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# Several Categories of Energy Harvested Routing Protocols, Challenges, and Characteristics in WSN: A Review

**Bhanu Priyanka Valluri, Nitin Sharma**
*Research Scholar, Department of Electronics and Communication Engineering,*
*Chandigarh University, Gharuan, Punjab-140413, India.* bhanu.publications31@gmail.com
*Professor, Department of Electronics and Communication Engineering,*
*Chandigarh University, Gharuan, Punjab-140413, India. nitinsharma.ece@cumail.in*

***Abstract:*** The routing protocol is a technique for determining the most efficient channel for data transmission. The route selection procedure, which relies on the kind of network, channel conditions, and measurement systems, presents several challenges. Routing is essential in Wireless Sensor Networks (WSNs) for environmental monitoring, traffic monitoring, and other applications. WSNs are small nodes that can sense, interpret data, and communicate wirelessly. Many routing, power control, and data dissemination techniques have been developed specifically for WSNs, where energy efficiency is a crucial design factor.

On the other hand, the focus has been on energy harvesting and standard routing methods, which can vary depending on the design and network architecture. In a Wireless Sensor Network (WSN), the data collected by the sensor nodes is typically transferred to the base station, which connects the sensor network to other networks (such as the internet), where it is processed and necessary action is taken. WSN has recently been developed to allow various applications, including traffic enforcement building automation, smart warfare, environmental sensing, and many more.WSN integrates several sensors or nodes deployed around a specific node to perform computational processes.

***Keywords:*** *Wireless Sensor Network(WSN), energy harvested, traditional routing methods, routing, node, network architecture.*

## 1. INTRODUCTION

In recent years, as technology has advanced and developed, sensor networks have been used in a variety of applications and professions for several years, [1,2] like IM (industrial management), medical, EC (environment control), military, etc. [3]. WSN comprises minimum cost, power SNs (Sensor nodes), small, and deployed to monitor various aspects of the environment. Typically, SN is created for four standard components, with additional units added based on the application's needs.

WSN is incomplete in terms of energy factors. Most of the EC is regarded as WT (wave transmission); enhancing EC if the routing methods is one of the significant techniques to improve the network lifetime [4].

Investigators have taken SNs that can harvest from the environment into concern. Thermo-electric, RF (radio frequency), and solar technologies are possible for EH (energy harvesting), which can significantly extend the lifetime of networks. This category of wireless sensor networks is known as EH-WSN. Energy harvesting-based WSN is the outcome of giving WSNnodes the ability to extract energy from the surrounding atmosphere. EH may exploit several sources of energy like wind, MVs (mechanical vibrations), MFs (magnetic fields), TVs (temperature vibrations), and so on. Constantly providing power and saving it for further use, EH sub-systems give WSNnodes to last possibly forever [5].

In an EH-wireless sensor network, routing is a significant task, i.e. to be managed wisely. A routing method is required for transferring the information between the SNs and the BS to establish signal communication. The primary principle is the routing method that changes based on the application. The routing issue leads to minimizing NLT (network lifetime). The routing methods may be divided based on the node's contribution, clustering methods, mode of working, and NS (network structure). Several limitations in routing scenarios [6] like EC (energy-consumption), ND (node-deployment), accessibility, coverage, security, and scalability.

WSN is a dynamic network that could contain a variety of sensory nodes. The environment is as diverse in terms of both hardware and software. The sensing node

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design prioritizes cost reduction, fault tolerance, and adaptability. Increase growth while saving energy. The sensing unit (sensor and analog to digital conversion), the processing unit(processor and memory), the communication module (transceiver), and the power source units comprise the sensor node. The primary blocks shown in Figure 1 include a brief overview of each section as it reads.

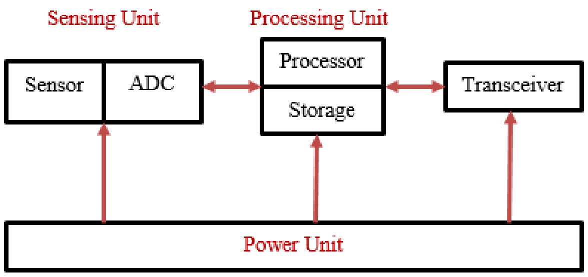


Figure 1. Structure ofWSN

*Benefits of routing protocol :*

- Identifying WSN Application Requirements: A quantitative analysis of the application is necessary based on the target application requirements to fulfill the accurate design.
- Recognizing Important Technical Trends: Microelectronics development has tremendously permitted technology to life rate. However, WSN is acknowledged to be a complicated and diverse system. In such a complex system, examining the design cost and restrictions is necessary to discover the best match for WSN with peak power optimization, depending on the application.

The paper is prepared as follows: section II discussed several analyses with different proposed work and routing methods in WSN. Section III described several energy harvesting and energy-based routing protocols in WSN. Finally, section IV explains the routing characteristics and challenges in WSN, followed by the conclusion in section V.

## 2. PRIOR WORK

**João Junior et al. 2021 [7]** described the WSN features like reliability, energy efficiency, availability, and power consumption. Power consumption was vital when defining RPs (routing protocols). When compared to other mechanisms of SN (sensor node), the power needed by radio transmitters was liable for most of the consumption. One way to reduce EC (energy feeding) was by using EA(Energy-Aware) methods. Such procedures consider the RE (residual energy) data when decision-making, giving EE through the suspicious management of EC. The proposed work is upcoming and researches a novel RP that utilizes the RE data and presents renewable energy data from sources like SCs (solar cells). They defined the RE-BORN (renewable energy-based routing) method, an EA geographical routing technique, as reliable for controlling both RE and available energy. The outcomes defined the benefits and efficacy of the RE-BORN method compared to the other methods. **Yuanyang et al. 2020 [8]** defined the JO (join optimization) of data transmission, and EUS(energy utilization) in EH-WSN (energy harvesting-WSN) was analyzed.aEH-WSN the imbalance of EH and consumption affects the communication and ability of the network. A new EA opportunistic RP with LSTM (along-shot-term-memory) method based on SE (solar energy)prediction was presented to resolve this issue. The method inventively takes account of the SNsirecent RE and the harvesting of solar energy in ST (short term)predicted by an SLSTM NN model as key aspects in forwarding candidates' selection procedure of the opportunistic routing method.Moreover, torJO the EC and data transmission, a novel metric with merged energy metric and relay productivity for each node, was implemented to assist RE and the working history of SNs. Experimental outcomes defined that the research method increases the network throughput by 12 % and mitigates the retransmission rate by 15% compared to the opportunistic routing method based on geography. Instantaneously, it can balance EC between SNs. **Shayestehq et al. 2022 [9]** discussed a novel method for routing in the WSN that was introduced utilizing the UI (ultra-innovative) method for BF (abacterial forging) and MS (mobile sink) that leads to EE. In the research technique, the number of SNs was committed according to two phases: (i)The quantity of energy on the battery interface and the proximity to the target that causes the WSN to form regular clusters. Nodes approved different step routing strategies.To connect with the target, nodes accepted several step routing mechanisms inside the WSN. The MS was utilized to manage the load and helps to consume uniform energy overall the WSN. The experimental analysis defined the better evaluation of the research technique like EC by 17.9 %, throughput by 30.0%, E2D by 64.0%, SNR by 32.8 %, PDR successfully information to the destination was 0.8 times maximum than the artificial-fish-swarm RP. **Anshu Kumar et al.2020 [10]**The FBC (fuzzy-based clustering) techniques were described that helped develop new EE-FB routing methods for WSN. The major motive of this paper was to analyze various categories of RPs with their benefits and challenges. Several methods have compared graphs with their network lifetime. **Kashif et al. 2020 [11]** described WSNi as becoming one of the serious areas where SNs were monitoring and sensing the environmental situations and data transmission to the BS via multiple hop routing methods. Similarly, the agriculture sector believed these networks would stimulate ideas for physical farming practices, reduce management costs, and achieve scientific cultivation. Due to their restricted capabilities, these have experienced energy issues and challenging routing techniques, resulting in data transmission catastrophes and delays in sensor-based ASs. The SNs closest to the BS were always relying on it and caused an extra burden on BS into a useless state. This analysis develops a GC-EE-C (gateway-energy-efficient-Centroid) based routing technique to identify these problems. CH(cluster head) was chosen from the centroid location, and GWN (gateway nodes) were chosen for each cluster. GWN mitigates the information load from Ch nodes and forwards the information toward the BS. Experimental was performed to calculate the research method with state-of-the-art methods. The simulation outcomes designated the better performance of the research method and gave more reliable network-based monitoring for temperature., illumination, and humidity in AS. **Zhihao et al. 2021 [12]** discussed the energy of SNs in WSN was incomplete, which was one of the most significant challenges due to the absence of a fixed power supply. Since data broadcast consumes the energy of SNs, a node that broadcasts more data packets executes out of energy faster than the others. Whenever the SN energy reaches the network's end, the operating method may be halted. The vital data in the networks cannot reach the hole and, finally, the BSs in the necessary quality. The main limitation was considering the dynamic topology and distributed behavior of WSN developing EE routing methods. This article defines the EA routing method based on the MO-PSO (multi-objective PSO) method. In the proposed paper, the PSO technique, the proportionality method for choosing the optimal threaded node, was set based on service quality objectives, which include RE, E2D, Delivery rate, etc. The investigational outcomes define that the research technique consumes minimum energy and has a longer lifetime compared to the other ways.

Table 1 discusses the proposed methods, problems and gaps, simulation tools used, and performance metrics such as PDR, E2D, throughput, etc.

Table 1: Comparison Analysis with several methods

| Author Name | Methods | Issues/Gaps | Simulation Tools | Parameters |
|---|---|---|---|---|
| Junior et al. 2021 [7] | RE-BORN method | Energy Shortage | Sinalgo | SI (solar intensity)<br>EC<br>DR (delivery rate) |
| Yuanyang et al. 2020 [8] | EA opportunistic routing method with LSTM model | Imbalance energy | - | Throughput<br>Retransmission rate<br>End-to-end delay<br>Sleep time<br>Standard deviation |
| Shayestesh et al. 2022 [9] | BFOABMS method | Without A limited battery, So how can you save energy while handling a complete network evaluation | OPNET | Throughput<br>E2D<br>PDR<br>EC<br>SNR |
| Anshu Kumar et al. 2020 [10] | Fuzzy-based clustering methods | Ch failure problem | MATLAB | FND (first node idie)<br>QND (Quarterinodeidie)<br>andiHND (halfinodeidie) |
| Kashif et al. 2020 [11] | GW-EE-Centroid Based routing method | Energy-hole issue | MATLAB | Alive nodes<br>Data transmission<br>The packet received by BS<br>EC |
| Zhihao et al. 2021 | MO-PSO method | Single-target | MATLAB | Energy |

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| | | | | |
|---|---|---|---|---|
| [12] | | issue | | Time<br>Throughput<br>Dead nodes<br>Network lifetime |

## 3. SEVERAL ENERGY HARVESTING-BASED ROUTING PROTOCOLS

The EH-WSN routing algorithm aims to enhance throughput as the network lifespan increases. However, the idea of sustainability is taken into account by several algorithms in this area. To be sustainable, each node must not take more energy than it can collect over time. The section here attempts to compile all of the material available in the literature on EH-WSN routing algorithms and explore how to assess the algorithms' long-term viability.

Energy harvesting-based routing protocols are essential for WSNs because they allow nodes to utilize energy harvesting techniques to prolong the lifetime of the network. Traditional routing protocols for WSNs do not consider energy harvesting capabilities, which can lead to premature node failure and reduce the network's overall lifetime. They enable nodes to make better decisions regarding data transmission and routing based on their energy levels and energy harvesting rates. These protocols help to optimize the use of energy in WSNs and ensure that nodes are utilizing energy harvesting techniques to the fullest extent possible. Furthermore, energy harvesting-based routing protocols can also help to reduce the energy consumption of WSNs by minimizing unnecessary data transmission and reducing the number of hops required to transmit data. This, in turn, can help to extend the lifetime of the network and reduce the need for frequent battery replacements. These protocols are crucial for WSNs because they help to prolong the lifetime of the network, optimize energy usage, and reduce energy consumption. These protocols ensure that nodes are making efficient routing decisions based on their energy levels and energy harvesting capabilities, which ultimately improves the overall performance of the network.

### 3.1 Traditional routing methods

The network topology is based on routing methods for WSNi and may be classified into the following three different types: (i) cluster-based, (ii) flat routing, and (iii) location-based method.

Every node plays a similar role in broadcasting data to neighboring nodes in multi-hop flat routing methods. Information reaches the destination node at last. However, energy is missed when the repeated information is conveyed to the destination node through distinct routes.

In a **HA (hierarchical architecture),** minimum energy nodes (ENs) are utilized to sense the near-final target, and maximum energy nodes are utilized to procedure and transfer the data. The maximum ENs are chosen as cluster-head (CH). The main contribution is the complete system lifetime, EE, scalability, etc.

**The cluster-based routing** method has performed information collection and aggregation to reduce the number ofmessagessenttotheBS. It is an effective way to minimize EC. However, the cluster-based method is unsuitable for other parameters like network throughput and data packet failure rate.

**In the position-based method**, the distance between the nearest nodes may be assessed based on external signal strengths. If there is no activity, nodes should enter the sleep stage to conserve energy. The problem of generating a localized sleep phase for each node was recognized. [13][14].

### 3.2 EH (energy harvesting) methods

**Randomized Max-Flow** Lattanzi et al. presented in [13] In an expanded version of the Ford-Fulkerson method, Lattanzi et al. calculated the maximum flow from the sensors to the base station. The Randomized Max-Flow (R-MF) algorithm is based on it. The method employs the precalculated maximum flow through the edges to determine a packet's path. The maximum flow across a border determines the probability of routing a packet. Each edge is given the following:

$$\text{Capacity} = \frac{harvest\_rate\_of\_the_{transmitter}}{Packet\_energy} \quad \text{eq.3.1}$$

This routing system relies on an offline routing table maintained in each node and lists the node links utilized for packet delivery. The routing scheme is based on the concept of maximum flow, where the flow across an edge in the network is determined by the available capacity of that edge. The capacity of each edge is calculated based on the harvest rate of the transmitter and the energy required to transmit a packet.

The equation you provided (eq. 3.1) shows how the capacity of an edge is calculated based on the harvest rate of the transmitter and the energy required to transmit a packet. This equation ensures that the capacity of each edge reflects the energy availability of the transmitter and the energy required for packet transmission. The routing scheme relies on an offline routing table maintained in each node. This table lists the node links used for packet delivery and is updated periodically based on changes in the network topology or the energy availability of nodes. When a packet needs to be transmitted from a source node to a destination node, the routing table is consulted to determine the optimal path for packet delivery. The path with the highest maximum flow (i.e., the path with the most available capacity) is chosen for packet delivery.

Overall, this routing scheme is designed to optimize energy usage in the network by selecting paths that have the highest energy availability for packet transmission. By using the harvest rate of the transmitter to calculate edge capacities, the routing scheme ensures that energy harvesting techniques are utilized to their fullest extent, which can prolong the lifetime of the network. Additionally, the use of an offline routing table helps to reduce the overhead associated with traditional routing protocols, which can improve the efficiency of the network.

### 3.3 Energy Harvesting Opportunistic Routing Protocol

Zhi et al.[13] proposed entrepreneurial steering convention for multi-bounce WSN-HEAP (fueled by surrounding energy gathering). This calculation utilizes entrepreneurial retransmission; it intends that when one hub comes up short, one more hub can be utilized for sending information parcels.

In WSN-HEAP, the energy-reaping gadget switches surrounding energy over completely to electrical energy. Additionally, there is an energy stockpiling gadget, which stores the energy reaped from the ecological [17-20]. When enough energy is collected, the transmitter works and ceaselessly broadcasts information parcels until the energy is finished. Then, at that point, it will switch off. This interaction rehashes in the following cycle. There are three potential stages for every hub, for example, charge stage, sending or getting location. In an organization with n district, any hub has n-1 getting time allotments for every locale and one transmission time allotment. When the hub accuses of sufficient energy, it is prepared to take an interest in getting a bundle. If it gets a fortune in any of its scheduled openings, it can recognize the parcel's locale. Then, at that point, assuming the locale is further from the sink than its area, it stores the information and holds it up till it arrives at its sending scheduled opening. Then, in communicating time, it picks the following district considering their need for sending, in the base of distance to sink and have sufficient energy [21-30]. Then, at that point, it will begin to send.

## 4. ROUTING PROTOCOLS CHARACTERISTICS AND CHALLENGES IN WSN

### 4.1 Characteristics [15]

WSN has been used to measure a range of parameters in unattended physical surroundings in the real world. As a result, the features of WSNs must be addressed for effective network implementation. The following are the significant properties of WSN.

- *Low cost:* Thousands of sensor nodes are often placed in a WSN to measure any physical environment. To keep the entire cost of the network as low as possible, the cost of the sensor node must always be kept as low as possible.
- *Computing power:* Most nodes have limited computational capability due to cost and energy constraints.
- *Communication Capabilities:* Wireless sensor networks (WSN) commonly communicate using radio waves across wireless channels and can interact with short distances using limited and dynamic bandwidth. Lines of communication can be bidirectional or unidirectional. In an uncontrolled and hostile working environment, it isn't possible to run smoothly. As a result, durability, privacy, and endurance must be addressed in communication hardware and software.
- *Security and privacy:* Every sensor node must have proper security mechanisms to avoid unauthorized access, attacks, and accidental data damage. Additionally, different privacy methods must be implemented.

### 4.2 Challenges [16]

- *Reall-time challenges* are focused on real-life scenarios. In many cases, sensor data must be communicated within a specific time window for relevant observations or actions. So far, there have been few accomplishments in reaching real-time criteria WSN. Most protocols either disregard real-time or try to process as quickly as possible, assuming that this speed would is enough to fulfill deadlines. Nevertheless, there are some preliminary findings for real-time routing. The only real-time results shown for WSN have been in routine.
- *Powermanagementchallenges*-The cheap cost of implementation is a well-known aspect of sensor networks. In addition, sensor networks' processing

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bandwidth and storage are two arguable restrictions that will be eliminated as fabrication techniques are developed. However, due to slow development in increasing battery performance, the energy shortage is doubtful to be remedied shortly. Furthermore, battery replacement is not a realistic option due to the unsupervised nature of sensor nodes and the dangerous sensing surroundings. On the other hand, the surveillance aspect of several sensor network applications needs a long lifetime; hence, offering a form of energy-efficient monitoring service over a geographic region is a significant study issue. Therefore, much of today's studies focus on providing partial core capabilities in energy conservation.

## 5. CONCLUSION

WSN routing protocols are still in progress since sensor nodes always discover new uses. The upcoming advancements in pervasive and ubiquitous computing and the ongoing growth in nanotechnology have led to new routing issues that the scientific community must address. These unresolved concerns require much work to be done as a part of their redressal. Since some points of reference regarding the underlying hardware, wireless sensor networks include various problems that must be solved, particularly regarding energy supply and shrinking. In the deployment region, we have categorized routing algorithms for this work based on the homogeneity and heterogeneity of sensor nodes. This categorization allows academics to delve further into those algorithms in areas where little study has been done till now. Regarding the critical areas of this research, we also gave an overview of all aspects of the several available routing protocols with a particular focus on data aggregation, query support, and the possible scalability of the network. Talking about the future considerations of the same, security routing, energy demand, and multiple objective routing are points that will require attention in the future in a significant way.

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