

# Performance Optimization in Dynamic Routing Protocols for Wireless Sensor Network

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## Abstract:

Energy-efficient management of Wireless Sensor Networks (WSNs) is a key factor for sustainable operation. Hence, this paper investigates new ideas for optimized dynamic routing protocols. Demonstrating in a careful analysis and empirical comparisons how clustering techniques can deal with the peculiar heterogeneity of WSNs while providing energy preservation. The study proposes attractive approaches to reduce energy overheads and extend the network longevity by noting the dynamic nature of the wins. The cloop proposed a hierarchical structure, including collective intelligence of sensor nodes and new adaptive methods. For more updates, Follow Us on Twitter! We can see a significant improvement in static or indefinitely placed networks since the standard techniques shift towards Enhanced Energy Aware Dynamic Sensor routing. EEDS demonstrated substantial improvements over the state-of-the-art schemes and ensured high packet delivery ratios, low data loss rates, small end-to-end latencies, and higher throughput. EEDS allows for improved efficiency through energy conservation and network operation optimization. Upon such dynamic network settings, EEDS is a positive form of emphasizing workload and addressing the efficiency of WSN operation. This paper illustrates the novel approaches of a robust and energy-efficient WSN setup as a baseline to drive IoT applications in India and beyond.

**Keywords:** Wireless Sensor Networks (WSNs), Energy Optimization, Dynamic Routing Protocols, Clustering Technique

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## 1. Introduction

The WSN space is constantly depreciating with advancements. The key goal of researchers applying this technology domain is to minimize every joule by simply implementing better system network efficiency and system performance while achieving seamless operation as expected. In the case of heterogeneous WSNs, this requirement is more critical due to the presence of nodes with different features and functionalities [9], [10]. This paper proposes orchestrating dynamic routing protocols with clusters to address this energy optimization problem efficiently, but only if we regard such an environment as a diverse and highly volatile network.

Heterogeneity WSNs dynamic routing by exploiting the provincial resourcefulness of energy optimization utilizing the clustering methodologies our contribution is the exploration of the complex interplay between dynamic routing schemes findings, energy efficiency, and cluster structure placement within the WSNs maze. Through this multi-pronged investigation, we aimed to

highlight new avenues in which energy starvation may be mitigated and network resilience augmented while progressively advancing relevant system-level performance benchmarks.

Our investigation is well-grounded in recognizing the inherent heterogeneity of WSNs, both via the tremendous disparity in computational capability, communication modality, and energy constraints of WSNs and via the need to develop and implement recon- augural structures to bring together disparate entities. Thus, the results of their operation in various heterogeneous WSNs must be considered to evaluate the requirements of dynamic routing protocols and clustering strategies.

In an investigation, we consider clustering to depend on its known affordance for localized communications, in which more overheads in using the WSNs are limited via the enhanced availability of the resources. Such clustering strategies not only shift the burden of processing but also help to move away from a single central collection point into a decentralized data management process that has been shown to reduce energy and increase the scalability of the network.

This work assesses dynamic routing protocols' performance and feasibility in heterogeneous WSN surroundings. Dynamic routing protocols are characterized by the ability to adjust themselves automatically to different network conditions due to variations in the network topology or the traffic pattern [2], which is helpful in energy savings, path optimization, and reliable networks. We are eager to clarify how these protocols operate in diverse WSN settings through detailed assessments of their empirical performances and, ultimately, theoretical analyses.

In addition to the technical aspect, this study acknowledges the practical challenges and implementation complexities of energy optimization schemes in heterogeneous WSNs. To optimize energy-efficient routing in WSNs, a range of components must be subconsciously considered based on the subtleties of network topology design and management of node heterogeneity.

By integrating insights gathered from previous works, empirical studies, and theoretical models, this study attempts to provide a comprehensive overview of energy optimization in dynamic routing protocols for heterogeneous WSNs using clustering as a core technology. We aim to steer the future advances of WSN technology by investigating the energy optimization methods in-depth and underscoring repercussions over diverse application domains, thus constructing a sustainable, capable-of-resilient-efficient networking paradigm for the IoT era and beyond.

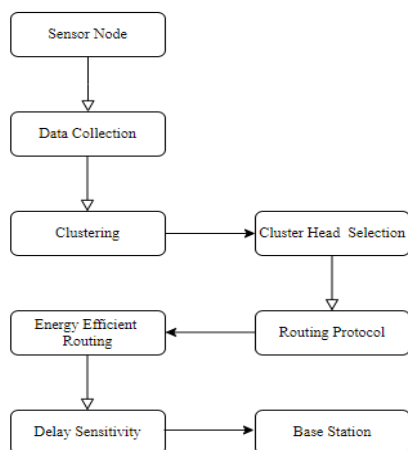


Figure 1. Flow of data from sensor nodes through various stages of processing

Figure 1. The flow of data from sensor nodes through various stages of processing and effective deployment of nodes has been labeled as a crucial factor in the network's longevity and coverage in the high-precision network area of WSNs. In this survey, we explore the labyrinth of WSN deployment strategies and summarize the diversity of these strategies in the static and dynamic deployment paradigms.

Static: The nodes in arbitrary static deployment stay in place for their lifetime. Extensive, complex polarization leads to mixing extremal wells but sparse coverage of hyperspace. So we need a lot of different targets to perturb to get maximal worker coverage with minimal energy. (e.g., deterministic or random itself) require node placement to be optimized depending on the context of the application. Deterministic methodologies are great where this is the case. However, in specific scenarios such as environmental crises or rescuing operations, a random manner of deployment would be needed; in this case, sensor nodes should be dispersed randomly, and self-organization shall be established afterward.

In contrast, dynamic deployment needs more information to find the optimized position for the sensor nodes, i.e., positions with the help of the IDs, apart from the sensors, like robots, especially while deployed in dangerous or inaccessible regions. However, dynamic node deployment will need a higher overhead than static.

The story takes its readers through resource utilization in WSNs, from node deployment to network topologies. A novel approach to the common Wireless Sensor Networks (WSN) communication abstraction is adopted as the basis for this new network topology where conventional strategies are adapted and enhanced. Traditionally, bus and tree topologies lie in contrast to a mesh or grid configuration, providing different advantages but having energy costs in scaling.

A significant strategy to augment energy efficiency in a WSN is based on data clustering, which typically alleviates communication, enables self-organization, and optimizes resources. Three clustering schemes are compared, ranging from single-hop star to multi-hop mesh and hierarchical structures that can enhance the efficiency and reliability of the network.

Energy-efficient routing schemes can be carried out more efficiently, which are difficult to achieve due to changed configurations and deployment scenarios. This paper analyses routing protocol design issues, problems, and types concerning the network lifetime in general and energy savings.

Next, for saving energy and more efficient energy consumption, chapter one, based on routing protocol design, is discussed, leading to the first proposal, specifically looking into the network layer and helping us to achieve a lower power. To maximize the network's lifetime and ensure that energy is consumed balanced, various routing protocols such as LEACH, PEGASIS, and TEEN are being scrutinized critically.

Early in this exploration of WSN mazes, we emphasize the importance of energy-efficient routing schemes in mitigating resource constraints and prolonging network longevity; such schemes also inspire the pursuit of wide-ranging improvements in efficient use within what could lead to the advancement of each sensor technology. This research endeavors to answer these questions through

various empirical evaluations and theoretical analyses, shedding light on novel/novel paradigm nature to sustainable, resilient, and efficient WSN infrastructures.

## 2. Literature Survey

This is a comprehensive survey of the state-of-the-art contributions across various domains pertinent to WSNs that can provide insights into routing protocols, mobility models, and energy-efficient solutions. For example, Al-Karaki and Kamal (2004) provided a literature survey summarizing routing schemes, and Ren et al. Energy-Balanced Routing Protocol (EBRP) is proposed in [2011]; in several types of applications, EBRP can achieve more efficient data gathering[18]. Mamalis (2014) introduces a Path-Constrained Mobile Sink to improve network lifetime with limited sink mobility. In addition, Nasr and Khan (2020) introduced a new Connectivity Enhancement Algorithm to address the partitioning issue for intermittent data collection. All this collectively improves how WSNs can be made better and more efficient, which is vital for using wireless sensor networks in deploying across multiple modern technology platforms.

Table 1. Literature work

Author(s)	Algorithm/Method	Outcome	Application
Cherappa(2023)	ASFO and a cross-layer-based expedient routing protocol	Energy-efficient clustering and routing	Wireless sensor networks
Feng, X., et al. (2023)	Vulnerability-aware task scheduling	Enhanced edge intelligence for trajectory analysis	Intelligent transportation systems
Lin, H., et al. (2023)	Adaptive multi-copy relaying	Improved delay tolerance	Vehicular networks
Nirmala Devi (2023)	Trust-aware optimized clustering	Reliable routing protocol	MANET
Soundararajan(2023)	Met heuristic optimization	Node localization and multi hop routing with mobile sink	Wireless sensor networks
Bangotra (2022)	Trust-based opportunistic routing	Secure intelligent routing	Wireless sensor networks
Kaidi (2022)	Dynamic levy flight chimp optimization	Optimization algorithm	Knowledge-Based Systems
Nagaraju(2022)	Energy optimization	Secure routing	IoT applications
Natesan (2022)	Hybrid mayfly-Aquila optimization	Energy-efficient clustering	Wireless sensor networks
Refaee (2022)	Fit-FCM	Trust and energy-aware cluster head selection	UAV-based wireless sensor networks
Renuga	Trust-based energy routing	Energy-efficient	Wireless sensor

Devi(2022)	protocol	secure transmission	networks
Wang (2022)	Artificial rabbits optimization	Engineering optimization	Various engineering problems
Nasr (2020)	Disconnected cluster connectivity	Time-critical data collection	Partitioned wireless sensor networks
Palak Keshwani (2020)	OPF-AOMDV protocol	Performance analysis	Wireless sensor networks
Alassery, F. (2019)	EERSM	Energy-efficient multi-hop routing	Wireless sensor networks
Holzwarth, F., et al. (2018)	Fault detection methodology	Fault detection	Wireless sensor networks
Sachan (2018)	Virtual-MIMO communication	Energy-efficient communication	Cluster-based cooperative wireless sensor networks
Rubel (2018)	Clustering approach	Priority management	Wireless sensor networks
Alnawafa (2018)	Multi-hop routing techniques	Energy efficiency	Wireless sensor networks
Divya Upadhyay (2018)	Maximum probability theory	Time synchronization	Wireless sensor networks

### 3. Methodology

EEDS is an Algorithm from the fault diagnosis challenge of WSNs. Although the dynamics of the faulty nodes in the energy-draining scenarios are taken care of, it is a long while for the routes to form again, and delays keep adding. Also, these faulty nodes reduce the network potential and increase the energy consumption, which decreases the network life. Reference trajectory method EEDS employs particle swarm optimization to get the best direction between the source and target node. The AOMDV protocol, which utilizes sound residual energy in node interception, is used by communication coordinative techniques. It is validated based on network energy consumption and time consumption under node faults, including the algorithm flow chart, fault diagnosis models, network energy, PSO description, etc. Particle Swarm Optimization is the behavior test of a flock of birds or a fish group, similar to the human thinking method. The PSO operates in established patterns in terms of stochastic groups of variables. PSO is named after the thematic schematization of rapid motion, outright orientation, and collapsibility of iterations of the bird. PSO was proposed by Dr. Eberhart and Dr. Kennedy in 1996 and has been widely implemented in function optimization, training of neural networks, radial-based neural networks, fuzzy system tuning, and engineering designs. The particle of PSO is shown as a potential solution. Note that these randomly positioned particles have vigor. The concept of PSO originates from a flock of birds searching for food. When these birds do not know the location of the food, they compare their positions with those of other birds. PSO repeatedly modifies these placements based on fitness assessment. These birds swap

their roles based on these evaluation results. Such evaluation movements lead the PSO to search for the best solution.

### 3.1 Network Model

Initially, nodes are randomly deployed in the sensor field as a homogeneous network with identical and low energy. These nodes exhibit both stationary and some dynamic behaviors. Due to energy constraints, nodes cannot be replaced or can only be recharged after being deployed. Then, jingles are assigned to nodes randomly and sent to nodes randomly. Static nodes are at varying data transmission rates, and dynamic nodes are at different speeds. It randomly transmits at a fixed bit rate and uses the UDP protocol. Even though the energy range is almost the same initially, some nodes run out first for their role as communication routers.

### 3.2 Energy Model

The experimental setup adopts an efficient radio and energy dissipation channel, incorporating free space and multipath fading channels for effective energy utilization. Energy consumption for transmitting data over distances is computed using an Equation. The energy dissipation at the receiver for receiving data is measured accordingly.

$$ETX(M,D) = M.E_{elect} + M.E_{fs}.d^2 \quad \text{if } d \leq d_0$$

$$M.E_{elect} + M.E_{mp}.d^4 \quad \text{if } d > d_0$$

The proposed algorithm considers soft faults in sensor nodes, distinguishing between hard and soft faults based on their communication capabilities and operational integrity. A sensor's fault probability is defined, reflecting discrepancies between readings and actual conditions.

$$p = P(S = \neg x | A = x)$$

### 3.3 Selection of Optimized Node

Particle Swarm Optimization (PSO), like any artist, gathers inspiration from the collective behavior of animals, working with minimal effort on the part of individuals while achieving the most complete task from a pool of efforts. They iteratively improve the location of each particle according to the personal best and the general best. Each particle keeps track of its best and the best of the neighborhood to guide its movement. In essence, the PSO algorithm starts with a swarm of randomly positioned particles and then steps through a sequence of positions and velocities to refine those values until they converge on the optimal solution. The inertia weight ( $\omega_i$ ) adjusts dynamically at each iteration to divide search space into a global search, which can be performed at a distance & the local search in a neighborhood to reduce the time taken for convergence. This work employs an adaptive PSO algorithm to dynamically adapt each iteration's height where the optimal number of cluster heads is searched in sensor networks.

$$P_i = [P_{i,1}, P_{i,2}, P_{i,3}, \dots, P_{i,D}]$$

$$V_{new,i} = w * V_i + c_1 * r_1 * (X_{pbest_i} - X_{i,d}) + c_2 * r_2 * (X_{gbest} - X_i)$$

$$X_{new,d} = X_{old,d} + V_{new,d}$$

$$W = w_{initial} - (\text{Max. Iteration} - \text{Current Iteration}) / \text{Total number of Iterations}$$

### 3.4 Designing the Fitness Function

Due to the high efficiency of algorithms, the superiority factor against WSNs depends on how well the chosen nodes are based on their fitness function. The proposed function includes two vital features of WSN: energy consumed in sharing information across the sensor nodes and energy consumption by aggregation and transmitting sensor packets to receiver nodes. Since the nodes

within each zone encompass every Node contributing to an extra zone, the equations were defined based on data within each zone, representing the energy consumption among sensor nodes. Such calculation is needed to evaluate the energy dynamics of the network.

### 3.5 Energy Consumption between Sensor Nodes and Zones

Equations delineate the process for computing energy consumption between sensor nodes and zones. A function,  $F(K_j, C_k)$ , evaluates this energy expenditure, considering parameters such as energy levels, distance, and threshold distances. The meticulous calculation accounts for the varying energy states within different zones, which is essential for optimizing node selection strategies.

Energy consumption between the sensor nodes and zones  $[F(K_j, C_k)]$  is given as

In WSN,  $E_{min}$  and  $E_{max}$  are minimum energy decay, respectively.

For the  $k$ th zone, use  $C_k$ .

The function  $S$  outputs the minimum distance of the  $j$ th node in the  $k$ th zone, with one indicating that this is a node located at position  $j$ -th within the given field and zero otherwise. The threshold distance is marked as a  $d_0$  symbol

### 3.6 Energy Consumption between Zones and Base Station

Equations are provided to extend the energy computation framework for inter-zone and base station (BS) energy consumption. This difference is measured in terms of energy expenditure, which involves a function denoted as  $G(C_k, BS)$  that includes the distance between zones and the BS. The comprehensive review of energy use in the network ensured optimal transmission pathways were developed, taking a holistic perspective.

### 3.7 Total Energy Consumption (Fitness Function)

By adjusting the equality of energy used from the two services, the Equation gives us the total consumed volume we will use to derive the fitness function.  $E_1$  represents the energy consumption of intermediate nodes in the routing path, while  $E_2$  indicates the energy consumption between sender/receiver pairs. Since one of the effective transmission designs to transmit a signal with little energy is an essential parameter called  $\mu$  depending on the sender-receiver distance, we tried to optimize it. By having an additional  $f_1$  fitness function detailed earlier, the overall chosen node scheme takes a lower learning step for the WSN-based algorithms.

## 4. Algorithm

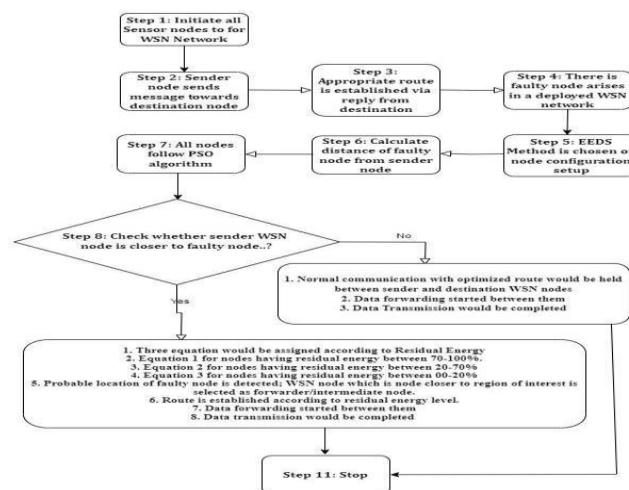


Figure 2. Algorithm Flowchart

### 4.1 Static Scenario of EEDS method

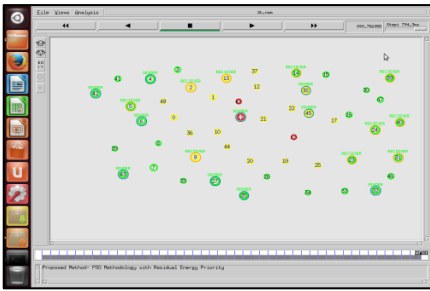


Figure 3 : Static Scenario- Experiment 1 for data rate=2000kbps

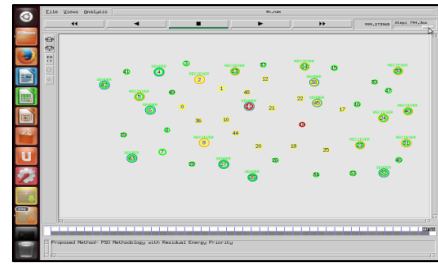


Figure 4: Static Scenario- Experiment 2 for data rate=4000kbps

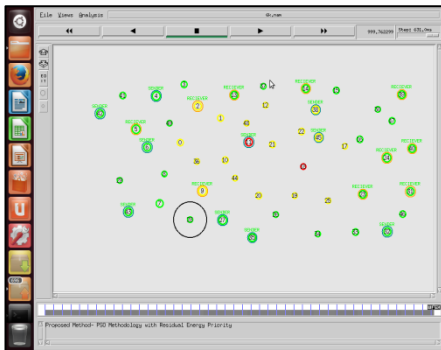


Figure 5 : Static Scenario- Experiment 3 for data rate=6000kbps

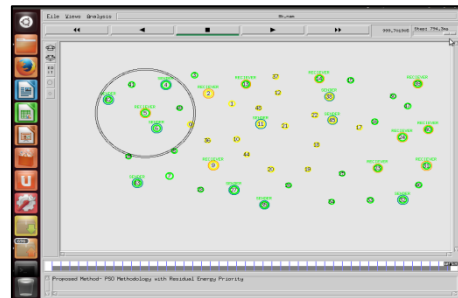


Figure 6: Static Scenario- Experiment 4 for data rate=8000kbps

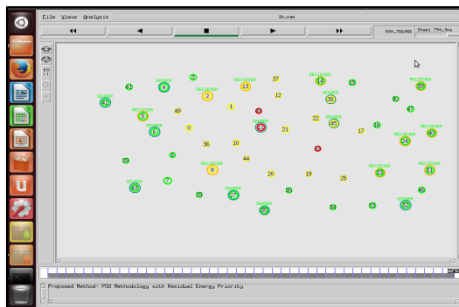


Figure 7: Static Scenario- Experiment 5 for data rate=10000kbps

### 4.2 Dynamic Scenario of EEDS method

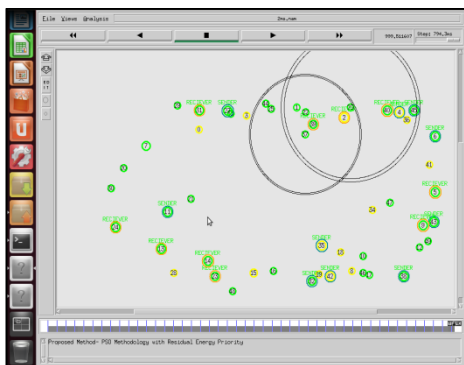


Figure 8: Dynamic Scenario- Experiment 1 for node velocity= 2m/s

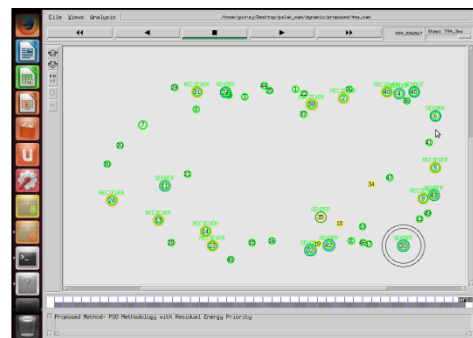


Figure 9 : Dynamic Scenario- Experiment 2 for node velocity= 4m/s

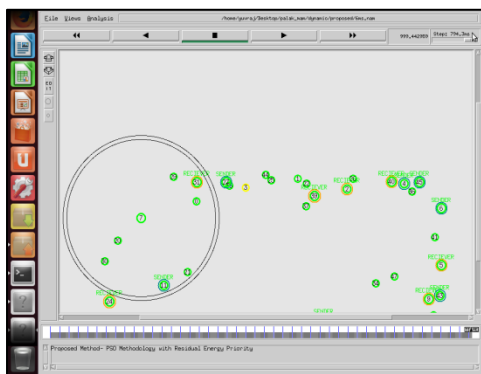


Figure 10 : Dynamic Scenario- Experiment 3 for node velocity= 6m/s

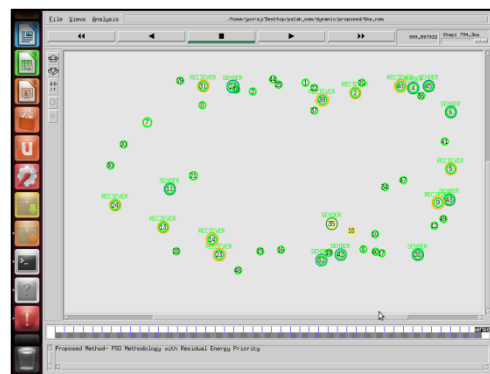


Figure 11 : Dynamic Scenario- Experiment 4 for node velocity= 8m/s

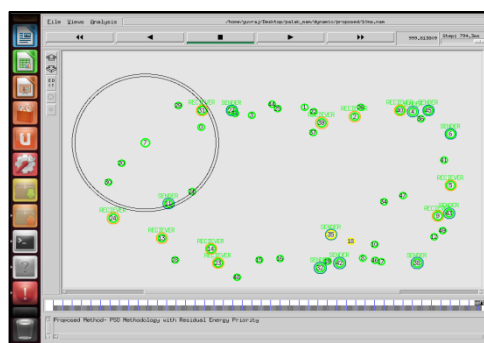


Figure 12: Dynamic Scenario- Experiment 5 for node velocity= 10m/s

## 5. Results

Throughput is the most basic network performance metric because it shows the average data rate forwarded correctly and, finally, to the destination. This may be a wavelength lawsuit of the transfer links efficiency; hence, it means the data travels continuously without interfering due to several factors, which include bits per second or packets per second, which depends on a high throughput compared to its alternative. Hence, we liken it to a well-functioning traffic flow.

Throughput (bits/sec) = (Total no. of received packets at destination \* packet size) / (Total Simulation Time)

Packet Delivery Ratio It measures the efficiency of the routing protocol so it defines the number of successfully received packets at the destination to the number that has been sent; so it acts in perfect harmony like a tuning orchestra

The Packet Loss Ratio indicates the inefficiencies in your packet transmission; therefore, it measures the lost data packets and divides them to conclude.

Energy consumption is a significant challenge of ad-hoc networks that is a measure for any energy management protocol. The energy consumption mirrors the cost of sending and receiving this relay information, which is required to keep the network and node alive. Wireless networks must run for extended periods, requiring all nodes to remain online; energy management becomes paramount for existence.

transmit a packet:  $TxEnergy = txPower \times (packet\ size/bandwidth)$

received packet:  $RxEnergy = rxPower \times (packet\ size/bandwidth)$

total energy consumed: Total Energy Consumed = Initial energy – Energy left at each node.

End-to-end delay entirely digests the distance between the two nodes; hence, it calculates the average number of packets that occur at both times to reach the destination.

Routing Overhead means the frequency of the packet used, hence the bandwidth. This presents the scalability of the protocols since congestion is a concern.

### Analysis of Simulative Parameters for Static Scenario

The network simulation components of the five experiments (static scenarios; the data rates between 2000 bps and 10000 bps) are going to be observed in the watch for six parameters, including, mainly, Packet Delivery Ratio (PDR), for visualizing experimental nodes and the best density location. The PDR results of AOMDV, CDMFD, and EEDS methods are illustrated in Table 4.3, and its graph is in Fig. 4.16. This is the core of our results: targeting larger PDR values, which are atypically arc physical insensitivity. Under different data rates, our analysis shows the superior performance of the EEDS approach compared to AOMDV and CDMFD in terms of PDR. In other words, EEDS outperforms all other methods. It works better and more thoroughly than other methods we used for experiments, a great success result for its specialty in network emulations.

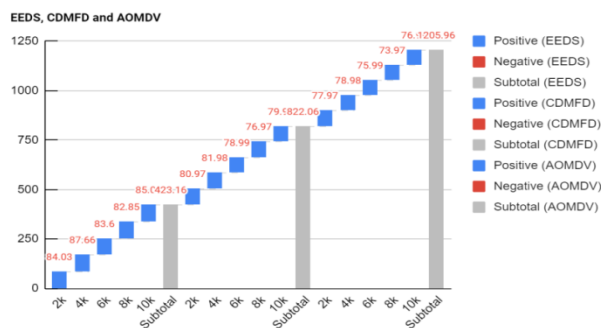


Figure 13: PDR- Static Topology

The Packet Delivery Ratio (PDR ) significantly optimizes the network performance compared to the data rates between k to kbps. From the result, we can see that EEDS has better PDR percentages in all experiments with data rate scenarios compared to CDMFD and AOMDV. Its packet delivery rates in the internal network range from 82.85% to 87.66%), showing high deliverability and reliability in the adjacent environment. Conversely, CDMFD and AOMDV algorithms have less PDR, between 73.97% to 81.98% & 75.99%-78.98 %, respectively. In summary, EEDS develops a low-power packet delivery solution for heterogeneous data rate environments that outperform competing solutions that absorb much more energy on a packet basis in a heterogeneous environment.

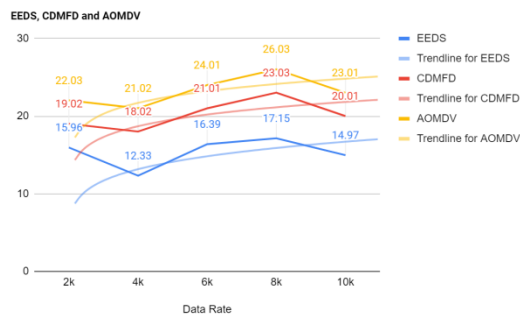


Figure 14 : PLR- Static Topology

This is a key parameter for network reliability working with network data rates in the range of 2k and to 10kb/s, i.e., timeslots. TABLE 4: PLR (%) comparison of EEDS, CDMFD, and AOMDV datasets of  $6 \pm$ EEDS of  $6 \pm$ CDMFD of  $6 \pm$ AOMDV methods, PLR percentage is always lower than in CDMFD and AOMDV at all data rate. ERR). As shown in EEDS, PLR values of 12.33% to 17.15 percent are very satisfying for the maintenance of data Sensitivity data over the flow of the network load distribution[10]. On the other hand, CDMFD and AOMDV show relatively higher average PLR percentages compared to our proposal: 18.02% –23.03 % for CDMFD and 21.02% –26. Our findings were exceptional in concluding that EEDS is best functioning under these fluctuating data rates to minimize packet loss. It is lovely for enhancing network reliability and performance [4], leading its competitors by high margins.

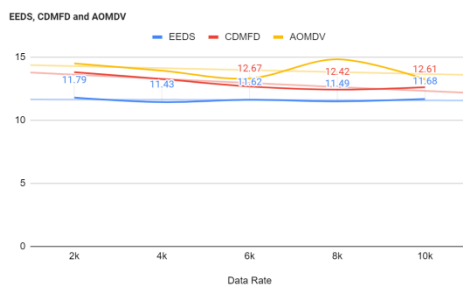


Figure 15: E2E Delay- Static Topology

End-to-End Delay: Fundamental of Efficiency in Network Obtained: it implies data rates here between 2k & 10k bps. Also, this aspect of EEDS includes a minimum transmission time other than CDMFD and AOMDV for any data rate. EEDS claims its End-to-End Delay times are 11.43 ms - 11.79 ms, which suggests that it can accelerate moving through data traversing the circuitous path within the network (opens new window). CDMFD and AOMDV have somewhat higher end-to-end delay-timings of 12.42 ms - 13.8 ms, while, on the other hand, delays of 13.. 24 ms - 14.. 82 ms, respectively. –2 These results further demonstrate EEDS' ability to reduce transmission latency and show that EEDS remains a potentially favored method to build more network-efficient and low-latency systems than the alternatives available today.

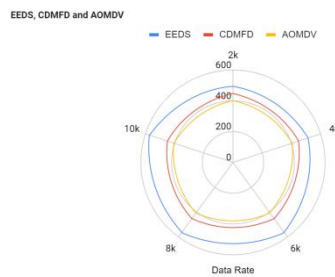


Figure 16: Throughput- Static Topology

Mechanism of network data rates: Google Earth Engine Data Security is better than its competitors and achieves a throughput of 41 measurements. The above table shows that EEDS showed more stable throughput at all data rates than CDMFD or AOMDV. In particular, EEDS proved that Throughput values were found to be in the range of 494.83 kbps to 574.03 kbps; this indicates this method offered the ability to observe and convey data, which is much quicker compared to CDMFD, with its Throughput record found to be within 445.56 kbps to 452.48 kbps. During this time, throughput was 401 kbps to 407.23 kbps<sup>34</sup>. Thus, the EEDS can provide better data transfer and flow, although the data rate could be escalated. Through this measurement unit, increased efficiency can be realized. One of the necessary measures is the better performance of EEDS compared to its rivals.

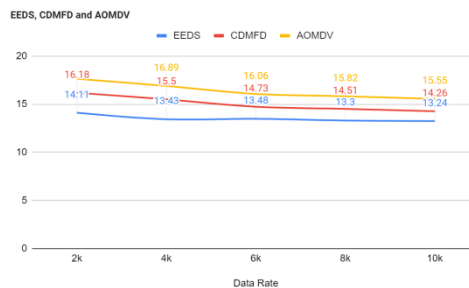


Figure 17 : Energy Consumption - Static Topology

Energy Consumption: A primary metric in the intricate web of network dynamics, it refers to how healthy power is consumed. Also, the energy consumption values of the EEDS method are consistently smaller than CDMFD and AOMDV in every data rate. Thus, the exhibited EEDS energy consumption varies around 13.24 joules. It reaches as high as around 14.11. Joule shows that it's good in saving power in the range of the network itself · Preen: Energy-saving label assignment mechanism for time-division long-term evolution — Sherien Sengupta et al. On the contrary, there is minimal high energy efficiency up to the range of 14.26–16.18 joules for CDMFD and AOMDV, whereas the average power between them is also near about 15.55-17.63 Joule. These observations delineate EEDS's sharp energy minimization performance despite data rate variation, thus making it an appropriate choice to improve the network lifetime and sustainability through the implementation literature in this essential perspective.

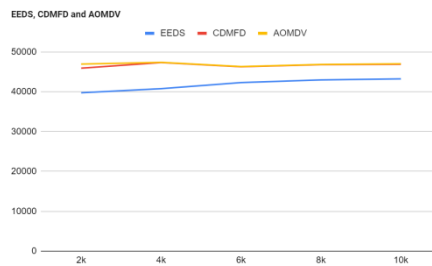


Figure 18: Routing overhead - Static Topology

Routing Overhead in an intricate network environment serves as a critical metric that responds to the operational mechanisms of routing protocols. Moving on to Note 9, we can observe that the Routing Overhead in EEDS is less than the CDMFD or AOMDV through all rate ranges. EEDS has less routing overhead, where 39,732 to 43,225 packets were shown in the route during communication loading, showing that it can handle network traffic better. On the contrary, CDMFD and AOMDV have a marginally higher routing load of approximately 45,910~46,900 packets and 46.314~47.006, respectively. These observations confirm that EEDS can achieve better routing efficiency when data rates change despite the lower throughput. This unique feature allows network scalability and overhead reduction to be implemented decisively and more efficiently than any other algorithm during this crucial parameter.

Analysis of Simulative Parameters for Dynamic Scenario

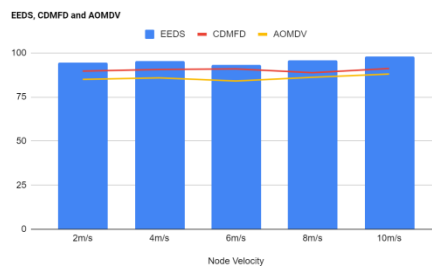


Figure 18: PDR - Dynamic Topology

Packet Delivery Ratio (PDR) is an important measure of network reliability, especially for dynamic subjects when the node's velocity varies from 2m/s to more than 10 m/m, as depicted below. Upon closer inspection, especially at high node velocity shown in the figure, the EEDS algorithm outperforms CDMFD, and AOMDV in terms of PDR percentage for every node velocity. EEDS archiving the PDR values of 93.38% to 97.8% shows that it performs better on sending packets while nthe ode continues to move (speed changes). Conversely, CDMFD and AOMDV have low PDR %, 88.77% to 91.16%. In the case of Poor Signal & High-Speed scenarios, the degree drops even more in between through a spectrum from  $\approx 84 \rightarrow > 88$  %. Our findings showcase the EEDS as a promising approach to ensuring reliable packet delivery in dynamic settings with diverse node mobility. It is a contender for bettering network reliability and performance because it is better than its rivals on this crucial point.

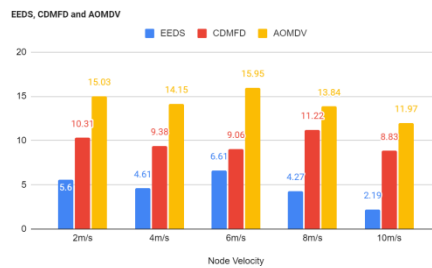


Figure 19: PLR - Dynamic Topology

As far as the reliability in the network, with its very smooth dynamic (between 2m/s and up to speed at a max velocity of something around ten m/s), a set of cascaded losses becomes critical... among them is the Packet Loss Ratio(PLR). By observing the plots, we can say that EEDS outperforms the percentage of PLR against CDMFD and AOMDV in all node velocities. EEDS reports PLR rates of 2.19% and 6.61%, indicating that it effectively decreases data loss through transmission for various node speed changes[rack14]. At the same time, CDMFD and AOMDV have a slightly high PLR (%), 8.06% to 11.22% and 11.97% of 15 O %. It illustrates that EEDS can efficiently enhance the capability of data transportation regardless of the velocity changes in the movement of the nodes and, thus, it also could be one of the solutions for optimizing the performance of the network and reducing the risk of data losses, which emphasize this method compared to others in the discussed critical area.

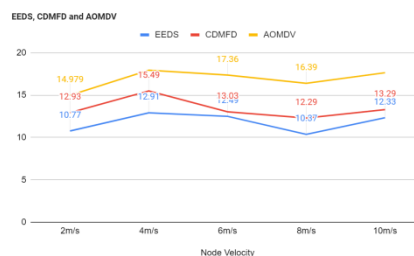


Figure 20: E2E Delay - Dynamic Topology

In the probabilistic node velocities between 2m/s to 10 m/s, end-to-end delay becomes an essential matrix; it measures how quickly data can be successfully transmitted across the network. The analysis found that the EEDS method has the lowest value of the end-to-end delay compared to CDMFD and AOMDV for all node velocities. EEDS End-to-End Delay Maximum End-to-End delay begins at 10.37ms, and its maximum value reaches up to 1298 EFFICIENTLY naively facilitates data transmission speed among different node rates in the network. In contrast, the end-end delay of CDMFD and AOMDV was a little high, with around 12.29ms–15 49ms & 14.979 ms–17—94 ms, respectively. The evaluation results portrayed do showcase how EEDS gets a better edge in terms of keeping lower delays upon it being highly visible between node velocities, which positions it as a choice to boost up the network efficiency while minimizing delay times as well, thus also highlighting itself among other competing processes for even lower latencies which one concern remains as a significant leading comparison dimension where it lags far behind.

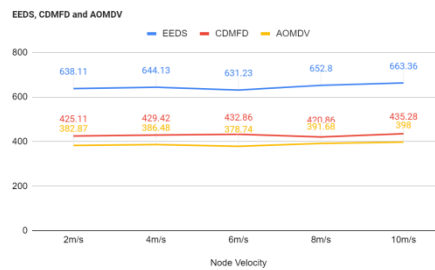


Figure 21: Throughput - Dynamic Topology

In the orchestra of max to min node velocities 2m/s to >10m/s (the collective node velocities, we seek a single measure of how this data can transmit over all node's Throughput. All node velocities of the EEDS method concerning CDMFD and AOMDV display better Throughput values. The throughput rates with EEDS were tagged from 631.23 kbps to 663.36, which means there is a high message delivery in heterogeneous node speeds (Figure 9). On the other hand, CDMFD and AOMDV are in the order of high Throughput, respectively, between 420.86 kbps and 435.28 kbps, and span from about 378.74 kbps up to about too much closestpeakrate=398kbps between the frames. The outputs found illustrate EEDS efficiency in constantly optimizing the data flow even when the velocity of a node is nonconstant, which was proved to be a key benefit to enhance the network in terms of amount and speed,” secured the best gain next to the others in this crucial aspect.

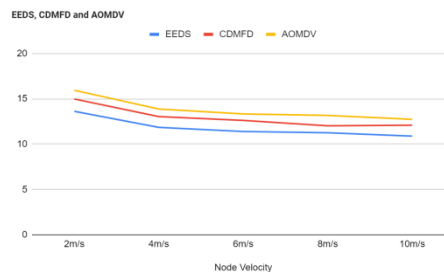


Figure 22: Energy Consumption - Dynamic Topology

Energy usage is a necessary metric for savings related to power consumption in the network [21]. Node velocities are anywhere between 2m/s and as high as they can push it, so energy efficiency is a considerable concern. The above analysis also analyzes how energy consumption varies for CDMFD and AOMDV against EEDS for different node velocities. Based on 10.89 Joules for the lowest range and 13.62 Joules for the highest range, EEDS shows corresponding power-saving potentials on varied node speed abilities, as shown with lower EDS measures relative to SD-GAFEC (bottom bar graphs). Conversely, CDMFD and AOMDV achieved slightly more energy consumption of 12.02 J to 14.98 J (CDMFD) and 12.74J to 15.94J (AOMDV), respectively. These arguments demonstrate EEDS's effectiveness in enduring altered communication conditions with rapidly changing nodes. Therefore, it is a suitable alternative to increase the longevity and sustainability of the network, which distinguishes it from other protocols on this critical issue.

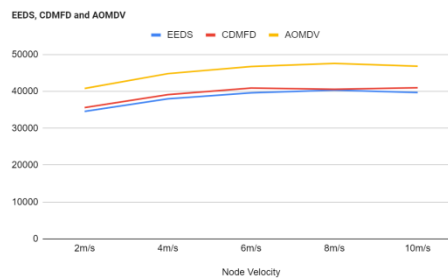


Figure 23: Routing Overhead - Dynamic Topology

Routing Overhead: This is one of the most crucial metrics used to provide information about the efficiency of the routing protocols in the network and indirectly indicates your ability to deliver your packets. In addition, we notice that the node speeds vary between 2m/s-10 m/s, and we conclude that the EEDS technique consistently demonstrates minimum routing overhead compared to the CDMFD and AOMDV algorithms for node velocities. The routing overhead numbers of EEDS from Section 5 are relatively low, and it is a good traffic distributor to spread the load over several nodes with different speed capabilities (routing overhead varies from 34,561 to 40,315 packets). When it comes to CDMSCSs, the routing overhead of the CDMFD and AOMDV is a bit, from 35,597 to 40,988package for the first one, while the corresponding value for the second one does fluctuate from 40.781 to 46.805package [30]. The combined results validate our EEDS to provide routing efficiency even with varied node velocities and make it possible to use such an algorithm to scale networks that can efficiently outperform other networks, at least in this critical dimension, with less overhead.

## 6. Conclusion

While not related directly to the dynamic part of network configurations, some exciting enhancements in different parameters come from CDMFD over EEDS. In the meantime, EEDS also improves PDR by 6.08% for a high success rate of data transmission, and it effectively reduces PLR by as much as 23.99%, indicating its effort to prevent packet loss in other ways. EEDS also decreases the end-to-end delay by 10.42%, makes data transfer faster, and increases throughput to better flow of information at a rate of up to 20.53%. Besides, EEDS reduces Energy Consumption by 10.41%, improves efficiency, and alleviates the Routing Overhead by up to a factor of 10.31%, enhances managing network works reliably at low data exchange rates for frequent user change thresholds in an IoT environment[]. In contrast, EEDS is the best-performing choice, with higher reliability and less wasted energy in static network scenarios.

This dataset presents a proof of concept as we transfer from CDMFD, capturing these differences more effectively than could be achieved by any static factor alone. EEDS presents a substantial 5.65%increasein Packet Delivery Ratio for ensuring data transmission with higher fidelity and also significantly reduces the packet loss rate (52.29%), inevitably leading to less data loss on transit/media streamlines [8]. Moreover, EEDS decreases end-to-end delay by 12.17%, making data transfer faster and increasing throughput to approximately 50.66% IO for each node every second so that information can pass rapidly between nodes. EEDS also results in 8.88% less Energy Consumption, making the entire network efficient and reducing Routing Overhead by 2.56%,

streamlining network operations. EEDS is a better choice, which, in turn, enhances scalability performance and universal efficiency, particularly for dynamic network environments.

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