34][41]. The sensor dataset uses hybrid hidden Markov and artificial intelligence models as an error detection method[35].

Exploration of Energy oriented Multipath Routing Protocol in WSN Based Commercial Applications:

Nowadays, multipath routing techniques are implemented in various commercial fields with the help of wireless sensor network such as environment, healthcare, IoT, road traffic control, underwater communication, agriculture field. In these all sectors energy constraint keeps a great impact for designing routing protocol. Let us concentrate on the following applications based analysis:

2. 1.Agriculture Sector:

In the current world, WSN is becoming a premising technical platform for accessing and following different environmental constraint and information to transfer data through multiple routes. Agricultural field has successfully adopted this type of network to ensure eco-friendly farming and reduced agricultural management cost. Energy constraint is effectively implemented in this sector to construct an efficient routing technique.

- **Limitations:** There are some significant limitations to implement energy based routing system in WSN based agricultural field like restricted capacity, difficult routing procedure, failure and delay of data transmission process.
- **Protocol:** Cluster based gateway and energy oriented centroid protocol, multiple level cluster oriented protocol, Terrain oriented routing technique using fuzzy logic are introduced as protocol in this field.
- **Key Technologies:** Objective based modular oriented network testbed using C++, NS2, MATLAB, TCL, and OTCL are the key technologies used here.
- **Advantages:** Monitoring system is feasible, improvement of load distribution among sensor nodes are the main advantages of this protocol in this field.

3. Environmental Sector:

Environment is the sector in which routing system can be configured in wireless network platform like monitoring flood disaster and harsh environment parameters like humidity, air flow, temperature etc. Frequently changes of the nature like wild fire disaster, necessary actions need to be taken using the analysis of environmental parameter values on that particular time. This can be done with the help of energy based routing technique in sensor network.

- **Limitations:** Survivability of routing in harsh nature, path safety, environmental effect, and possibility of information loss are the main limitations in this field.
- **Protocol:** Energy based ensemble of clustering technique using black window optimization protocol, maintainable multiple path routing technique, and environmental fusion based multiple path routing system are different proposed protocol in this area.
- **Key Technologies:** MATLAB, NS1 are the key technologies.
- **Advantage:** Efficient data transfer, improved packet delivery rate, real time environmental data analysis, and prolonged network lifetime are the advantages of this field's protocol.

4. Healthcare Sector:

In twenty first century, healthcare is a prominent field in which implementation of wireless network is growing gradually day by day. Wireless body area network (WBAN) and internet of medical things (IoMT) are the

latest technology of wireless network based healthcare applications. Specifically in vivo nano communication is applied in WBAN and various types of machine learning algorithms can be applied in IoMT based network.

- **Limitations:** Unstable and impulsive features of health information, packet time delay are the limitations of routing technique in this area.
- **Protocol:** Reliability oriented multiple path routing technique, area and energy based multiple routing systems, energy based framework for WBAN, quality of service oriented multiple path routing system for WBAN are the various protocols proposed in this field.
- **Key Technology:** JAVA, Solidity, NS2, Jupyter are the key technologies used in this field.
- **Advantages:** Network reliability, packet loss rate, packet delivery rate, throughput, node to node delay can be improved by the proposed protocol in this area.

5. Road/Vehicle Traffic Management Field:

Road traffic management is a very popular sector in which energy based multiple path routing technique can be configured using sensor network to perform various functionalities like vehicle detection, noise detection, road traffic signaling, avoiding accidents and so on. Permanent road side surveillance process can be established by installing wireless sensor network in a particular area in which traffic pattern will be analyzed. Drone based network and internet of vehicles (IoVs) are promising technique used now a days in such types of applications.

- **Limitations:** Location coverage restriction, hardware malfunctions, mechanical vulnerability, signals collisions due to weather are the remarkable drawbacks in this field.
- **Protocol:** SDN based drone network, intelligent based transportation process for vehicle identification and traffic calculation, urban traffic noise detection technique, intelligent network based energy oriented multiple hop routing technique are different proposed protocol in this area.
- **Key Technology:** Unmanned aerial vehicles, NS2, Jupyter are the technologies used here.
- **Advantages:** Security and reliability of road network are ensured using the proposed protocol.

Protocol Analysis:

As multiple paths routing in WSN is widely used technique in numerous commercial sectors and energy is the most vital parameter considered to ensure efficient routing scheme in this type of network, more concentration should be given on energy constraint like energy distribution, capacity of sensor node and path, residual energy, and so on. Researchers already have proposed several routing protocol for WSN but there are some limitations also in that technique. Let us concentrate some of the following remarkable routing protocol techniques:

- **IoT Network Based Routing Technique:** The intelligent and multiple input multiple output oriented 5G enabled routing technique which is energy effective is proposed to ensure quality of service. This routing mechanism is applied in the cluster oriented IoT network. This routing protocol extends the energy utilization and network lifetime. Energy restriction, sensor node's static position, and variations of the capabilities of the sensor nodes throughout the network are the prime drawback of this protocol.
- **QEMR:** Quality of service based and energy oriented multiple path routing technique is proposed in another paper. This routing method is configured using hybrid optimization technique. This protocol keeps positive impact on network traffic, speed and density of sensor node of the network. It also improves the network performance and quality of service. This protocol can be used in the IoT based network. Restricted resources and worldwide communication in IoT based network is very tuff.
- **ESEERP:** Extended smart energy oriented routing scheme is proposed in a paper which can be used WSN and IoT based network. This protocol enhances the network lifetime and develops it's inter connection pattern. Packet delivery rate, energy and bandwidth utilization are comparative better. Node's consumption inequality and absence of cluster optimization technique are the main limitations of this protocol.
- **CEER:** Cooperative energy oriented routing technique is introduced in WSN for underwater communication purpose very recently. In order to enhance the network longevity period and to ensure reliability of the network, this protocol is being used. This protocol improves energy consumption, delay time, and packet loss during transmission time.
- **PDBRC:** Pragmatic distribution oriented routing scheme for WSN is proposed which is energy efficient. This protocol is basically clustering of network based technique that extends network lifetime. This protocol can be implemented in both homogeneous and heterogeneous area network.

Key Challenges:

Based on the above discussions, which are mentioned in the background study and outcome of the literature genesis part, as well as considering the existing research in this field, we can now clearly identify the main challenges that are frequently faced in multipath routing in this type of network [36] [37]. In order to ensure error-free and effective development of the energy-oriented multipath routing technique of wireless sensor networks, we have to honestly face and handle these challenges, which are as follows:

1. Energy dissipation issue
2. energy hole impediment
3. Strong reliance on battery life duration
4. Battery expenditure
5. Accurate energy storage
6. Controlled energy availability
7. Low transmission capacity
8. Energy quantity
9. Network lifetime
10. Energy harvesting technique

Block Diagram of Proposed Energy effective and Load Balanced Multipath Routing Protocol:

Considering the limitations of the existing routing technique of WSN field, a well-organized multipath routing system for WSN is proposed here where energy is considered as a prime parameter and balanced load for all sensor nodes is also ensured. This proposed protocol completes its task by four steps. Following is the block diagram of our proposed protocol:

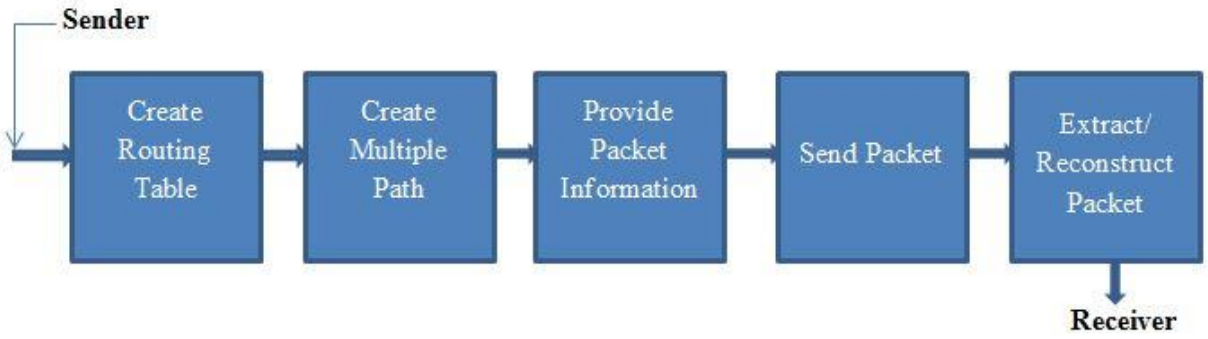

Fig. 4: Block Diagram of the Proposed Protocol

Discussion about the Proposed Protocol:

The proposed protocol focused on some very challenging issues on routing protocol in WMSNs. It will try to resolve energy efficiency problem and data communication even after node failure. It can utilize the energy of all the nodes properly. After node failure new path will be designed using the broken path and the working paths. Thus the on-going transmission will not be hampered and it will make sure that data can be delivered even after node failure or any such kind of incident. We wish it will work successfully and meet the future goal. The proposed protocol works in the following steps:

- Creation of routing table.
- Generate multiple paths over the network.
- Choose the best path.
- Start packet transmission.
- Calculate packet transmission time.

The simulation parameter table is mentioned below:

Network Area	200m X 200m
Sensor Quantity	30-100
Sinks and Sources Quantity	1 and 1
Minimum Trans-mission Range	5m
Protocol Standard	IEEE 802.11

Energy Threshold	5 Units
Highest Buffer Size	256 Kilobytes
Simulation Duration	150 sec

Algorithm of the Proposed Protocol:

Algorithm of the Energy Effective and Load Balanced Multipath Routing Protocol for WSN:

1. ***Start***
2. *To implement our proposed routing protocol we can initially use the following functions used in different section of code and which has different purposes such as:*
3. ***CreateRoutingTable ( ):*** *The purpose of this function is to create Neighbor table/ Routing table of each sensor node.*
4. ***CreateMultipaths ( ):*** *This function is used to create possible multiple paths from source node to sink node.*
5. ***PacketInformation ( ):*** *The purpose of this function is to send the packet data at each sensor node.*
6. ***PacketSend ( ):*** *This function discusses about the processing of choosing alternative paths if any node during transmission will fail.*
7. ***ExtractReconstructPacket ( ):*** *This function is used to extract and reconstruct all the packets at the sink node.*
8. ***End***
9. ***CreateRoutingTable ( ):***
10. ***Declare Variables:***
11. *Nodes= Total nodes quantity in the network*
12. *pos[ ].a pos[ ].b= a and b are the quadratic point of present node position, nodeId= Unique id of each node*
13. *ResEnergy= Energy of each node (Randomly generated)*
14. *ThresholdEnergy= 5 units*
15. *Distance= distance from current node to all other nodes.*
16. *MinDistance=5 sq.meters. Hcount = 0*
17. ***Start***
18. *Input total number of nodes.*
19. *Input the position of each node (x and y coordinates)*
20. *Calculate the distance from one node to all other nodes*

    $distance = \sqrt{(b2 - b1)^2 + (a2 - a1)^2}$

    Where a1 and b1 are quadratic point of present node, and a2 and b2 are position of the node from which the distance is to be measured.
21. *For current node to all other nodes- if(distance != MinDistance)*
22. *then if (pos:ResEnergy<=ThresholdEnergy)?*
23. *then Update the Routing table of current node*

24. *Repeat the step 5 for all other nodes.*
25. ***End***
26. ***CreateMultipaths ( ):***
27. ***Declare Variables:***
28. *pos[ ].neighbor[ ]= array that store the selected neighbor nodes of the current node*
29. *pos[ ].route[20]=structure to store all selected possible paths from current node*
30. *src=source node*
31. *sink= destination node*
32. *pos[ ].ResEnergy[ ]= structure to store the energy level of neighbor nodes*
33. *pos[ ].status[ ]=structure that stores status of each node (0= sleep mode and 1=Alive mode)*
34. ***Start***
35. *Input source and destination node id*
36. *Access every node and its neighbor node's information from neighbor table*

    pos[i].neighbor[j]== 1 where j is neighbor of i
37. *if (pos[i].status[j]==1) [where 1 means node is alive]*
38. *if endpoint is neighbor of source then show as direct path from source to sink*
39. *else*
40. *From the source node start finding the route to destination, first consider the neighbors of source node, check their status and then select the node with highest energy.*
41. *if(max(pos[i].ResEnergy[j]))*
42. *then*
43. *Repeat the step 4 until creating all possible multipaths from current nodes.*
44. *The selected node will act as source node and repeat the step 3 and create multipath until reaching to the destination*
45. *Store all the selected paths in route[ ] array in all nodes*
46. ***End***
47. ***PacketInformation ( ):***
48. ***Declare Variables:***
49. *TotalData[ ]= array that store total number of data packets*
50. *pos[src].nodevalue=data generated at the source*
51. *src=source node*
52. *Data=variable name to store intermediate data. metric= metric value of spitted video data(scalar data=0, image data=1, audio data=2)*
53. ***Start***
54. *User input data in the source node. data=pos[src].nodevalue*
55. *Unpack the spitted multimedia data*
56. *Convert the unpacked data into binary*
57. *Assign sequence number, metric value, and calculate the checksum for each packet*

58. *Arrange data in the data format shown below:*

Scalar Packet size: 8-bit

Sequence no: 2 bits Data: 4 bits

checksum: 2 bit

metric: 0

Image Packet size: 16-bit

Sequence no: 2 bits Data: 12 bits

checksum: 2 bit

metric: 1

Audio Packet size: 32-bit

Sequence no: 2 bits Data: 28 bits

checksum: 2 bit

metric: 2

59. *Stores the data packets into the TotalData[ ] array*
60. *Ready for transmission of packets*
61. ***End***
62. ***PacketSend ( ):***
63. ***Declare Variables:***
64. *SelectedPath[ ]= array to store selected path of current node*
65. *pos[ ].ResEnergy[ ]= The residual energy of nodes*
66. *Threshold Energy=5*
67. *units TTL= 150 sec*
68. ***Start***
69. *Get the packets*
70. *(Check Path Failure from source node)*

if any path is failed due to insufficient energy(Insufficient energy less than thresh- old)

71. *then delete the corresponding path and choose another path from next queue of source node.(choose next highest energetic path)*
72. *If (no of paths>= the number of data packets) Then send one packet through each path*
73. *else*
74. *If (no of paths != the number of data packets) Then send audio, image data through corresponding highest energetic, Mid energetic path and remaining scalar data through low energetic path and store the selected path into SelectPath[ ] array*
75. *(During Transmission) If any node fails during transmission then the previous node will fiends the next energetic selected paths from its routing table and choose that path which is not used in that time either after Time to Live period(TTL) source again delete the path and by repeating step 3 it selects the alternative path, update its routing table and sends the packet until it reach to the sink node.[The algorithm calls from Cre- ateRoutingTable() function, CreateMultipaths(), PacketInformation() and PacketSend() functions again.]*
76. *After one transmission reduce the battery life of of sensor nodes by 5 units*

pos[i].ResEnergy=pos[i .ResEnergy-5

77. *End*
78. *Extract Reconstruct Packet ( ):*
79. *Declare Variables:*
80. *SeqNo= sequence numbers of data packets used for packet synchronization*
81. *dest= Destination node Id*
82. *pos[dest].node value=data at the destination node data= variable name that store final data*
83. *Final Data[ ]=array that stores the decoded data*
84. *Start*
85. *Get the packets to the destination node which arrive and store them in data = pos[dest].node value*
86. *Extract the actual data from the coded data and arrange all packets into their sequence numbers (SeqNo).*
87. *Store the actual decoded data into FinalData [].*
88. *End*

Proposed Protocol Performance Analysis for WSN:

Network performance can be evaluated by metric which is termed as network performance metric. It reduces the downtime of any particular network. This can be done by finding probable and unexpected errors. The fundamental performance metric of WSN are: network coverage area, energy consumption, and delay time. There are some important parameters used to calculate the sensor network performance like packet loss, throughput, bandwidth, latency, jitter, and so on. Network structures, specific application of network, security are the factors affected network performance. Let us explain various sensor network performance metric parameters:

Energy:

Let us consider E be the primary energy of a node and E_E be the internal energy of any node at any particular time t,

Then, $E_E = E - Ec$, where E_C = Consumed energy

Total consumed energy of the network can be calculated as the addition of all node's internal energy plus the product of a particular node's primary energy and node quantity.

Suppose, total no. of node = n,

$E_{T.Com} = n*E + \sum (E_{E1}+E_{E2}+E_{E3}+\ldots\ldots\ldots+E_{En})$

Where, $E_{T.Com}$ = Total consumed energy.

Network Lifetime:

The time duration while the node is active and able to communicate with its immediate next node in the sensor network is called sensor network lifetime.

Percentage of sensor network lifetime,

T_N = ((Time savings quantity/(Time duration of total active node quantity (1-Retention rate)))*100

Network Delay:

The addition of latency (Delay time) occurred by a packet transmission from source to sink node over the network is referred to as network delay time. It can be calculated as:

Network delay= (Distance between the adjacent nodes/Data transfer speed) + (Packet size/Data transfer rate)

Packet Delivery Ratio:

It is a ratio between packet quantities effectively received by sink node to packet quantity sent by source node.

$R_{PD} = \sum P_R / \sum P_S$

Where P_R = No. of packet received by sink node,

P_S = No. of packet sent by source node.

Throughput:

Throughput is the transmitted packet quantity per unit time. It is measured by bit per second. Basically it is a

ratio of total transferred packet quantity to total packet sending time.

Throughput = total transmitted packet quantity/total packet sending time.

Comparative Analysis:

This comparative analysis section attempts to represent a discernible significant difference between the available research work and our contribution on this network's energy efficient multipath routing system. To complete this task, the last five years' (2018) research papers on this topic from the Google Scholar database are considered. For example, in order to decrease the energy utilization of the sensor nodes in the network, a life-spanning time-aware routing technique for sensor networks is introduced in one research paper. While our research article attempts to focus on the overall research in this field as well as identify the fundamental challenges and provide necessary guidelines for dealing with them from various perspectives.

Let us reflect on the subsequent table, where a number of the recent research articles on energy-oriented multipath routing of wireless sensor networks are taken into consideration. In the following table, we try to portray an apparent comparative status by which our explicit role in this area will be measured.

TABLE 1.Comparative analysis between our research contribution and existing research work

Serial No.	Year	Authors	Their Work	Our Work
1.	2018	R. Logambigai and et al.	Authors have proposed grid oriented clustering approach to design routing protocol in order to increase energy utilization in an optimized manner and to reduce the design complications in this paper.	Our research article is a thorough research work which is focused on background work, energy constraint impact on this field and a new protocol is introduced.
2	2019	Thangaramya Kalidoss and et al.	In this paper authors have introduced quality of service oriented and energy based routing technique of sensor network to reduce energy expenditure and to enhance network life time.	We have tried to draw attention to the key challenges of using energy constraint in multipath routing of this network.
3.	2020	Deepak Mehta and Sharad Saxena	In order to overcome restricted energy quantity and transmission power, cluster head oriented multi objective energy conscious routing technique is proposed in this paper.	Concrete guidelines are introduced to handle the frequently faced challenges of energy oriented multipath routing system of this sensor network in our article.
4.	2020	Aram Mosavifard and Hamid Barati	Authors have explained level wise cluster based routing technique of wireless sensor network to decrease energy utilization throughout this paper.	We have tried to design energy effective and load balanced multipath routing technique for WSN in this paper..
5.	2021	Rachid Zagrouba and Amine Kardi	This paper is a survey based paper where a comparative analysis among various routing system is provided.	Our research article explains theoretical study, different methods, challenges, design and performance analysis of our proposed protocol.

From the above Table 1, it is noticed that there is a noteworthy variation between our research contribution and the related existing research paper on energy-oriented multipath routing techniques in wireless sensor networks.

TABLE 2. Comparative psychoanalysis of key challenges vs. parameters in energy-efficient routing techniques for Wireless sensor networks

Sr. No	Parameter / Challenges	Quality of service	Latency	Network design	Protocol	Bandwidth	Distance
1	Energy consumption		✓	✓	✓	✓	✓
2	Energy hole	✓				✓	
3	Battery life dependency	✓	✓			✓	✓
4	Battery cost	✓			✓		✓
5	Energy quantity	✓	✓	✓		✓	✓
6	Network life time			✓	✓		✓
7	Energy availability	✓		✓		✓	
8	Energy harvesting	✓			✓		✓

From the above table 2, it is evidently seen that out of various types of challenges, energy consumption and energy quantity are the most frequently faced challenges, which are handled with the help of key parameters like latency, protocol, bandwidth, network architecture, and distance. Similarly, we can mention that while using quality of service, bandwidth, and distance as parameters in a multipath routing system, we should be more careful as these parameters are facing most of the energy-related changes in wireless sensor networks. We have taken the last twelve years (2010–2022) of research in this area in order to perform this task with the help of the Google Scholar database.

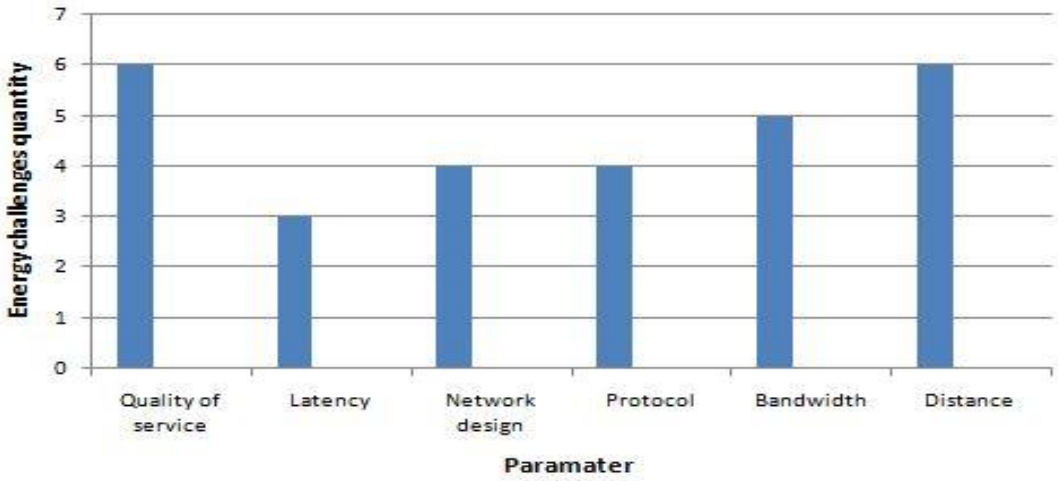

Fig. 4: Different Energy Related Parameters vs. Energy Challenges Quantity in Multipath Routing

Figure. 4 is a graphical representation of Table-2, with various energy-related multipath routing parameters on the X axis and energy challenge quantity on the Y axis. According to the graph above, the two most significant energy-related challenges are quality of service and distance. The bandwidth parameter faces five energy-related challenges of multipath routing in this network.

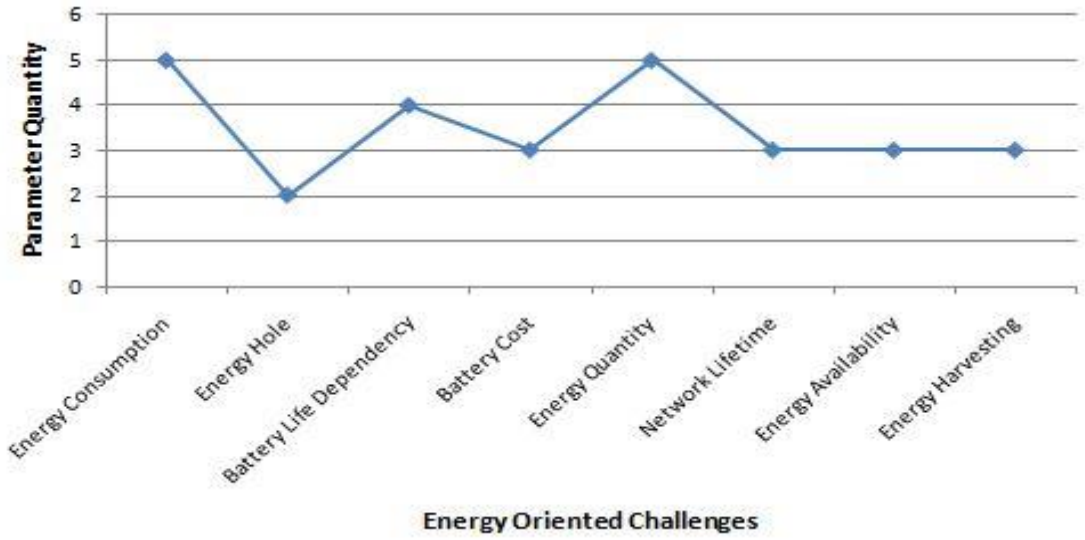

Fig. 5: Various Energy Oriented Challenges vs. Parameter Quantity in Multipath Routing

Figure.5 is another graphical representation of Table-2 from different perspective, with a variety of energy-related challenges on the X axis and relevant parameter quantities on the Y axis. It is clear from this figure that the highest numbers (05) of parameters are used to handle energy consumption and energy quantity challenges among different energy-related challenges.

Empirical Analysis:

In the empirical analysis section, a number of accessible published research works in the field of energy-efficient multipath routing systems for wireless sensor networks are taken into consideration from the Google Scholar database. We have tried sincerely to sum up the basic ideas that are explained in these research articles using a variety of parameters in that area. Let us think about the following table 3, which obviously represents several typical research papers' proposed concepts along with the tools or parameters used in that field. This table also reflects the progress made in this area of research over the last two decades (2013-2022).

TABLE 5. Summary of last ten years (2013- 2022) research work on energy oriented multipath routing of wireless sensor network.

Sr. No.	Authors	Year	Proposed work	Parameter used
1.	Guang Jie Han and et al.	2016	Authors have proposed green routing idea to reduce energy consumption in multipath routing system in this paper.	Quality of service, latency, and reliability are considered as parameter in this paper.
2.	Nabajyoti Mazumder and Hari Om	2017	In this paper, authors have proposed distribution oriented asymmetrical clustering routing technique for wireless sensor network.	Network life time, network density is taken into consideration as parameter here.
3.	Abdulhamid Zahedi and Faryad Parma	2018	In this article, authors have explained energy oriented trustworthy routing technique using gravitational search concept to save energy.	Reliability and scalability are used as parameter in this paper.
2.	Addisalem Genta and et al.	2019	Authors have introduced genetic algorithm based optimization technique using cluster network concept to diminish energy consumption problem in this article.	Authors have taken distance and performance as parameter in this work.
5.	Md Asri Ngadi and et al.	2013	In this research work, authors have discussed about energy efficient and cluster based routing technique to	Distance, latency, scalability are taken as parameter in this article.

			handle the energy conservation issue sincerely.
6.	Aradhana Behura and Manas Ranjan Kabat	2020	In order to handle network lifetime and energy utilization, authors have introduced energy oriented and optimized routing technique in this paper.	Performance analysis is taken parameter here.

6. Results and Discussions:

Based on the above-mentioned justified discussion, which is reflected in the empirical analysis and comparative study sections, we can noticeably identify that energy is the most important constraint that needs to be considered while designing multipath routing techniques in wireless sensor networks. There are some relevant challenges related to energy constraints that are usually associated with some common parameters [38][29]. We earnestly try to underline those energy-related challenges and associated parameters. Through comparative analysis, we also try to show the relationship between these energy-oriented challenges and parameters. To complete this task effectively, we reviewed several recent research papers on this topic that are indexed in the Google Scholar database. Based on the aforementioned discussion, an energy effective and load balanced multipath routing protocol is proposed in this paper.

Key Points: Let us sum up a number of significant points based on our analysis:

1. It is undeniable that, among the various existing constraints in the multipath routing field, energy is the most common and important issue that must be addressed today [39].
2. We have noticed that there are some significant energy-relevant challenges like energy utilization, network life, battery expenditure, battery life time dependency, energy amount, and energy availability in our research field.
3. Similarly, protocol, distance, network infrastructure, latency, and quality of service are the most frequently used parameters, which are generally associated with energy constraints in this field.
4. In today's world, energy-efficient multipath routing techniques can be successfully implemented in the latest network-based applications like mobile sensor networks, ad hoc networks, satellite networks, defense systems, and other real-time applications.
5. According to research, despite significant advancements in the use of energy constraints in this field, there are still some gaps that need to be addressed.

Proposed Clarifications to deal with Challenges: If we want to handle and administer all the notable energy-oriented challenges of the multipath routing technique of wireless sensor networks successfully, then the following recommendations should be followed cautiously:

1. As it is no doubt today in sensor network routing area that energy is the prime constraint, we should be more careful when considering this constraint in different multipath routing techniques due to its various relevant challenges to be faced.
2. According to research, the most frequently encountered energy-related challenges are energy consumption and energy quantity, which can be effectively addressed by an optimization technique (a genetic algorithm) in a cluster-based network.
3. It is observed that quality of service and distance are the two common parameters that are involved in most of the energy-oriented challenges in routing technique. These two parameters can be efficiently utilized by using the best-shortest-path routing technique. Here, Bellman Ford's approach is recommended for this purpose.
4. Research also shows that bandwidth is another significant parameter in multipath routing. To utilize bandwidth in multipath routing effectively, we should implement the orthogonal frequency division multiplexing (OFDM) technique in this area.
5. In order to get better performance on routing in a wireless sensor network, machine learning-based routing techniques can be implemented.
6. It may also be mentioned here that in order to maximize network life in sensor networks, fuzzy logic concepts can be applied in multipath routing systems.

7. Conclusion:

Nowadays, it is justified to say that energy constraints have a great effect on the construction of efficient multipath routing methods in wireless sensor networks [40][41] In our research paper, energy effective and load balanced multipath routing algorithm is proposed which takes energy and load of each node as prime parameter. Additionally, we genuinely try to emphasize the common challenges that are related to energy constraints and several parameters that are associated with this constraint in our network. Through comparative study and empirical psychoanalysis, some precise guidelines are recommended to manage those energy-related challenges. A number of concrete algorithms and methods are also suggested to do this. We are confident that if we follow and apply these algorithms and methods in multipath routing techniques, we will be able to move forward with advanced research in this area.

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