# A LOW-ENERGY DATA AGGREGATION PROTOCOL USING AN EMERGENCY EFFICIENT HYBRID MEDIUM ACCESS CONTROL PROTOCOL IN HIERARCHAL WIRELESS SENSOR NETWORKS

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## ABSTRACT

*Recent wireless sensor network focused on developing communication networks with minimal power and cost. To achieve this, several techniques have been developed to monitor a completely wireless sensor network. Generally, in the WSN network, communication is established between the source nodes and the destination node with an abundant number of hops, an activity which consumes much energy. The node existing between source and destination nodes consumes energy for transmission of data and maximize network lifetime. To overcome this issue, a new Emergency Efficient Hybrid Medium Access Control (EEHMAC) protocol is presented to reduce consumption of energy among a specific group of WSNs which will increase the network lifetime. The proposed model makes a residual battery is utilized for effective transmission of data with minimal power consumption. Compared with other models, the experimental results strongly showed that our model is not only able to reduce network lifetime but also to increase the overall network performance.*

## KEYWORDS

*Wireless sensor networks, data aggregation, EEHMAC protocol and clustering in WSN*

## 1. INTRODUCTION

WSNs have gained huge attention in recent years from both the research community and industrials. They are regarded as a low-cost data aggregation method that can greatly improve the reliability and efficiency of infrastructure systems [1]. The lifetime of WSN is the key characteristics for sensor network evaluation. It is necessary to reduce energy consumption at each sensor node to improve the lifetime of the wireless sensor network. It can be made by eliminating redundancy from the wireless sensor network.

In recent years, many organizations have broadly studied WSNs, where several applications in military monitoring can be found. With the latest climate change scenarios, WSNs can be used to control climate changes by using sensor networks to collect environmental variables such as temperature, humidity, and pressure. One of the various benefits of these sensors is their ability to work unattended, which that is ideal for inaccessible areas [1].

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However, WSNs are designed to monitor and control most of these functions, in network-processing such as data aggregation, computing, and transmission operations it can involve these sensors to improve their energy utilization to maximize the lifetime of the network.

Sensor nodes are sensitive to energy failure and breakdown, and their battery source may be irreplaceable instead of deploying new sensors. Therefore, the continuous Re-energizing of wireless sensor networks as old sensor nodes fall and/or the Sensing region's irregular terrain can result in energy imbalances or variance among the sensor nodes. This can adversely affect the network system's Sustainability and efficiency if the additional energy is not used and leveraged correctly. Several clustering systems and algorithms such as EEHMAC [2] were suggested with different goals such as load balancing, fault tolerance, maximizing network lifetime, enhanced connectivity with decrease delay and longevity of the network.

The rest of this paper is structured as follows: In Section 2, we have presented some related researches about the performance evaluation of data aggregation protocols. In Section 3, we have mentioned the motivations and contributions of the research. In Section 4, we have described the preliminaries used in this research. A novel improvement is proposed in Section 5. In Section 6 we have analyzed the security of our protocol. Finally, we have given conclusions and future work in Section 7.

## 2. RELATED WORKS

Several data aggregation protocols have been developed for data transmission to avoid great amounts of traffic in the network. These data-aggregation protocols are widely classified into structure-based [3], [4], [5], [6] and structure-free [7], [8] data aggregation.

In paper [3], [4], [5], [6], the authors used a structured data aggregation which several structures sensor nodes are created to collect the data, aggregate the collected-data and transmit the aggregated-data to the (BS) base station. Data aggregation structures are chain-based, tree-based, cluster-based [7], tree-cluster-based or hierarchical-cluster-based [8]. The intermediate nodes are designated as leader node [9], root [10] and cluster heads [11], [12] in the chain, tree, and cluster respectively.

These intermediate nodes gather and aggregate the data from all the sensor nodes. The structure-based data-aggregation involves small overhead maintenance for static and fixed traffic level. However, in the case of event-based applications, the data aggregation benefits might exceed the overhead and maintenance of the construction [13]. In a distributed event, the absence of an exact center or any clear point for the best aggregation makes structured data aggregation approaches inapplicable. The structured technique which calculates the aggregation-tree [14] involves extreme communication overhead so it is not practical in dynamic cases. Besides, the structured data-aggregation performance relies on the waiting time interval of information for the intermediate nodes after receiving the data from all down-stream nodes. A short waiting duration may result in bad aggregation and a long duration may result in high latency and delay. Thus, it is very important to calculate the ideal waiting duration from the relative location for the node based on the sub-tree for dynamic situations.

In paper [15], [16], the authors used structure-free data-aggregation techniques.Multiple source nodes with the same information select the same down-stream node so that the redundant information could be aggregated at this node and the energy wasted building a structure could be saved.

However, the energy consumed at the aggregation point due to the transmitted-data by all the sensor nodes and data-aggregation couldn't be avoided. Therefore, the main problem of structure-free data-aggregation is the decisions of routing for effective packets aggregation and the pre-constructed structure is unavailable. For delay performance, data-aggregation, the waiting time intervals of the packets is necessary to be calculated manually on the intermediate nodes. In structure-free-data-aggregation, numbers of down-stream nodes for obtaining packets of data is not specified. Thus, there is also a need for effective buffer management and scheduling scheme to avoid overcrowding in the network and to increase throughput.

In this research, the main processes are cluster formation, cluster-head selection, gateway creation, and collector construction. The mobile sink works as a gateway which helps the cluster to transmit the data to the base station without more delay and loss. Swapping is used here to reduce the energy consumption in the network. Finally, two systems are proposed: EEHMAC (Emergency Efficient Hybrid Medium Access Control) which is energy-efficient, and low delay and latency MAC protocol, which has used interruptive process in order to specify preference for a certain mobile node which expected to be set in a critical loop of the control domain. Time-critical and mission-critical applications demand not only energy efficiency but also strict timeliness and reliability. The proposed EEHM-Hybrid MAC protocol is simulated in NS2 environment. The study at hand shows how the proposed protocol provides better performance compared to the conventional MAC protocols.

# 3. Motivations and Contributions

## 3.1 Motivations

In WSNS (wireless sensor networks), if one sensor's battery is consumed, the sensor is considered to be dead. Not all sensor nodes in the network die at the same time. But, if the first sensor is dead, the network will be unbalanced. So, if the dead sensor(s) cannot send the data, most of these data will be lost. Sensor nodes are batteries-powered it is hard to change or energize the batteries of the sensor nodes. The wireless sensor relies onits battery to keep running along its life time. In this way, the life time relies on the energy consumption. This is identified with many factors such as the distance between the transmitter and receiver (between the cluster head and the base station).

In our solution, to save energy, we set the spare nodes in the asleep state. They are prepared to be switched on when any initial node (i.e., a node which is not a spare) consumes its energy. (We assume only node failures because of battery discharge). It is difficult to replace fatigued sensors nodes with spare sensors nodes to improve the network lifetime; coefficient network management is needed. This is our purpose. The operational lifetime of a WSN relies on its energy resources. Enhancement of WSN lifetime can be obtained by adding spare nodes to the network. When a primary node exhausted its energy, Spare nodes are ready to be switched on. A spare node which replaces a primary node becomes a primary itself.

The aim of our protocol EEHMAC is maximizing the network lifetime, reducing energy consumption and optimizing the performance of the network.

### 3.2 Contributions

The contributions of this paper are cluster formation, cluster-head selection, gateway creation, and collector construction. The mobile sink works as a gateway which helps the cluster totransmit the data to the base station without more delay and loss. Swapping is used here to reduce the energy consumption in the network. Finally, two systems are proposed: EEHMAC (Emergency Efficient Hybrid Medium Access Control) which is an energy-efficient and low delay and latency MAC protocol that has used the interruptive process to specify a preference for certain mobile nodes which expected to be set in a critical loop of the control domain. Time-critical and mission-critical applications demand not only energy efficiency but also strict timeliness and reliability. The proposed EEHM-Hybrid MAC protocol is simulated in NS2 environment. The study at hand shows how the proposed protocol provides better performance compared to the conventional MAC protocols. Our proposed scheme enjoys the following properties:

- Establish a topology discovery.
- Establish nodes' schedules (TDMA slot assignment).
- Manage local time synchronization to minimize clock drifts.
- Manage two queues with a priority for the various priority packets.
- Respond to emergency events by changing MAC behavior (MAC prioritization) with a large volume of traffic.
- Manage the network when the topology changes.

## 4. PRELIMINARIES

### 4.1 Network lifetime

This research introduces some definitions of WSN lifetime. We accept the first definition (Kułakowski et al., 2013): [15] which states that WSN lifetime is "the period of time, beginning with the primary transmission within the wireless network throughout the setup stage and ending while the proportion of reports from sensor devices fall below a particular threshold, which is set based on the type of the application [16], [17].

### 4.2 Network formation

Here the node deployment is transferred by the network formation, division of the region, calculation of the number of nodes, coverage zone computation, and the calculations for regions probability [18]. The process of a route request, route reply, neighbor node selection, and intermediate hop counts are calculated. The neighbor node selection is done by the top-disc algorithm.

### 4.3 Clustering of WSN Network

The cluster is defined by a group of nodes formation in the network. And the cluster head is defined as the head among the cluster children. The sensor network is separated into clusters with each cluster being represented by one node, known as the cluster head. All the sensors nodes in the cluster can be reached by the (CH) cluster head directly because they're all within their scope of communication.

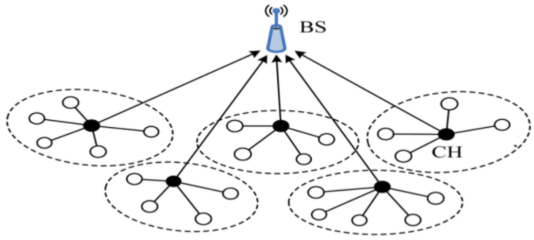


Figure1: Shows clustering in WSN, where the black node indicates the cluster head and the white node indicates the sensor nodes.

### 4.4 Data Aggregation in WSN

"The cluster-head (CH) nodes execute the process of data-aggregation that means: gathering the data from all the ordinary nodes". After collecting all the data, they send them to the base station or the neighboring cluster head with the help of the gateways.

## 5. Proposed EEHMAC Model

The essential mechanism associated with this EEHM-MAC protocol includes some steps:

**Step 1-**The network nodes start with determining the first neighbor from its location. This is possible by sending ping memory is traded among all the nodes, thus enabling the nodes to have two-hop neighbours list message now and again. The ping message is done every 30 seconds in this simulation. What's more?

**Step 2-** The nodes then start sensing their respective parameters and transfer data to the sink using CSMA mechanism. This is continued as long as there is no increase in traffic load or an emergency packet is trying to transmit.

**Step 3-** When the node in the high priority region is transferred, that particular node id is available. By using this information, the nodes in the neighbourhood stopped their information's and changed-over to TDMA, it gives the first slot to the node which is in high priority-region.

**Step 4-** If there are two nodes located in the same "high priority-region", so the slots are allocated on the nodes, one after the other. By following of the transformation, the wireless network changes to CSMA.

**Step 5-**The information of the node id is available in the packets then this information is passed through the other packets that enable them to transmit data from a node to another one faster
If a node produces packets of data, it records the "context information" such as time sensing, node ID, and the grade of the context of the packet-header. In the other end upon the reception of a data packet, extract the context information marked by the sender when the packet was made. The node receiving a packet identifies the latter's context and checks the buffer condition in terms of the number of packets received. When the data received are from a high priority node, the node rules the current transmission time. It transmits the data to the sink node in the shortest path.
In general, most hybrid protocols combine the TDMA and CSMA feature, as is the case in Z MAC, having the ability to switch over based on traffic. This is the first feature used by the paper at hand. The other feature utilized is the increased buffer memory which is an added advantage

that enables the network nodes to save energy, i.e. the buffer level of the memory in each node increases as the nodes to the sink. The figure shown below explains the different industry-used regions where some nodes are found to be within the high priority region while the others are in the ordinary or normal region.

## 5.1 Mathematical model for clustering in the simulation

These mathematical equations are used to perform clustering in the simulation area, and the cluster head is chosen effectively in line with the network formation. The average power of E(r) as a mirrored image of the lagging energy and node energy, besides considering node coverage rate, will be as follows:

$$p_i = p_{opt}\left[\frac{E_{res}(i)}{E(r)}\right]\left(1-\frac{1}{\eta(m)}\right). \quad (1)$$

- Pi: probability of nodes.
- E(r): the average power.
- $E_{res}(i)$: The residual energy.
- $p_{adv}$: Possibility for advanced nodes.
- $p_{nor}$: Possibility for normal nodes.
- 

$$p_{adv} = \frac{p_{opt}}{1+(\rho-1)\gamma}. \quad (2)$$

$$p_{nor} = \frac{p_{opt}\rho}{1+(\rho-1)\gamma}. \quad (3)$$

- If the network is heterogeneous, nodes should be allocated different initial energies and use different reference variables. Inside the two-level heterogeneous networks, the weighted probability is chosen as the node reference value:

$$p_i = \begin{cases} \frac{p_{opt}}{1+(\rho-1)\gamma}\left[\frac{E_{res}(i)}{E(r)}\right]\left(1-\frac{1}{\eta(m)}\right) . \text{advanced } mode \\ \frac{p_{opt}\rho}{1+(\rho-1)\gamma}\left[\frac{E_{res}(i)}{E(r)}\right]\left(1-\frac{1}{\eta(m)}\right) . normalmode \end{cases} \quad (4)$$

- In case of a multi-level heterogeneous network, and through the use of the measured probability of Equation

$$p_i = \frac{p_{opt}N(1+\rho_i)}{[N+\sum_{i=1}^{N}\rho_i]}\left[\frac{E_{res}(i)}{E(r)}\right]\left(1-\frac{1}{\eta(m)}\right) . \quad (5)$$

- The residual energy balance for the cover-relevant nodes (s) and (V), if the initial energies are (Eu) and (Ev), then the identical residual energies are Eres (u) and Eres (v) are as follows:

$$T_{off}(u) = \frac{\mu(1-|E_u-E_{res}(u)|)}{(E_{res}(u))t_u} . \quad (6)$$

$$T_{off}(\nu) = \frac{\mu(1 - |E_\nu - E_{res}(\nu)|)}{(E_{res}(\nu))t_\nu}. \quad (7)$$

- $t_i$ Is the current time of node I, i = s, v, and _x0016_ is the adapt parameters of the system.
- If$T_{off}(\nu) \neq T_{off}(u)$, the timer is considered as a node sleep.
- If $T_{off}(\nu) = T_{off}(u)$, the node ID is as priority inaction technique.

The general EEHMAC simulation steps will be as shown in flow-chart

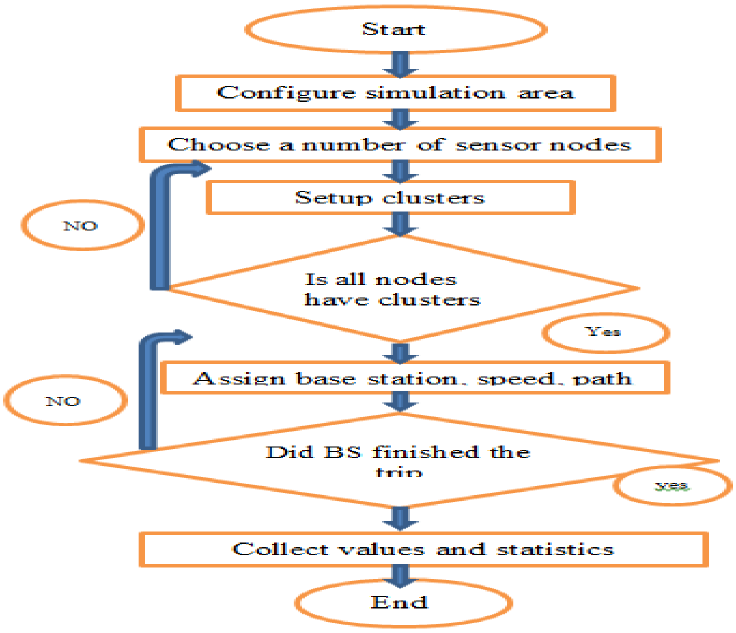


Figure 2: EEHMAC Flow-chart simulation

## 6. Simulation Results And Analysis

In this section, we make the performance evaluation of our proposed protocol through NS-2.30 simulation. The goal of the simulation is to compare the performance of our protocol (EEHMAC) with the other structure-free data-aggregation protocols such as:(RAG, SFEB, LEATCH, and PEGIS)deployed in an area of 50*50 m2. The transmission range of a sensor node operates in a multi-hop network.

The simulation parameters for EEHMAC protocol are summarized in Table 1

**Table 1**

| Parameter | Value |
|---|---|
| Number of sensor nodes | 400 nodes |
| Simulation area | 50*50 m2 |
| Transmission range of a sensor node | 50 m |
| Data rate | 200 Kbps |
| Sensing range of a sensor node | 50 m |
| Packet length | 60 byte |
| Initial energy of each sensornode | 0.6 Joules |
| Energy consumption for TX and RX | 50 nj/bit |
| Energy spent in sensing aggregation | 0.083 J/s<br>5 nJ/bit /signal<br>10 pJ/bit/m2 |
| Buffer length of each node | 65 packets |
| Number of simulation repeat | 25 times |

### 6.1 Average Delay of the Network

Figure 3 describes the comparison between our protocol and the existing protocols concerning average delay. From figure 3 we can conclude that the red line indicates LEACH protocol, the green line indicates R-HEED protocol, the blue line indicates PEGIS protocol and the purple line indicates our proposed EEHMAC protocol. We can show that our protocol achieves the least delay compared with the other protocols.

### 6.2 Energy Efficiency of the Network

Energy is the amount of energy left in the node after every few instances. The initial energy of each node is 100 joules, after that there is energy reduction seen as time passes. The energy is wasted because of transmission, discovering the route, checking of priority, and reception and found that this protocol is efficient because it reduces the energy consumption. Each node has an initial energy 100 joules and after then, the energy will reduce as the time passes, we note that our protocol gives high efficiency. Figure 4 describes a Comparison between our protocol and the existing protocols with respect to energy efficiency, each node has an initial energy 100 joules and after that, the energy will reduce as the time passes, the curve indicates that our protocol gives high energy efficiency**.**

### 6.3 Loss of the Network

The Effective wireless network needs to have minimal PLR ratio (power loss ratio) of minimal range. PLR is measured through the number of packets received to the number of packets transmitted over the network.  Figure 5 describes comparison between our protocol and the existing protocols w.r.t loss in the network, PLR of the proposed approach is drastically minimum than the other existing approaches in the network. The performance plot of the PLR stated that as time increases, the PLR rate also increases. I.e. PLR increases with the increase in packets number in the IEEE 802.11 network. Maximum PLR is observed for the proposed EEHM approach is 0.15. In the case of other approaches, maximum PLR values for PEGIS and so on are 0.97, 0.85, 0.57 and 0.23 respectively.

### 6.4 Packet Delivery Ratio of the Network

The effective wireless network needs to have significant PDR (packet delivery ratio) value for effective performance in the network. Figure 6 describes comparison between our protocol and the existing protocols w.r.tpacket delivery ratio (PDR), PDR for proposed EEHM is maximal than other techniques in WSN network. Maximum PDR value for the proposed approach is 0.98. Here EARC algorithm provides almost similar characteristics as of EEHM whose PDR value is 0.98. whereas the other existing techniques values are 0.4, 0.47 and 0.58 respectively.

### 6.5 Routing Overhead of the Network

In Figure 7, the curve demonstrates the performance comparison plot for the routing overhead in the WSN for the proposed approach. Through the simulation graph, it is observed that proposed EEHM provide effective routing overhead than other existing algorithms. It is also identified that the EEHM algorithm also provides almost similar characteristics as of EEHM algorithm. Other approaches values are significantly higher than the proposed approach. As time increases, routing overhead also increases in the ECRK - IH and for time 90 the value is obtained as 28 which is significantly minimal than other approaches.

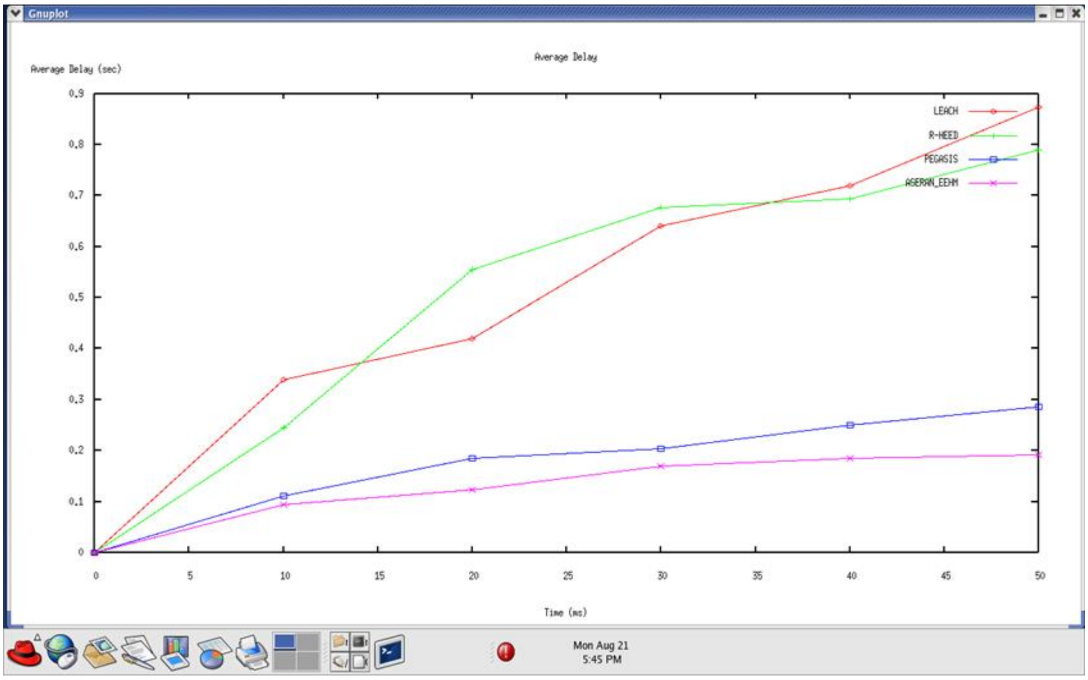


Figure 3: Comparison of average delay

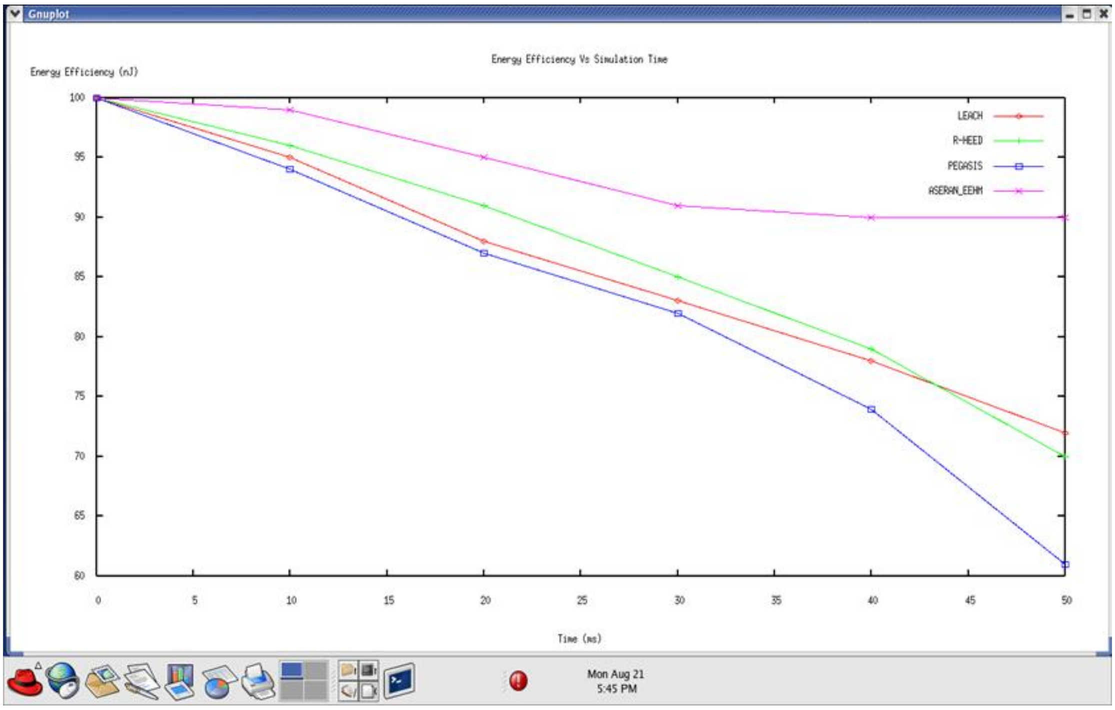


Figure 4: Comparison of energy efficiency

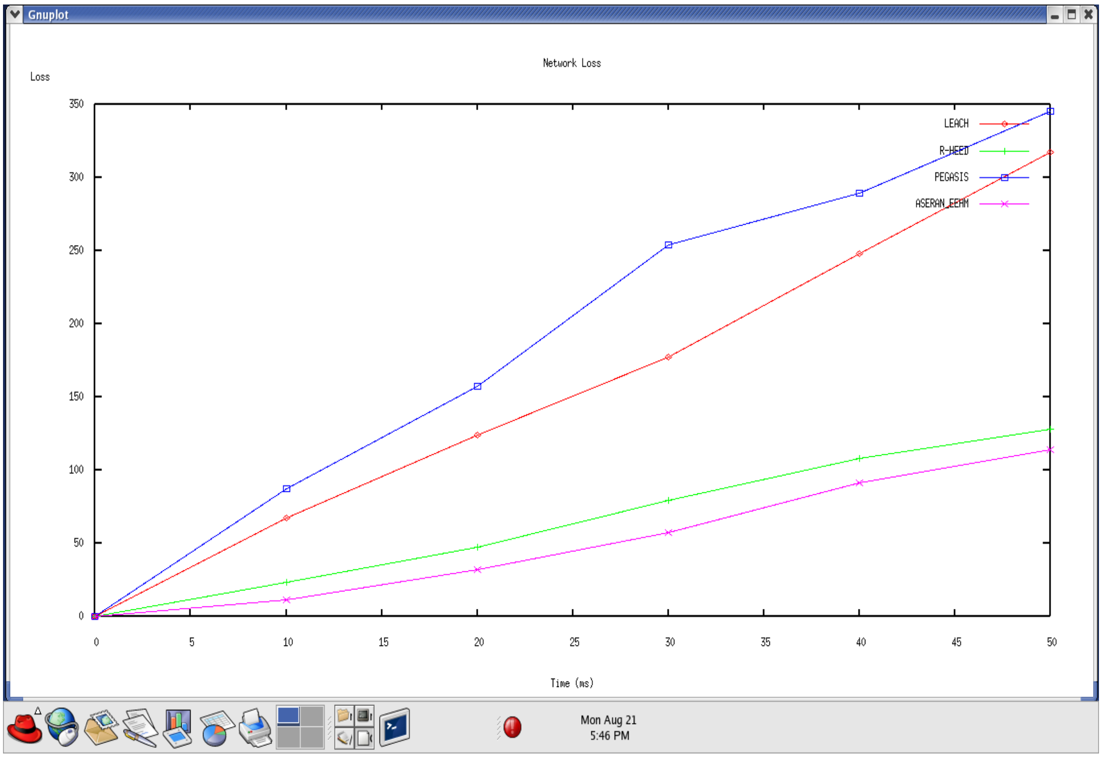


Figure 5: Comparison of loss in network

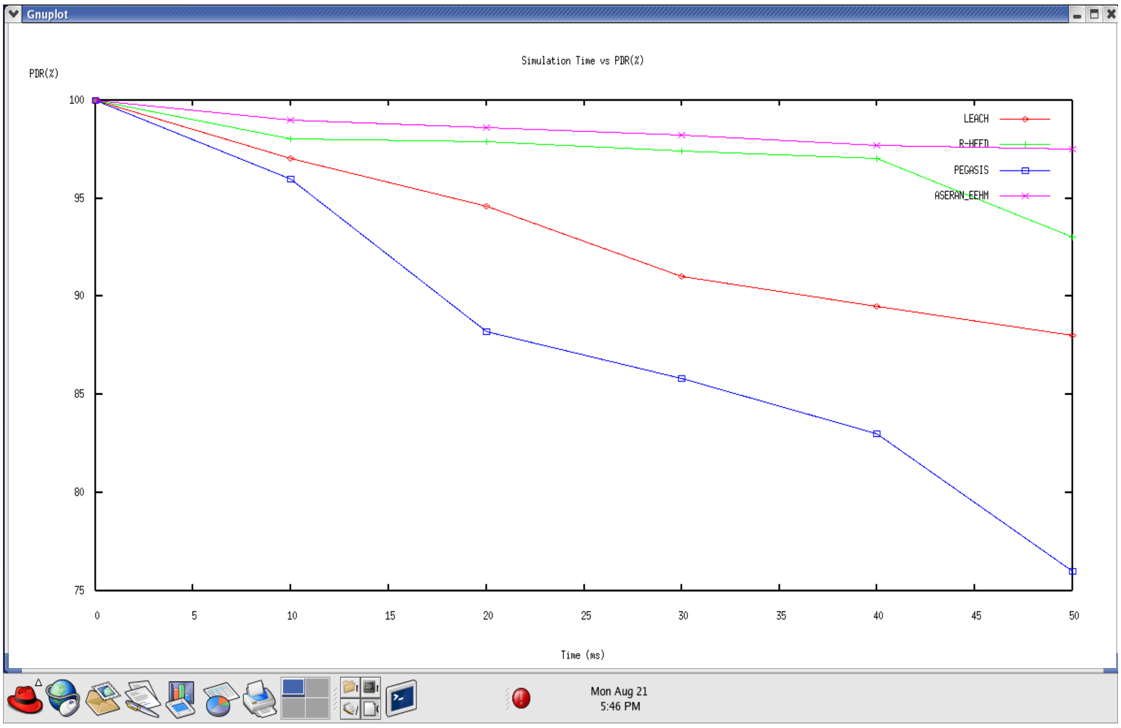


Figure 6: Comparison of PDR

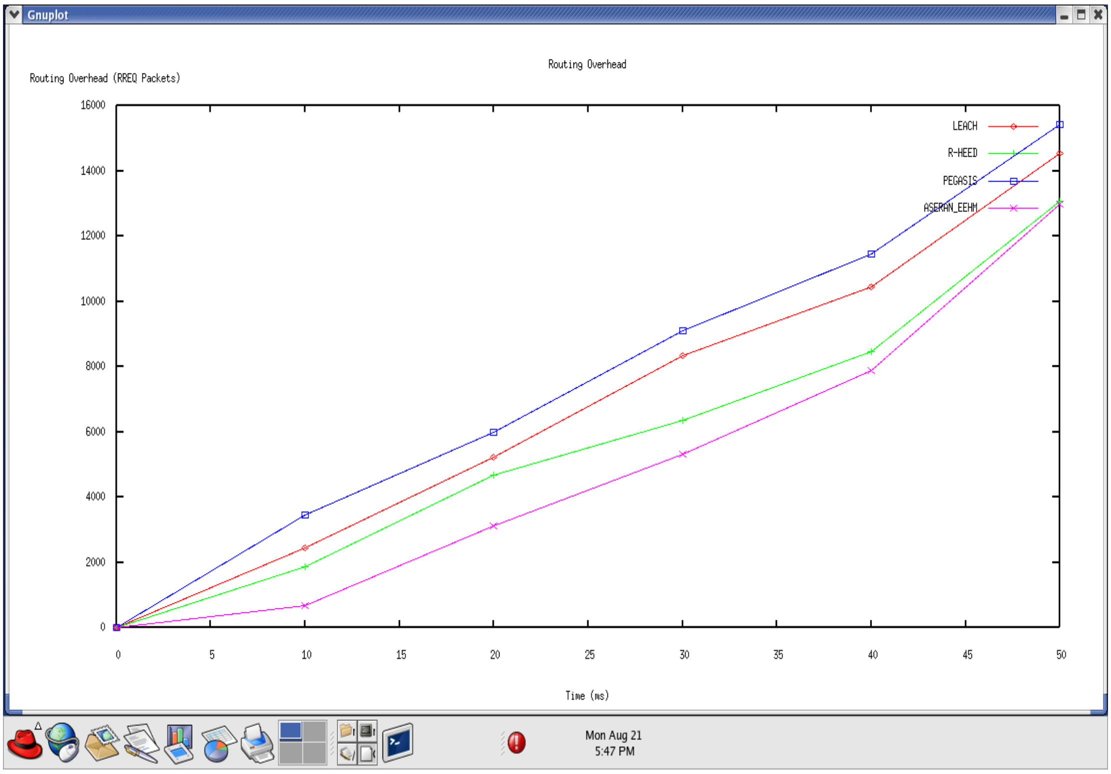


Figure 7: describes the performance comparison for the routing overhead

## 7. CONCLUSION AND FUTURE WORK

In this paper, we have proposed a reliable energy-efficient and structure-free data aggregation protocol for WSNs. In the EEHMAC, we have considered the sensing region divided into different subregions that are sensed with different reliability requirements. Our proposed protocol allows a selected number of senders to transmit the sensed data depending on the reliability requirement. This not only saves the energy consumption of the sensors but also decreases the traffic load in the network increasing, at the same time, the performance of WSN. In addition, we have considered the problems of near traffic load in case of our proposed protocol in comparison with the existing protocols showing how it decreases the end-to-end delay due to congestion and loss recovery. Furthermore, the structure-free data aggregation approach used in our protocol saves energy consumed. The efficient next node selection method used in our protocol improves spatial and temporal convergence for data aggregation. The sensed data are aggregated selectively to improve energy consumption and decrease miss ratio as well as end-to-end delay. The miss ratio is also minimized through an efficient buffer partition and management.

In a future study, the proposed protocol needs to be modified and tested to adopt the real-time dynamic environment. The protocol needs to be tested for real-time WSN applications that require diverse reliability required in the sensing field.

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