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RESEARCH ARTICLE

HEERPOP: Hybrid Energy Efficiency Routing Protocol for Optimal Path in the Internet of Things-Based Sensor Networks

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Abstract – Internet of Things applications that employ wireless sensor networks (WSNs) most often experience packet loss, delays, and sensor node battery drain. Random cluster head selection, malicious node security flaws, and scalability issues in larger networks cause LEACH (Low-Energy Adaptive Clustering Hierarchy) to use energy unequally. Cluster maintenance costs may negate energy savings, and frequent cluster head re-election wastes energy. Increased cluster traffic may cause packet collisions and interference. Complex OSEAP algorithms may strain resource-constrained sensor nodes and complicate implementation. Security approaches waste energy and weakens key management and attack point security. OSEAP may have data transmission delays due to node mobility and scalability as nodes grow. Energy management and routing are strengths of both protocols, but they must improve to improve wireless sensor network performance and dependability. A routing system that enhances network performance without sacrificing service quality is our greatest hope of overcoming these obstacles. We devised a routing strategy that is effective and energy-efficient to address the unfairness of high traffic loads on WSNs used by Internet of Things (IoT) applications. The suggested protocol chooses the best path based on reliability, lifespan, and next-hop node traffic. For stiff simulations, MATLAB R2015a was utilized. The suggested protocol's Hybrid Energy Efficiency Routing Protocol for Optimal Path in the Internet of Things-Based Sensor Networks (HEERPOP) performance is also compared to other existing modern protocols. The proposed protocol gives better outcomes in terms of energy consumption, packet delivery ratio, end-to-end latency, and network longevity.

Index Terms – Internet of Things, Energy-efficiency, WSN, LEACH, OSEAP, Clustering.

1. INTRODUCTION

Wireless sensor technology has enabled sophisticated pervasive IoT applications, which have given rise to modern IoT uses. The IoT is a collection of interconnected technologies that allow for a constant network to be available almost anywhere. The IoT relies on wireless connections to link various things and provide ubiquitous connectivity. The IoT has many applications, including in the military, medical monitoring, smart homes, smart farms, and smart cities [1]. Efficient routing methods increase the data speed, scalability, and energy efficiency in WSNs. However, low-power wireless networks aren't always reliable, and their limited resources don't always meet the necessary Quality of Service (QoS) standards. Developing a fresh and effective protocol for communication between WSNs and the Internet of Things requires tackling these issues. Along with the aforementioned need, many IoT applications necessitate the development of a multipath-aware routing protocol that minimizes latency, loss rate, and energy usage [2].

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With the limited energy resources that are connected to sensor nodes being taken into consideration, the data must be sent in a way that makes use of all network nodes. To operate gracefully, it will reduce energy consumption for every node by selecting nodes for data routing based on certain criteria. When all nodes in the network have used all their energy and there is no more power left, the network will stop working. Within this paradigm, there are a plethora of applications in development, several standardization efforts, and various forms of research [3]. The IoT systems like this collect data, such as motion, temperature, and change information, by distributing nodes to specific areas for specific purposes. The nodes collect data and they have collected to the next nodes since their transmission range is limited. In the realm of artificial intelligence, emerging gadgets are characterized by decreasing size and growing spatial density. A high density of nodes indicates competition over a limited bandwidth, and the tiny physical size of the devices signals that they have a limited capacity for battery life [4].

Therefore, it is of the utmost importance that communication in devices makes effective use of these resources throughout the operation. The process of forwarding packets requires intermediary nodes to use energy without their own will. This motivates nodes to utilize energy more quickly and speeds up the process of network segmentation. In addition, sensor nodes do not possess a great deal of power, computational capabilities, or memory; as a result, they are not ideal. Because these resources need the use of batteries and often function in large-scale, unsupervised contexts where it is difficult to replace or replenish the batteries, it is essential to make prudent use of them [5]. Therefore, the most significant factor that determines the spreading of Internet of Things networks, node energy efficiency affects network performance [6].

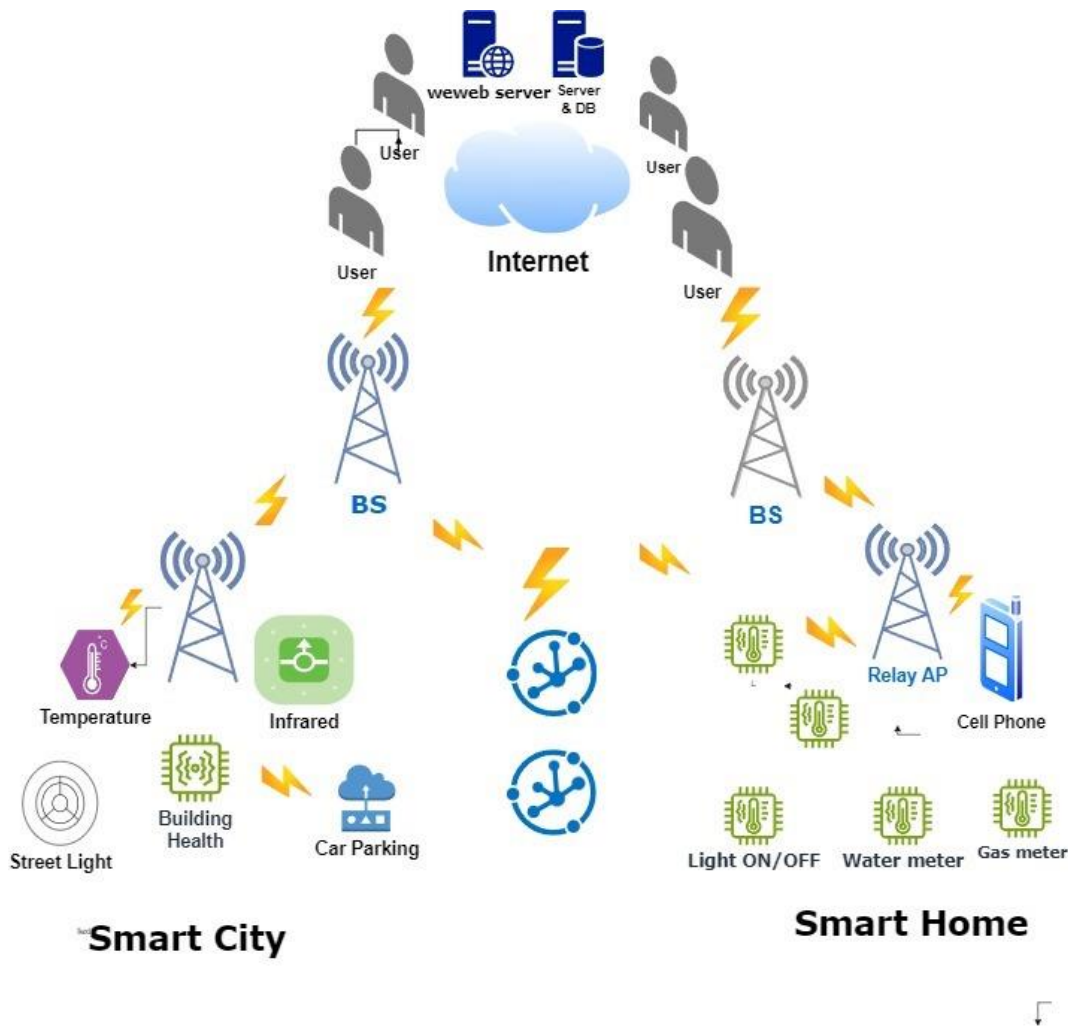

Figure 1 IoT Network Architecture

In Figure 1, we can see the WSN architecture in action for applications of IoT. The figure shows the source node data transmission process to the end user, including the steps involved in the multi-hop route and gateway. Users can access their data easily and whenever they want thanks to this. In the context of IoT applications built on WSNs, routing plays a very important role. Wireless sensor networks (WSN) take the energy efficiency of the routing protocol into account during design. Reducing energy consumption, improving the quality of service of networks, and increasing the network's lifespan are the goals of the targeted procedures. In this study, we provide a new approach to multipath routing for WSNs. This protocol builds many pathways using the optimality factor, which considers a node's lifespan, communication dependability, and traffic intensity. The protocol enables the source node to choose a data transmission path from among several feasible options, taking into account the projected optimality factor (OF) [7].

1.1. The Highlight of the Contribution in the Paper

- The HEERPOP model is to design an energy-efficient protocol for IoT applications.
- In this study article, the suggested model focuses on the development of a routing protocol that is both safe and energy-efficient to ensure dependable network connection for smooth transmission.
- Performance of HEERPOP is evaluated based on comparing energy consumption, packet delivery ratio, end-to-end latency, and network lifetime to comparable energy-efficient Internet of Things-based wireless sensor network (WSN) systems including OSEAP, LEACH, and Hy-IoT.

1.2. Problem Statements

The author has been motivated by some lacuna from the Energy-Efficient Optimal Multi-Path Routing (EOMR) protocol to improve the QoS for IoT applications. Its adaptability to network dynamics is not explicitly discussed or evaluated [8].

The study emphasizes energy economy and QoS enhancement but may not handle dynamic network topology, node mobility, or environmental circumstances [9].

- To further understand and use the proposed EOMR protocol in varied IoT environments, additional research into its resistance to dynamic situations and adaptation to real-world deployment issues is needed.
- Future research should simulate or experiment with dynamic network settings to fill this gap and get insight into the protocol's performance in non-static contexts.

Some limitations to the energy-efficient routing protocol [10].

- Restricted Scalability: IoT routing technologies often face restricted scalability issues. Some protocols may struggle with a high number of IoT devices, depending on their architecture and approach.
- Complexity and Overhead: Some routing protocols may demand more memory and processing, which might be negative in resource-constrained IoT devices.
- Network Topology Dependency: Protocols relying on certain topologies may suffer in fluctuating contexts. If the routing protocol is susceptible to network structural changes, it may be disadvantageous.
- Security Concerns: Routing systems are not immune to security concerns in IoT networks. The document may suffer if it fails to address security issues or adds vulnerabilities.
- Energy: An "energy-efficient" routing protocol may be limited if it does not optimise energy use or react to changing node energy levels.
- Limited QoS Support: The document may be disadvantaged if it fails to handle QoS needs, particularly in IoT networks with different data transmissions.
- Lack of Real-world Validation: Protocols without practical implementation or substantial validation may be questioned. The suggested routing protocol may be limited if it has not been tested in practical IoT scenarios.

1.3. Organization of the Paper

The rest of this work is summarized below. In the section 2, relevant literature has been discussed. In section 3, the suggested model HEERPOP is further explained. The result and discussion are analyzed in Section 4, and it is compared to the performance of other methods that are currently applicable. At long last, Section 5 concludes the work and the future work has been discussed.

2. RELATED WORK

The term "wireless sensor nodes" refers to electronic devices that have a limited energy resource and low power consumption. Because they are powered by batteries, the devices in issue cannot be replaced on their own without special assistance. Comparatively speaking, the quantity of energy that is expended during communication (both transmission and receiving) is much larger than that which is expended during other activities. One of the primary goals of developing routing protocols is to identify the path that will provide the greatest amount of efficiency between the origin and the destination [11].

To reach this objective, it is necessary to identify the most efficient route between the two places. As a consequence of this, the researcher is now confronted with the challenge of

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inventing a routing protocol that is not only more friendly to the environment but also meets higher standards for quality of service. As a consequence of this, several attempts have been made by researchers and academics to identify the most efficient route while taking into consideration various aspects of the quality of service, such as throughput, reliability, or latency [12]. The practical implementation of the IoT is becoming more widespread, evident in various domains, including different areas such as traffic management, weather systems, security systems, smart infrastructure, etc. Although the magnitude of these applications is vast, the capabilities of devices and the duration of battery life are constrained. Wireless Internet of Things (IoT) networks now have limitations in ensuring extended network lifetimes and sustained sensing coverage. Furthermore, the methods described in the existing body of research exhibit a high degree of complexity and provide challenges in terms of practical implementation within real-world contexts. The energy constraint issue about devices in IoT applications can be characterized as an optimization challenge. To optimize energy consumption in device nodes, a cluster approach has been employed by using the routing protocol that involves grouping devices depending on various criteria.

These criteria include the distance between the devices and the BS, the duration of the data or messages being transmitted, and the data derived from the environment at the period in question. Subsequently, the selection process designates each cluster head (CH), and a directed acyclic graph (DAG) is constructed, wherein all the CH are represented as individual nodes. The calculation of edge weights involves the utilization of a developed equation that serves to depict the communication purpose originating from the transmitter and directed towards the receiver. Efficient real-time routing necessitates the computation of the less cost to the BS. The utilization of sleep scheduling is also employed as an optional measure to enhance the energy efficiency of networks. The routing protocol under consideration has undergone simulation and has superior performance compared to currently employed routing protocols [13]. IoT enables are confronted with substantial issues regarding energy usage. This article presents a unique approach to improving energy efficiency WSNs, founded on the IoT present a unique challenge [14].

It combines the following:

1. Energy Harvesting: Utilizing the energy of the surrounding environment to power sensitive devices. Optimizing sleep modes to reduce the amount of energy that is used during periods of inactivity is the second technique.

3. Data Compression: The process of reducing the overhead of transmission by effectively encoding data. Clustering is the process of grouping sensors to reduce the quantity of energy that is necessary and communication distances.

2.1. Exploring Routing Protocol

The Sensor Protocol for Information via Negotiation (SPIN) was a routing protocol, developed for WSNs. Its purpose is to lessen the amount of energy that is consumed and to improve the dissemination of data. This is accomplished through the utilization of a negotiation-based approach, in which sensors advertise metadata to their neighbours, negotiate the transfer of data, and send acknowledgements to confirm that they have received the data. The versatility of SPIN allows it to accommodate huge data space for applications such as environmental monitoring, and industrial automation. Its decentralized architecture and energy-efficient design make it suited for WSNs. There are, however, constraints that require more focus. The possibility of delay, and scalability concerns in extremely large WSN operations. Given these challenges, SPIN presents a promising solution for energy-efficient data dissemination in WSNs. Its advantages, which include reduced energy consumption, improved data accuracy, and flexibility, make it a valuable protocol for a variety of applications. However, to fully realize its potential, it is necessary to continue developing and optimizing it. The routing protocol is vital for forwarding packets between nodes. Additionally, it utilises its method to determine the most efficient route to take to avoid congestion and achieve the most possible throughput potential. Protocols include SPIN [15] and Directed Diffusion, which are often used for a fat-network topology that is very straightforward. In the case of a fat network with homogenous nodes, both of these data-centric protocols are also capable of being implemented. Through the establishment of a hierarchy inside the network, hierarchical routing was presented as a means of achieving energy efficiency.

If all of the nodes continue to function for the duration of the data transfer, there is a potential that the energy supply will be depleted. From this point forward, the energy is only delivered to the nodes that are still in an inactive condition. Unwavering control over the amount of energy used is provided via the EARP protocol. Mann and colleagues came up with the idea for the Energy Aware Routing Protocol (EARP) was developed in 2004 specifically for ad-hoc wireless sensor networks. By picking routes based on the node's residual energy rather than the standard shortest-path metrics, EARP seeks to reduce the amount of energy that is used and to extend network lifespan. In this protocol, proactive and reactive routing approaches are used in conjunction with one another. This means that nodes keep track of their local topology information and respond to any changes that occur in the network. An innovative "energy-aware" measure is also included in EARP. This metric takes into consideration the amount of energy that is used by nodes, which enables it to adjust to the ever-changing circumstances of the network. EARP is a viable solution for energy-constrained wireless sensor networks, as shown by the results

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of simulations, which show that it beats current protocols in terms of energy efficiency, network longevity, and data delivery ratio [16].

To be more exact, it works to achieve a balanced use of energy among all of the mobile nodes that contribute. Within the context of EARP, it is not necessary to stop the reception nodes to get the most energy-efficient routing route to transmit the information. Nodes can govern whether or not they receive the acceptance and send route request messages to their neighbouring nodes, and this decision is determined by the amount of battery life remaining in the power supply. In the meanwhile, the energy is not squandered since this protocol helps consumers use the least amount of energy possible. The group key distribution method is used for the transmission of messages from the source node to the destination node once the energy consumption has been reduced via the utilization of the Optimal Secured Energy-Aware Protocol (OSEAP) [17]. The goal of this technique is to reduce the amount of energy that is used by the network and to effectively offload jobs from other regular nodes. This is accomplished by assigning the responsibility of routing to cluster leaders. The GEAR protocol is an excellent example of an energy-efficient protocol that may be used for location-based routing. On the other hand, the routing algorithms that were discussed before are not without their share of issues. In each of these protocols, there are specific areas of the network that may have a higher frequency of communication than others, while other parts of the network may not be used as often during the lifespan of the network [18].

SEP, which stands for "Stable Election Protocol," was developed based on the election likelihood for CH as per their energy level. The CH is chosen at random depending on the percentage of energy that is contained in each node. The SEP algorithm employs two weighted probabilities for both the normal and advanced nodes, taking into account both the random number and the nodes that were previously chosen as CH representatives [19].

To design a hybrid process, the energy level and y coordinates are taken into consideration. There are three zones that Z-SEP assumes to exist: 0, 1, and 2. When it comes to Zone 0, the normal nodes are selected at random. There is a random distribution of advanced nodes inside both Zone 1 and Zone 2, and these nodes are distributed with equal distribution across the two zones. Direct communication, which was used by conventional nodes directly, and delivering the data to the base station (BS) are the two techniques that Z-SEP utilizes to communicate data to the BS. In contrast, transmission via CH is employed in zones 1 and 2, and CH is selected. This is the case in both zones. A comparison is made between a random number that is chosen (which may range from 0 to 1) and the threshold value that takes into account the probability of advanced nodes. This comparison is used by each node to determine whether or not it is a CH throughout a round. Environments that are part of the Internet of Things are made up of a broad range of devices that are different from one another in terms of their energy consumption, their accessibility on the Internet, and other features. It is common practice to split an Internet of Things ecosystem into zones, even though it contains a tremendous variety of devices of varying types. In each of these zones, it is not uncommon for one kind of gadget to be the predominant one, while just a few of the other types of devices are present. There was a significant majority of protocols that were developed that were capable of successfully managing either homogeneous or heterogeneous devices [20].

Hy-IoT [21] is a heterogeneous-aware Internet of Things protocol that is proposed in this study. The suggested protocol presents an effective hybrid protocol that is ideal for the mixed heterogeneous dominating zones and the homogeneous dominating zones that are present in an Internet of Things environment. This model is referred to as Hy-IoT technology. There is the potential for an extension of the stability period using the protocol that has been recommended for the Hy-Internet of Things. There are several different weighted election probabilities that Hy-IoT uses to become a Cluster-head correspondingly. These probabilities are based on the heterogeneity of the zone. When compared to the Z-SEP, LEACH, and SEP, the simulation reveals that the Hy-IoT increases the stability period by a significant amount. An exhaustive investigation is carried out to determine the effect of heterogeneity, particularly in situations when a greater number of devices have an excess of energy, which is the situation for the majority of IoT applications. In WSNs, the radio model that is used in Hy-IoT is the one that is most widely employed. In Table 1, the authors present the related works.

Table 1 Summary of Related Works

S. No	Reference	Focus Areas	Key Contributions
01	[12]	Energy efficiency, Bandwidth Constraints, Algorithm Developments	Maximizing efficiency in energy-, bandwidth-, and transceiver-constrained wireless networks for multicasting sessions
02	[13]	Reliability and Load Balancing, Network coding, Clustering, Energy	The DAG-Coder, which uses clustering and network coding to increase data packet

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		efficiency.	recovery and reduce energy usage, is a major addition.
03	[14]	Energy Efficiency, Internet of Things (IoT), Wireless Sensor Networks, WSNs.	Hierarchical Network Design, Optimization Model, Minimum Energy Consumption Algorithm,
04	[15]	SPIN Protocol Overview, Data Dissemination, Comparison and Evaluation, Applications and Use Cases.	Comprehensive Review, Detailed Analysis, Identification of Challenges, Insight into Variants.
05	[16]	Energy-aware routing, Ad-Hoc Wireless Sensor Networks, Protocol Design and Mechanism.	Introduction of EARP, Energy Efficiency Mechanisms, Performance Evaluation, Dynamic Adaptation.
06	[17]	Secure Routing, Energy Efficiency, Evolutionary Approach,	Development of an Evolutionary Secure Routing Protocol, Enhanced Security Features, and Energy-Efficient Design.
07	[18]	Geographical Routing, Energy Awareness, Performance Evaluation.	Development of a Geographical and Energy Aware Routing Protocol. Comparative Analysis, Practical Implications.
08	[19]	Clustered Heterogeneous Wireless Sensor Networks, Stable Election Protocol (SEP), Energy Efficiency and Network Lifetime	Introduction of SEP, Heterogeneity Handling, Cluster Head Election Mechanism, Stability and Longevity, Performance Evaluation, Practical Implications.
09	[20]	Zonal Stability, Cluster Head Election, Energy Efficiency.	Introduction of Z-SEP, Improved Stability, Energy Efficiency, Zonal Approach.
10	[21]	Hybrid Energy-Aware Protocol, Heterogeneous IoT Networks, Clustering Mechanisms.	Development of a Hybrid Protocol, Energy-Aware Clustering, and Handling Heterogeneity.

3. HYBRID ENERGY EFFICIENCY ROUTING PROTOCOL FOR OPTIMAL PATH IN THE INTERNET OF THINGS-BASED SENSOR NETWORKS (HEERPOP) MODEL

The proposed model is designed as per the following points:

1. HERRPOP considers energy-efficient routing, optimum multi-path selection, and QoS for IoT applications in wireless sensor networks. The method optimizes path options, accounts for energy restrictions, and meets QoS criteria to route data packets.

2. HEERPOP initializes the network state, sets parameters, and finds neighbouring nodes within the communication range. It updates a routing database by exchanging energy, connection quality, and QoS data between nodes. When receiving a data packet, QoS-aware route selection ensures that the suggested pathways match QoS criteria and consider energy efficiency and network quality. Traffic is distributed over designated pathways using load-balancing algorithms to reduce congestion and improve network performance. The programme incorporates energy-aware forwarding algorithms to meet sensor node energy constraints. This entails frequent energy level adjustments and avoiding low-energy nodes during forwarding. Multi-path optimization including energy efficiency, connection quality, and QoS criteria is also used in the method. An adaptive and efficient routing approach uses optimization techniques to pick alternative pathways.

3. It maintains also Path maintenance checks chosen pathways for connection quality, energy levels, and other dynamic aspects. Dynamic routing decision adjustments make the algorithm network-resilient. Data integrity and confidentiality are protected by security measures against possible assaults. As network circumstances change, QoS monitoring and adaptation systems dynamically update routing choices to maintain or enhance QoS along chosen pathways. The technique mitigates packet loss and faults to improve end-to-end dependability.

4. Termination criteria describe when the algorithm should stop. This might mean accomplishing goals, reaching a condition, or realizing the network is down. The goal for

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IoT applications is to design Energy-efficient, optimum multi-path routing in wireless sensor networks.

3.1. Need of the Proposed Model

Usually, the need for a proposed model in a research paper comes from the need to fix specific problems or holes in frameworks, protocols, or procedures that are already in place. For the most part, this is what happens. Being able to offer a plan is important for this reason, which is why it is important. We have explained about the algorithm for better visibility.

Algo_HEERPOP (nodes, network, source, destination, optimisation_criteria, QoS_requirement, data_packets)

{

 # Discover Neighbor and update the routing table

discovery_neighbor_nodes (networks)

#QoS aware path selection

result= Dijkstra (network, source, destination)

a= (result, QoS_requirement)

#load balancing

load balancing(a)

 # Energy-aware forwarding

select_node_with_high_energy(node)

 # Optimal path

find_optimal_path (a, optimisation_criteria)

 # security considerations

encrypt(node)

#QoS Monitoring and Adaptation:

Continuously monitor the QoS metrics selected paths.

Dynamically Routing to improve QoS

#End-to-End Reliability:

Implement mechanisms_end-to-end reliability, potential packet loss or failures.

Termination:

- Terminate the algorithm when the specified criteria are met or when the network is no longer operational.

}

Algorithm 1 Proposed HEERPOP Algorithm

3.2. Explanation of Algo_HEERPOP (Algorithm 1)

- Neighbour Discovery and Routing Table Update: Discovering adjacent network nodes starts the process. The discovery_neighbor_nodes(network) function performs this. This function locates communication-range nodes. To optimize route selection and data delivery, every node must update its routing database with neighbour information.
- QoS-aware Path Selection: Dijkstra's algorithm determines a source-to-destination path after discovering neighbors. Edge weights like distance, latency, and energy cost determine the shortest path. For QoS, the route is filtered (filter_path_by_QoS(result, QoS_requirement)). This route is shortest and meets latency and bandwidth requirements.
- Load Balancing: The next step involves (load_balancing(path)) to share the data of the traffic evenly over multiple paths. This prevents congestion on any single path, which can lead to delays and packet loss. By spreading the load, the algorithm enhances overall network performance and efficiency.
- Energy-aware Node Selection: The program chooses nodes based on energy to extend network longevity. Choose_node_with_high_energy(balanced_path) finds balanced path nodes with high energy to convey data. This phase prevents fast node energy depletion and guarantees data transmission across load-bearing nodes.
- Optimal Path Calculation: After determining the load-balanced paths and selecting high-energy nodes, the algorithm computes the optimal path based on defined optimization criteria (find_optimal_path (balanced_path, optimisation_criteria)). This can involve minimizing energy consumption, and latency, or maximizing throughput, ensuring the chosen path is efficient.
- Security Considerations: Security is a critical aspect of the algorithm. Before transmitting data, the algorithm encrypts the data packets (encrypt (data_packets, selected_node)) using a specified encryption method. This step protects the data from potential eavesdropping or tampering, thereby enhancing the security of the communication.
- QoS Monitoring and Adaptation: The algorithm continuously monitors QoS metrics for the selected paths (continuously_monitor_QoS_metrics(optimal_path)). By assessing metrics,the algorithm can adaptively reroute traffic as needed (adapt_routing_to_improve_QoS(optimal_path)). This dynamic adjustment ensures that the network maintains optimal performance, even under varying conditions.
- End-to-end Reliability: To guarantee reliable communication, the algorithm implements mechanisms for end-to-end reliability (implement_end_to_end_reliability_mechanism(optimal_

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path)). This includes strategies to handle potential packet loss or failures, ensuring that data reaches its destination without significant loss.

- Termination Conditions: Finally, the algorithm includes termination conditions to determine when to stop executing (termination_criteria_met() or network_no_longer_operational()). If these conditions are met, the algorithm safely terminates, ensuring that resources are appropriately released and that the network does not continue to operate in an inefficient state.

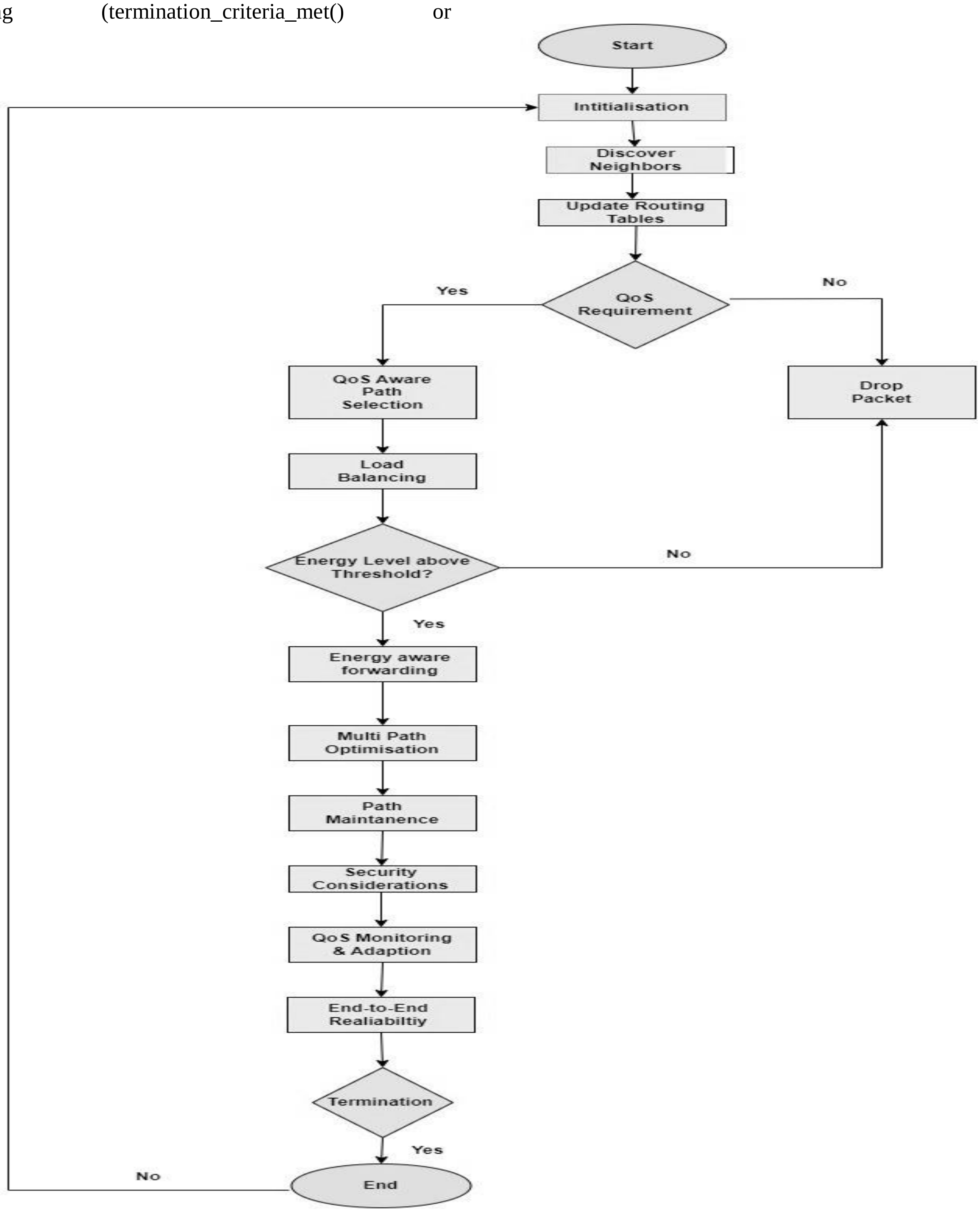

Figure 2 Flowchart of HEERPOP Model

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In Figure 2 After initiating the initialization procedure, the first node locates its neighbour. It adds the node to the routing table after finding it. Path selection and load balancing are initiated if the QoS criterion is met; if not, all packets are dropped. Following the completion of the load balancing and node route selection processes, the node energy level is checked. If it exceeds the threshold energy, the procedure proceeds; if not, packets are dropped. Six crucial tasks, including energy-aware forwarding, multipath optimization, path maintenance, security concerns, QOS monitoring and updating, and end-to-end dependability, have been a source of worry throughout the process.

3.3. Advantages and Disadvantages of HEERPOP

These are the important points of advantages of the HEERPOP model:

- Energy Efficiency: it reduces energy consumption by using the data aggregation method at the CH level, minimizing the amount of data transmitted to the base station.
- Scalability: It may be quickly scaled to accommodate a larger number of nodes by allowing cluster creation and CH selection.
- Adaptive Clustering: Protocol adapts to changes in network conditions by re-selecting cluster heads and forming new clusters during each round.
- Reduced Transmission Load: By aggregating data at the CH, it decreases the amount of data sent to the base station, which helps extend the network's lifespan.
- Simple Implementation: its design is relatively straightforward, making it easier to implement in various applications.

These are the following points of disadvantages of the existing Model:

- Random Cluster Head Selection: It can lead to uneven energy consumption, where some nodes use their energy more quickly than others.
- Limited Network Lifetime: If cluster heads are not rotated effectively, it can result in premature network failure due to energy depletion of specific nodes.
- Security Vulnerabilities: The random nature of cluster head selection may make the network susceptible to attacks, such as a malicious node taking over a cluster head role.
- Communication Overhead: The process of forming clusters and electing new cluster heads can introduce overhead, which might negate some energy savings.
- Assumption of Uniform Node Distribution: It assumes a uniform distribution of nodes, which may not reflect real-world deployments, leading to inefficiencies.

4. RESULTS AND DISCUSSION

This study is focused on the most recent energy-efficient solutions that have been implemented on WSNs. Consequently, constructing WSNs and including devices that are efficient in the MATLABR2015a simulator. The design of the layout was by them. WSNs with a range of sensor nodes (100-1000) and a total of sixty mobile agents collect and aggregate data to accomplish energy efficiency, load balancing, and in the network. OSEAP, LEACH, SEP, and Hy-IoT are implemented in MATLABR2015a by following the methodologies that were presented by the authors. In Table 2, To configure the WSNs, the network characteristics were used.

Table 2 Simulation Parameters

Parameters	Values
No. of SNs	100-1000
Routing Protocols	OSEAP, LEACH, Hy-IoT
Simulation Time	100s
Mobile Agent (MA)	30
Mobility of Mobile Agents	10m/s
Initial Energy of SNs	5Joul/bit
Network Size	100 x 100 m^2
Data Packet Size	500 bytes
MAC	IEEE 802.11
Antenna	Omni Antenna
SNs Transmission Range	20 m

4.1. End-to-End Delay

In the context of data transmission, the phrase "end-to-end delay" refers to the amount of time that passes between the moment of the source node sending the packet and the moment of the destination node receiving it.

Figure 3 compares the average end-to-end latency of the HEERPOP protocol to various options. This assessment used several node density topologies. Due to high data traffic, congestion, and hostile nodes, end-to-end latency became more valuable. In contrast, the HEERPOP protocol offered lower end-to-end latency than earlier options, particularly when network loads were high and user populations were large. The numerical findings showed that the HEERPOP protocol reduced execution time without delays, unlike earlier techniques. The HEERPOP protocol also improved data forwarding node reliability and consistency. Unlike previous systems, HEERPOP measured network analysis to circle cluster heads in the sensor field. This reduced routing gaps and data delays.

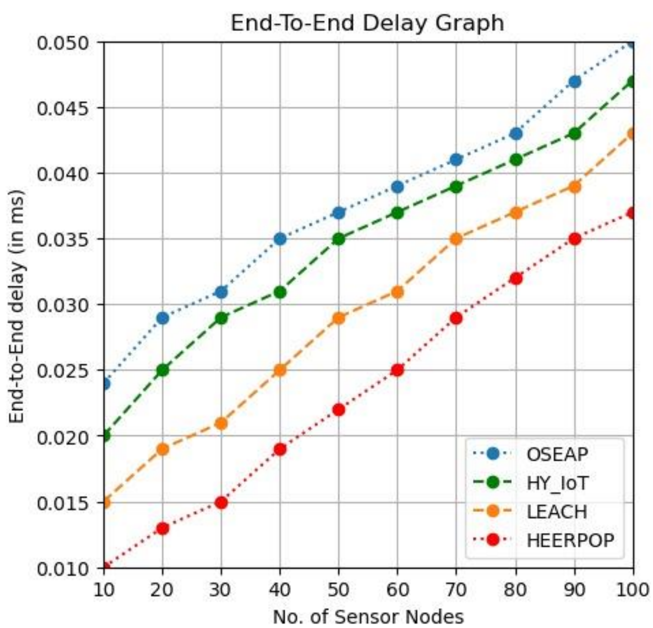

Figure 3 End-to-End Delay vs No. of Sensor Nodes

4.2. Packet Delivery Ratio (PDR)

When referring to the proportion of packets received at the destination. In contrast to the total packets that are sent from the source node, the term "packet delivery ratio" (PDR) is used.

The performance assessment of the HEERPOP protocol in terms of the packet delivery ratio is shown in Figure 4. This comparison is made against the work that has been done before under a variety of different node density topologies. The HEERPOP solution has shown the largest data delivery ratio improvement compared to other solutions, particularly in topologies with a high number of nodes. This is seen in Figure 4. This is because the HEERPOP protocol takes into account several different and optimum factors when selecting cluster heads. Additionally, the nodes that are more suited for the generation of stable and energy-efficient clusters were given a higher point of priority. Furthermore, when the clusters were constructed, they remained permanent, and HEERPOP restarted the process of selecting cluster heads. This was done to ensure that the clusters remained stable. This was done to choose cluster heads. In addition, the dependability of the data packets that were sent between the base station (BS) results in a decrease in the number of route breakages, which ultimately increases the performance of the data delivery system's overall performance.

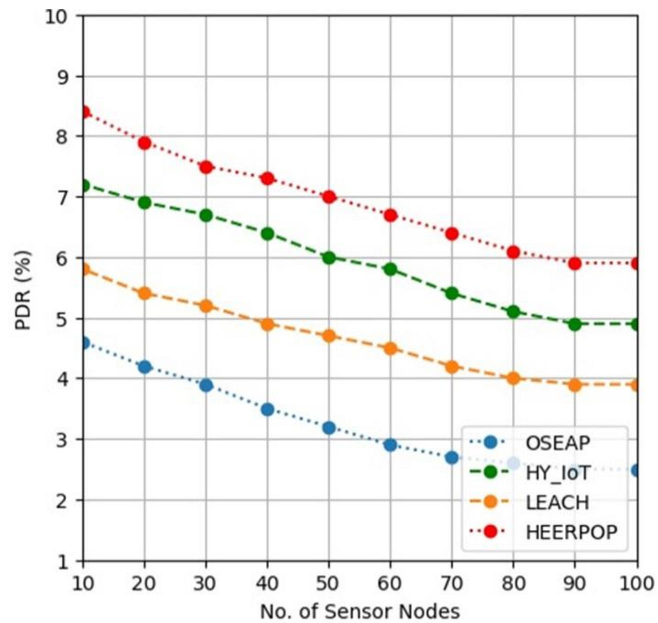

Figure 4 PDR vs No. of Sensor Nodes

4.3. Energy Consumption

Energy consumption is the total amount of energy that is utilized by the network during the process of routing packets from one site to another. The term "energy consumption" refers to the overall quantity of energy that is used.

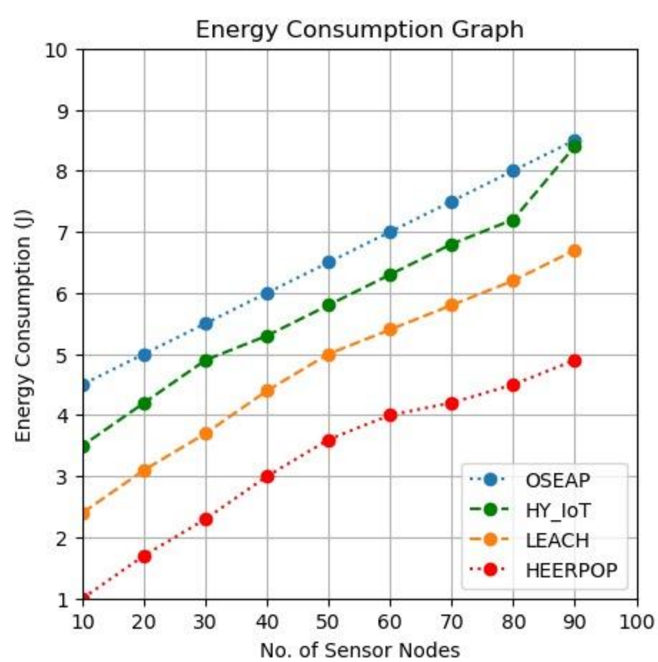

Figure 5 Energy Consumption vs No. of Sensor Nodes

In terms of the amount of energy that is used, Figure 5 provides more conclusive findings than the other approaches that are currently in use. When computing energy consumption, the average ratio of power consumption between sensor nodes that transmit and receive cluster head election packets is taken into consideration. The impacts of route breakages are shown in Figure 5, which indicates that the results are superior to the potential outcomes. Figure 5 illustrates the transmission distance for each of the setups that were measured and analyzed. Consequently, the performance of Figure 5 is superior to that of other protocols that are currently in use, such as OSEAP, HY-IOT, and LEACH, in terms of the ratio of packets that are delivered on time.

4.4. Network Lifetime

The period that starts with the beginning of the network and ends with the point at which the node energy in the network is exhausted is referred to as the "network lifetime" (NLT).

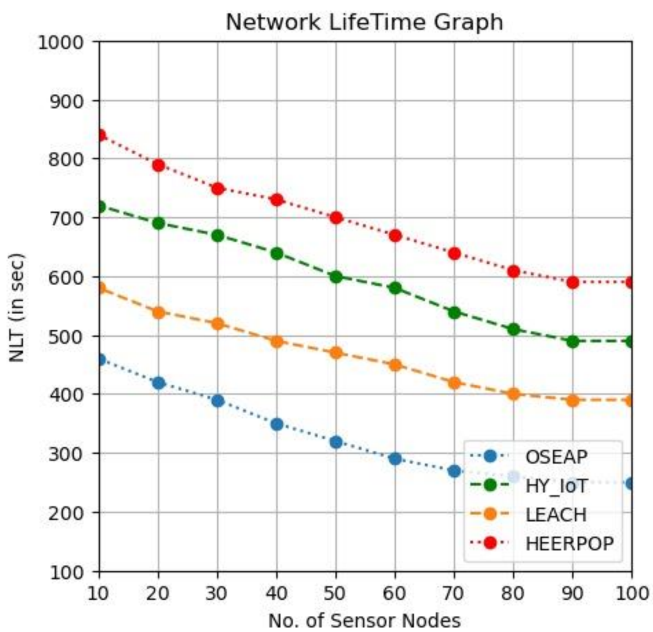

Figure 6 Network Lifetime

In Figure 6, the performance of the HEERPOP protocol is shown about the network lifespan in comparison to the work that has been done before. This is demonstrated for a variety of topologies with varied node densities. It can be shown in Figure 6 that HEERPOP is superior to other solutions in terms of its ability to extend the lifespan of a network, particularly when the network is under a high load. This is a result of the optimization of the cluster creation process and the initiation of the re-election mechanism on the network analysis. Additionally, the HEERPOP protocol took advantage of local clustering capabilities, which brought a reduction in overheads and the use of energy that was not required during the re-clustering phase. In addition to this, the HEERPOP provided a lightweight secure routing system that assisted in the transmission of the encrypted sensory information to BS. Figure 6. NLT vs No. of Sensor Nodes.

5. CONCLUSION AND FUTURE WORK

This study's objective is to provide a description of the Hybrid Energy Efficiency Routing Protocol for Optimal Paths in Sensor Networks that are Based on the Internet of Things (IoT). When there are a huge number of malicious nodes and a great amount of network congestion, this results in a substantial rise in the number of route discovery processes and re-transmissions processes. This particularly occurs in circumstances when there is a considerable amount of network congestion. The HEERPOP algorithm was designed to optimize the use of a distributed approach for the construction of clusters to achieve an equitable distribution of energy consumption. The recommended protocol will be enhanced in the course of future development by taking into account multi-hop network communication in addition to mobility needs. This will be done to fulfil the necessary criteria.

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