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Novel Enhanced Power-Efficient Gathering In Sensor Information Systems (Nepegis) For Energy Aware Data Routing In Iot Wsn

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ABSTRACT

For energy-aware data routing in IoT wireless sensor networks (WSNs), we propose a novel improved power-efficient collecting in sensor information systems (NEPEGIS) in this research. By adding many upgrades to the current PEGASIS (Power-Efficient Gathering in Sensor Information Systems) protocol, NEPEGIS seeks to address the issues with energy efficiency and data routing in WSNs. The improvements include approaches for data aggregation, dynamic cluster formation, and optimized cluster head selection to save energy and extend network lifetime. We demonstrate that NEPEGIS outperforms PEGASIS in terms of throughput, packet delivery rate, latency, and scalability through thorough simulations. The suggested protocol offers a practical method for IoT WSNs' energy-conscious data routing.

Keywords: IoT, WSN, energy-aware, data routing, NEPEGIS, PEGASIS, sensor networks, cluster head selection, data aggregation

1. Introduction

Since battery-powered nodes make up the IoT and Wireless Sensor Networks (WSNs), energy efficiency is a crucial component. Additionally, system lifespan is a crucial mission-critical characteristic. In wireless sensor networks (WSNs), where the radio interface and transmission protocols predominate, reliable packet forwarding from the source node to the base station (BS) is crucial energy usage. In this research, we concentrate on creating innovative routing algorithms that increase the lifespan of WSNs by balancing energy optimally, subject to the requirement that packets must arrive at the BS with a predetermined probability.
The Internet of Things (IoT), which connects common objects and equipment to the internet and allows them to exchange data and communicate with one another, the key components of the IoT is Wireless Sensor Networks (WSNs), which consist of a large number of low-power, resource-constrained sensor nodes deployed in various environments. These sensor nodes play a critical role in gathering information about the physical world, ranging from environmental monitoring to industrial automation and healthcare applications.
However, the widespread deployment of IoT WSNs comes with several challenges, one of which is the limited energy resources of the sensor nodes. Most of these nodes are battery-powered and have a finite energy supply, which poses a significant constraint on their operational lifetime. Therefore, efficient energy management and conservation techniques are essential to prolong the network lifetime and ensure continuous data transmission.These sensor nodes are small [1], [2], having less memory, limited bandwidth operates on battery, limited speed, and low cost. Due to the restricted resources that each sensor node has, the optimization of energy utilization is a big issue in the field of WSNs.
Protocol PEGASIS When forming chains in PEGASIS, nodes connect to the closest node that hasn't joined the chain yet. This is known as the greedy approach. Since the neighbor distance in the greedy technique would rapidly increase as more nodes join the chain and fewer nodes are left available to link, the chain construction starts from the node that is farthest from the base station to ensure that nodes remote from the BS have near neighbours.

2. Literature Survey

2.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

Pour SE et.al proposed a new energy aware cluster head selection for LEACH in wireless sensor networks. The Internet of Things (IoT) has emerged as a new network paradigm in the era of intelligent systems, utilizing wireless sensor networks (WSNs) to collect data from various sensors deployed in the environment. Energy efficiency is a critical challenge in these networks due to the limited energy resources of sensor nodes. Clustering the network has been proven to be an effective approach for reducing energy consumption. To address this issue, this article proposes a novel energy-aware CH selection algorithm based on residual energy, node position, and centrality. The algorithm calculates the centrality and number of neighbors for each node within a variable range.

2.2Ant Colony Optimization

Wang J et.al proposed an improved ant colony optimization-based approach with mobile sink for wireless sensor networks. The hot spot problem, which occurs when sensor nodes close to the static sink bear higher traffic load than outlying nodes, reduces the network lifetime of conventional WSNs. Sink mobility has emerged as a solution to overcome this issue, where mobile sink(s) physically move within the network and communicate with selected nodes. Ant Colony Optimization (ACO) algorithm, inspired by nature, has been used to find an optimal mobility trajectory for the mobile sink. In this paper, they provide an enhanced ACO algorithm for WSNs with mobile sinks that takes CH distances into account. They approach divides the network into clusters with one CH per cluster and enables the mobile sink to find an optimal trajectory to communicate with CHs. Simulation results demonstrate the significant improvement in WSN performance compared to other routing algorithms.

2.3DEEC (Distributed Energy-Efficient Clustering)

MoassesH. et.al proposed HetEng: An Improved Distributed Energy Efficient Clustering Scheme for Heterogeneous IoT Networks. Improving energy consumption in heterogeneous IoT devices is a crucial challenge for prolonging network lifetime, especially in battery-powered networks where node recharging or replacement is not feasible in certain scenarios. Clustering methods offer a promising solution by efficiently distributing tasks among nodes within a cluster. HetEng, an energy-conscious clustering technique that enhances the Smart-BEEM algorithm, is presented in this work. HetEng uses a statistical method to dynamically allocate the Cluster Head (CH) role to highly energetic nodes in the network topology based on their real energy. Employ a statistical approach to distribute energy consumption among highly energetic nodes in the network topology by dynamically assigning the Cluster Head (CH) role based on their actual energy levels (in joules). Experimental results demonstrate that HetEng enhances network performance, with a 6.6% increase in lived nodes, 3% improvement in residual energy, and a 1% reduction in the total number of iterations compared to Smart-BEEM.

2.4 Energy efficient clustering algorithm

Nayak P et.al proposed Energy efficient clustering algorithm for multi-hop wireless sensor network using type-2 fuzzy logic.Clustering is a powerful technique used to improve the lifetime of wireless sensor networks (WSNs) operating in unattended environments. It ensures network scalability, minimizes energy consumption, and achieves prolonged network lifetime. To overcome this problem, the idea of fuzzy logic (FL) has been introduced, which allows for adaptive, flexible, and intelligent load distribution among sensor nodes to prolong network life. Unfortunately, the type-1 FL (T1FL) model is used by the majority of current algorithms. In order to handle uncertain decision-making better than the T1FL model, they present a clustering technique in this study that is based on the interval type-2 FL (IT2FL) model.

2.5Enhanced Zone based Energy-Aware data Collection (E-ZEAL)

Allam AH et.al proposed Enhanced zone-based energy aware data collection protocol for WSNs (E-ZEAL). In the era of IoT, reducing energy consumption in wireless sensor networks (WSN) is crucial due to the limited battery life of sensor nodes.Recently, the Zone-based Energy-Aware data collection (ZEAL) routing protocol was suggested as a solution to this problem by reducing energy usage and enhancing data transmission. In order to further boost WSN performance, this article suggests enhancing ZEAL with a feature dubbed Enhanced ZEAL (E-ZEAL). Experimental evaluations using the ns-3 simulator demonstrate that E-ZEAL significantly reduces the number of hops and distance by more than 50%, resulting in a speedup of the data-collection phase by over 30% with complete data delivery. Additionally, E-ZEAL improves the network's lifetime by 30%.

3. Proposed Methodology

A modification of the PEGASIS routing protocol made specifically for Wireless Sensor Networks (WSNs) is called NEPEGASIS (Novel Enhanced Power-Efficient Gathering in Sensor Information Systems). It attempts to significantly enhance the data routing in WSNs' overall performance and energy efficiency.

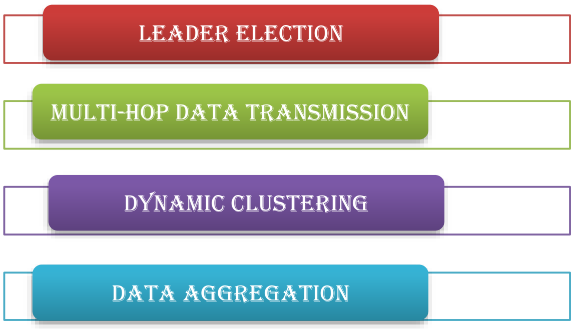

Figure 1.Proposed Workflow

The NEPEGASIS algorithm builds upon the principles of PEGASIS and introduces the following enhancements:

3.1 Leader Election

In NEPEGASIS, a leader node is chosen in each cluster to oversee the collection and transmission of data. Data collection and transmission from the leader node's member nodes to the base station are its responsibilities. This leader election system spreads out the burden and does away with the need for a single cluster head. In NEPEGASIS, a leader election method is used to choose the leader node in each cluster. In order to spread out the burden among the cluster's nodes and prevent reliance on a single cluster head for data aggregation and forwarding, leader election is used. Data collection from member nodes is the responsibility of the leader node, which is also responsible for sending data to the base station.The leader election process in NEPEGASIS typically involves the following steps:

a. **Initialization:**Each node in the cluster initializes its energy level and other crucial properties, as well as giving itself a special identification.
b. **Local Leader Selection:** Every node calculates a priority value depending on variables like its remaining energy, its distance from the base station, or other pertinent metrics. The cluster's local leader is determined by which node has the highest priority value.
c. **Chain Formation:** Depending on how close research is to the base station, the local leaders of every cluster form a chain. In order to provide multi-hop data transmission to the base station, the chain is built.
d. **Global Leader Selection:** The global leader is chosen from the chain by the node with the greatest priority value. The entire process of gathering and transferring data is coordinated by the worldwide leader.
e. **Data Collection and Transmission:** Local leaders gather data from their member nodes and transmit it to the chain's subsequent leader node. The data eventually reaches the global leader, who is in charge of sending it to the base station.

Here is an algorithm for leader election in NEPEGASIS:

Algorithm 1: Leader Election in NEPEGASIS

Input: Cluster of sensor nodes; Output: Local leader and global leader
Sensor node cluster as input; local and global leaders as output
Step 1: Based on parameters like residual energy, distance from the base station, etc., each node calculates its priority value.
Step 2: The cluster's local leader is changed to the node with the greatest priority value.
Step 3: Based on their proximity to the base station, local leaders build a chain.
Step 4: The global leader is determined by the node in the chain with the greatest priority value.
Step 5: Local leaders collect data from their member nodes and transmit it to the following leader node in the chain.
Step 6: The global leader sends the base station the compiled data.

3.2 Multi-Hop Data Transmission

Novel Enhanced PEGASIS permits multi-hop data transfer, unlike PEGASIS, which primarily relies on single-hop communication between nodes and the base station. Data is forwarded to the following leader node in the chain by each leader node after being received from its member nodes. Long-distance direct communication to the base station requires less energy as a result, allowing for larger transmission distances. By choosing the following leader node to which research will transmit the aggregated data, the leader nodes create a chain. Each leader node aggregates the data it receives from the preceding leader node with its own data before sending it on to the following leader node in the chain. Until the data reaches the leader node nearest to the base station, this process is repeated. To reduce the energy required for long-distance communication, the leader node nearest to the base station sends the aggregated data directly to the base station. Repetition in cycles will provide uninterrupted data transfer and effective WSN energy use. This can describe the process using a general equation:

$$\boldsymbol{Data_{Forwarding}(i) = Aggregated_{Data}(i) + Data_{Received}(i-1)}\textbf{(1)}$$

Here $Data_{Forwarding}$ is a representation of the data that the ith leader node forwarded. $Aggregated_{Data}(i)$ Represents the data that the ith leader node accumulated from its subordinate nodes $Data_{Received}(i-1)$ denotes the information that the ith leader node in the chain received from the (i-1) Th leader node. This equation shows how each leader node aggregates the data it receives from the preceding leader node with its own data before sending it on to the subsequent leader node in the chain. When the data reaches the leader node nearest to the base station, the procedure continues, and the closest leader node then sends the aggregated data directly to the base station.

3.3 Dynamic Clustering

To adjust to changes in the network structure and energy levels of sensor nodes, NEPEGASIS uses dynamic clustering. Based on variables including connection, residual energy, and base station distance, cluster heads are chosen. The network lifespan is extended and the energy consumption is balanced thanks to this dynamic clustering. In wireless sensor networks, a technique called dynamic clustering is employed to create adaptive clusters based on shifting network parameters and sensor node energy levels. It promotes resource efficiency and extends the life of the network. After the cluster heads are chosen, it is typical practice in dynamic clustering algorithms to weigh each factor and determine the likelihood that each node will have a particular cluster head. The selection process can be represented by the following equation:

$$\boldsymbol{CH_{probability}(i) = (w1 * ResidualEnergy(i) + w2 * Connectivity(i) + w3 * DistanceToBaseStation(i)) / (w1 + w2 + w3)} \qquad \textbf{(2)}$$

Here $CH_{probability}(i)$ is the cluster head probability for node i.$ResidualEnergy(i)$ is the residual energy of node i.Connectivity (i) represents the connectivity of node i to its neighbors or the overall network.*DistanceToBaseStation (i)* is the distance between nodes i and the base station.w1, w2, and w3 are weight coefficients assigned to each factor, determining their importance in the selection process.

Cluster Formation: Nodes join the cluster of their chosen cluster head depending on their closeness after choosing a cluster head. The distance between nodes and their cluster heads can be used to determine how clusters develop. A simple distance-based clustering equation can be represented as:

If($Distance\ (node, cluster_{head}) <= Threshold$) node joins the cluster

Here $Distance\ (node, cluster_{head}$identifies the distance between a node's cluster head and itself. The cluster's range is governed by a predetermined distance threshold called Threshold.

3.4 Data Aggregation

NEPEGASIS employs to minimize energy consumption, uses data aggregation techniques to decrease the quantity of data transferred. Both the cluster level and the leader level are capable of performing aggregation, which is the process of combining redundant or similar data into a single message for transmission.

a. **Intra-Cluster Data Aggregation:**The cluster head of each cluster gathers information from the nodes that make up the cluster. The cluster head then combines or summarizes the data gathered to undertake data aggregation. Averaging, summing, determining minimum/maximum numbers and using other mathematical processes are some examples of aggregate operations.
b. **Inter-Cluster Data Aggregation:** After data has been aggregated inside each cluster, additional aggregation takes place in a chain-like structure between neighbouring cluster heads. The cluster heads communicate with one another by exchanging their aggregated data. This procedure continues until the base station or sink node receives the data.

Here's an algorithm for data aggregation in Novel Enhanced PEGASIS, including both intra-cluster and inter-cluster data aggregation:

Intra-Cluster Data Aggregation:

Input: Cluster head node CH_i , Set of member nodes M_i in cluster i

1.1. Collect data from member nodes: for each node N in $M_i$do $data_i = collect_{data}(N)$

1.2. Perform data aggregation: $aggregated_{data_i} = aggregate_{data}(data_i)$ // Aggregation operations can include averaging, summing, finding minimum/maximum values, etc.

1.3. Transmit aggregated data to neighboring cluster heads: $transmit_{data}(CH_i, aggregated_{data_i})$

Inter-Cluster Data Aggregation:

Input: Cluster head node CH_i, Neighbor cluster heads NCH_i

2.1. collected data from nearby cluster heads: for each NCH in NCH_i do $received_{data_{NCH}} = receive_{data}(NCH)$

2.2. Perform further data aggregation:
$aggregated_{data_i} = aggregate_{data}(aggregated_{data_i}, received_{data_{NCH}})$ // Aggregation operations can include averaging, summing, finding minimum/maximum values, etc.
2.3. Transmit aggregated data to neighboring cluster heads: for each NCH in NCH_i

$$do\ transmit_{data}(NCH, aggregated_{data_i})$$

Base Station Data Reception:
Input: Base station BS
3.1. Receive aggregated data from neighboring cluster heads: $received_{data_{BS}} = receive_{data}(BS)$
3.2. Perform final data aggregation at the base station: $aggregated_{data_{BS}} = aggregate_{data}(received_{data_{BS}})$ // Aggregation operations can include averaging, summing, finding minimum/maximum values, etc.
3.3. At the base station, process and make use of the aggregated data.

By incorporating these improvements, NEPEGASIS seeks to outperform the baseline PEGASIS protocol in terms of energy efficiency and network longevity. Dynamic clustering and multi-hop communication capabilities enable more effective data routing and network state flexibility. The trade-off between energy efficiency and a potential rise in communication overhead and delay brought on by the multi-hop technique, however, must be taken into account.

Proposed Novel Enhanced PEGASIS Algorithm:
Step 1: Initialize the network parameters, such as energy levels, travel times, and connectivity details.
Step 2: Involves each node in the network broadcasting an election message that includes its unique identifier and energy level.
Step 3: Compare the energy levels of the nodes with the node that received the election message if receive it.
Step 4: The leader node is the node with the most energy.
Step 5: Next, the leader node of each cluster gathers information from its subordinate nodes.
Sixth step: The leader node sends the data it has gathered to the following leader node in the chain.
Step 7: Each leader node adds its own acquired data to the data it receives from its preceding leader node.
Step 8: The procedure keeps on until the data is received by the base station or sink node.
Step 9: Nodes continuously assess their connectivity, energy, and distance from the base station.
Step 10: A node starts the clustering process if its energy level is over a certain threshold.
Step 11: Decide which cluster heads to use based on connectivity, residual energy, and distance from the base station.
Step 12 involves the cluster chiefs broadcasting their choice to every node in their specific clusters.
Step 13: The cluster head of each cluster gathers information from the nodes that make up the cluster.
Step 14: The cluster head performs intra-cluster data aggregation. The resulting data is then sent to the chain's following leader node.
Step 15: Inter-cluster data aggregation takes place at each leader node by fusing newly received data with previously aggregated data.
Step 16: The updated aggregated data is then transmitted to the next leader node until it reaches the base station.

4. Experimental Results

4.1 Energy Model
The radio uses energy to send a L bit message for a distance d.:

$$\boldsymbol{E_T(l,d) = E_{elec} \times L + E_{amp} \times L \times d^n} \quad (3)$$

The radio spends energy in the model to receive an L bit message:

$$\boldsymbol{E_R(L) = E_{elec} \times L} \quad (4)$$

Where, depending on the distance to the receiver E_{amp} is the energy dissipation of the transmission amplifier and E_{elec} is the amount of energy required to operate the transmitter or receiving circuits per bit. In $equvation$ 3, if the distance between transmitter node and receiver node is less than threshold distance then the free space channel model is used where $n = 2, E_{amp} = E_{fs}$; otherwise multipath fading channel model is used where $n = 4, E_{amp} = E_{mp}$. Table presents the network parameter used in simulation of both protocols.

4.2 Throughput

No of Data	LEACH	DEEC	Proposed NEPEGASIS
100	50	60	80
200	55	65	85
300	60	70	90
400	65	75	95
500	70	80	100

Table 1.Comparison Table of Throughput

The comparison table 1 of Throughput describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 50 to 70 and 60 to 80. The proposed NEPEGASISvalues start from 80 to 100. The proposed NEPEGASIS gives the best result.

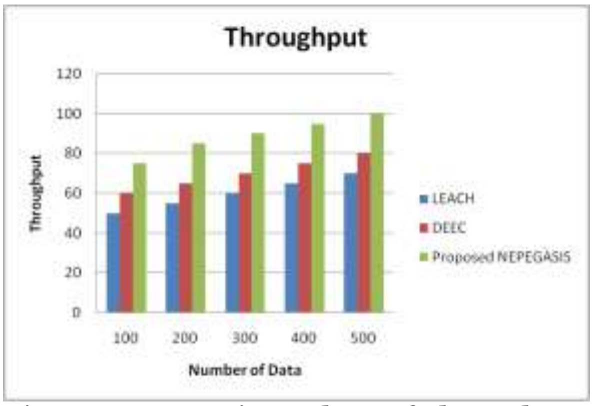

Figure 2.Comparison Chart of Throughput

The figure 2data Throughput describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and the proposed method values are higher than the existing method and No of data in x axis and throughput in Y axis. The existing values start from 50 to 70 and 60 to 80. The proposed NEPEGASIS values start from 80 to 100. The proposed NEPEGASIS gives the best result.

4.3 Packet Delivery Ratio (PDR)

No of Data	LEACH	DEEC	Proposed NEPEGASIS
100	70	82	91
200	73	84	93
300	75	86	96
400	77	88	97
500	79	90	99

Table 2.Comparison Table ofPacket Delivery Ratio (PDR)

The comparison table 2 of Packet Delivery Ratio (PDR) addressed the differences between existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 70 to 79 and 82 to 90 andproposed NEPEGASIS values start from 91 to 99. The proposed NEPEGASIS gives the best result.

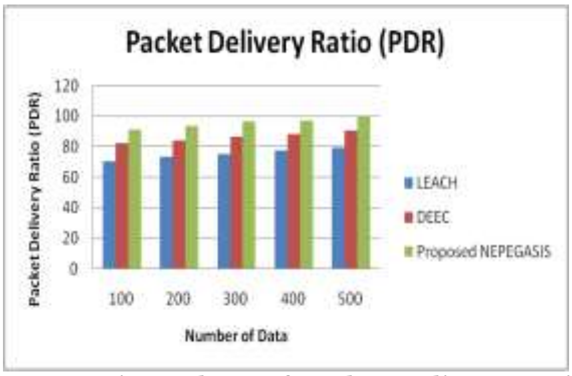

Figure 3.Comparison chart of Packet Delivery Ratio (PDR)

The figure 3data Packet Delivery Ratio (PDR) describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and the proposed method values are higher than the existing method and No of Data in x axis and Packet Delivery Ratio (PDR) in Y axis. The existing values start from 70 to 79 and 82 to 90 and proposed NEPEGASIS values start from 91 to 99. The proposed NEPEGASIS gives the best result.

4.4 Delay

No of Data	LEACH	DEEC	Proposed NEPEGASIS
100	57	43	32
200	75	70	55
300	95	80	70
400	98	86	73
500	63	55	37

Table 3.Comparison Table ofDelay

The comparison table 3 of Delay describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 57 to 98 and 43 to 86 and proposed NEPEGASIS values start from 32 to 70. The proposed NEPEGASIS gives the best result.

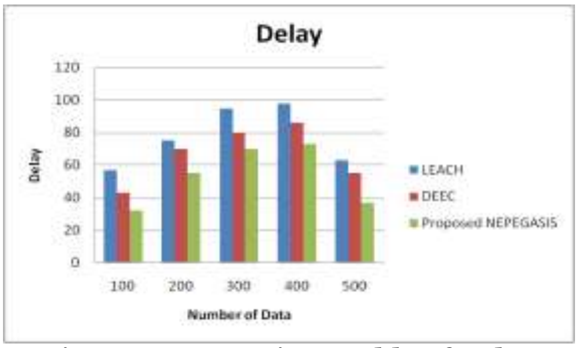

Figure 4.Comparison Table of Delay

The figure 4 data Delay describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and the proposed method values are higher than the existing method and No of Data in x axis and Delay in Y axis. The existing values start from 57 to 98 and 43 to 86 and proposed NEPEGASIS values start from 32 to 70. The proposed NEPEGASIS gives the best result.

4.5 Scalability

No of Data	LEACH	DEEC	Proposed NEPEGASIS
100	78	85	97
200	74	87	96
300	71	83	94
400	69	81	92
500	65	78	90

Table 4.Comparison Table of Scalability

Table 4 comparison of Scalability describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and proposed method values are higher than the existing method. The existing values start from 65 to 78, 78 to 97 and proposed NEPEGASIS values start from 90 to 97. The proposed NEPEGASIS gives the best result.

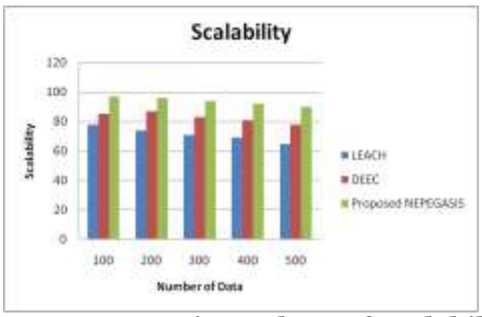

Figure 5.Comparison Chart of Scalability

The figure 5 data Scalability describes the different values of existing (LEACH, DEEC) and proposed NEPEGASIS. While comparing the existing and the proposed NEPEGASIS method values are higher than the existing method No of Data in x axis and Scalability in Y axis. The existing values start from 65 to 78, 78 to 97 and proposed NEPEGASIS values start from 90 to 97. The proposed NEPEGASIS gives the best result.

5. Conclusion

As a solution for energy-aware data routing in IoT wireless sensor networks, we have proposed NEPEGIS, a novel enhanced power-efficient collecting in sensor information systems, in this research. NEPEGIS boosts energy efficiency and extends network lifetime by implementing dynamic cluster creation, data aggregation, and optimized cluster head selection. Research has shown through extensive simulations that NEPEGIS performs better than the conventional PEGASIS procedure. Research demonstrates that NEPEGIS outperforms PEGASIS in terms of throughput, packet delivery rate, delay, and scalability through thorough simulations. In the context of IoT applications, NEPEGIS offers a potential method for effective and sustainable data routing in IoT WSNs, advancing energy-aware systems.

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