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Energy Efficient Routing Protocol for Self-Adaptive Sleep/Wake-Up Scheduling Approach in WSN

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Abstract: WSN sensors, usually deployed in the non-accessible environment, are powered using small batteries along with techniques for power harvesting where replacing batteries are not an option. Relying on a battery not only limits the sensor's lifetime but also makes efficient design and management of WSNs a real challenge. The energy supply limitation provoked many research on WSN allthe protocol layers. This project focus on efficient sleep/wake-up scheduling, aiming to minimize idle listening time thereby reducing the energy consumption, which is one of the fundamental research problems in WSNs. The nodes are kept in rest mode keeping in mind the end goal to spare the vitality of every node to the extent that this would be possible without comprising on packet delivery effectiveness and consequently lifetime was increased. The proposed strategy proposes a vitality productive directing convention with self versatile sleep/wakeup planning that precisely predicts the path and sends the packet through cluster based predicted path in P-LEACH the cluster arrangement technique of LEACH in the chain based architecture of PEGASIs is utilized. Finally, the simulation results of the proposed method show improved lifetime, low energy utilization and reduced delay.

Keywords: Self-Adaptive Sleep/Wake-Up Approach, P-LEACH.

I. INTRODUCTION

In recent years an efficient design of a Wireless Sensor Network has become a leading area of research. A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing. Wireless Sensor Network (WSN) can be defined as a self-configured and infrastructure-less wireless network to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to the main location or sink where the data can be observed and analyzed. A sink or base station acts like an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals.

Wireless sensor devices can be equipped with actuators to "act" upon certain conditions. When it comes to energy consumption, one often encounters difficulty, as evaluation and optimization of the network as a comprehensive model that takes the energy consumption into account hardly exists. Thus sleep/wake-up scheduling is introduced to decrease the energy consumption in the network and as an advance self-adaptive sleep/wake-up approach is studied in detail and implemented. The main operational sustainability concern in WSN is its energy resource constraint. This brings in recent years that a great number of energy efficient routing protocols have been proposed for WSNs based on the network organization and the routing protocol operations. A few of them are discussed below.

Dayong Ye et al. [1], proposed a self-adaptive method for sleep/wake-up scheduling which avoids the use of duty cycle. Unlike most existing studies that use the duty cycling technique, which incurs a tradeoff between packet delivery delay and energy saving, the proposed approach, which does not us duty cycling, avoids such a tradeoff. The proposed approach, based on the reinforcement learning technique, enables each node to autonomously decide its own operation mode such as sleep, listen, or transmission in each time slot in a decentralized manner. Each node makes a decision based on its current situation and an approximation of its neighbors' situations, where such approximation does not need communication with neighbors. Sarwar Morshed et al. [2], presented TR-MAC, an energy-efficient preamble sampling based MAC protocol for low power WSNs suitable for low data rate and low duty cycle scenario.

However, the low data rate is not always maintained in wireless sensor networks which often have to deal with event-driven scenarios where a sudden event rapidly increases traffic load within the network. A traffic-adaptive duty cycle adaptation mechanism was proposed in order to provide responsiveness to traffic rate variations for TR-MAC protocol. Peng Guo et al. [3], contributed a sleep scheduling method to reduce the delay of alarm broadcasting. Their method uses staggered wake-up schedules to create unidirectional delivery paths for data propagation, significantly reducing the latency of the data collection process. When a node detects a critical event, it creates an alarm message and quickly transmits the message to a center node along a predetermined delivery path. The center node then broadcasts the alarm message to the other nodes along another predetermined delivery path. Their approach works very well if packets are delivered in the designated direction, but it is not efficient when packets are delivered in other directions.

Chih-Cheng Hsu et al. [4], jointly designed an asynchronous sleep/wake-up scheduling approach and an opportunistic routing protocol. In the sleep/wake-up scheduling approach, each node wakes up for a wake period of length and then enters the sleep mode for a sleep period of length alternately. The wake-up event follows a Poisson process with rate λ. Properly setting λ can save the energy and the bandwidth. The opportunistic routing protocol is then designed on the basis of the sleep/wake-up scheduling approach. When data are disseminated, forwarders with more residual energy have higher priority to be selected into the forwarder set. The sleep/wake-up scheduling approach works very well with the opportunistic routing protocol, but it is not clear how the scheduling approach works with other routing protocols. Lei Tang et al. [5], analyzed PW-MAC (Predictive-Wakeup MAC), a new energy-efficient MAC protocol based on asynchronous duty cycling. PW-MAC protocols enable senders to predict receiver's wake-up times with a pseudo-random wake-up scheduling approach which also avoids and efficiently resolves any radio collisions caused by multiple concurrent traffic flows. It also minimizes sensor node energy consumption by enabling senders to predict receiver wake-up times to enable accurate predictions. PW-MAC introduces an on-demand prediction error correction mechanism that effectively addresses timing challenges such as unpredictable hardware and operating system delays and clock drift. However, the pseudo-random wake-up scheduling approach increases energy consumption to always broadcast and receive beacon messages before the transmission of data.

Abdul Razaque et al. [6], provided a description of PEGASIS-LEACH (P-LEACH), a near optimal cluster-based chain protocol that was an improvement over PEGASIS and LEACH both. The LEACH protocol is based on cluster formation, where all nodes in a network organize themselves in a local cluster and select a cluster head, which collects information from the non-head node and transmits it to the base station. PEGASIS protocol, a chain of sensor nodes is formed and leader node is selected for each round randomly. A leader of a particular round collects the data, fuses the data, and sends the data to the base station. Thus in P-LEACH, the cluster formation technique of LEACH was used in the chain based architecture of PEGASIS. Al-Karaki et al. [7], presented a survey of state-of-the-art routing techniques in WSNs. The design challenges for routing protocols in WSNs followed by a comprehensive survey of routing techniques were outlined and introduced an enhancement over the LEACH protocol. The protocol called Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is a near optimal chain-based protocol.

Muhammad Omer Farooq et al. [8], presented multi-hop routing with the LEACH protocol to prolong the lifetime of WSN is implemented based on Received Signal Strength Indicator (RSSI). It introduces the concept of equal clustering in which any node reaches the BS in an equal number of hops. This reduces energy consumption. But using a direct communication protocol, it requires a large amount of transmission power and thus drains the battery. This results in a reduction in network lifetime.

II. PROPOSED METHOD

The P-LEACH routing protocol is incorporated in the self-adaptive sleep/wake-up scheduling approach. LEACH and PEGASIS are the most well-known energy efficient protocols for wireless sensor networks. LEACH considers a dynamic cluster approach and energy efficiency during wireless transmission, while PEGASIS considers the power consumption, reduced traffic overload, increased network lifetime and cost efficiency, but doesn't take into account a dynamicity. The combination of the two protocols is to design an ideal routing protocol for wireless transmission and networking. The cluster headset is responsible for data forwarding in LEACH, while in PEGASIS, hierarchical chain formation is implemented through an energy efficient algorithm for the same. The proposed new protocol P-LEACH combines the chain formation technique within the clusters for data forwarding. The self-adaptive sleep/wake-up scheduling approach was not designed incorporated with a specific packet routing protocol. Thus one of the energy efficient routing protocol, P-LEACH is incorporated with the self-adaptive sleep\wake-up method. PEGASIS-LEACH (P-LEACH) a near optimal cluster-based chain protocol that is an improvement over PEGASIS and LEACH both [6]. This protocol uses an energy efficient routing algorithm to transfer the data in WSN.

The LEACH protocol is based on cluster formation, where all nodes in a network organize themselves in a local cluster and select a cluster head, which collects information from the non-head node and transmits it to the base station. LEACH protocol effectively increases the network lifetime but greatly reduces total energy consumption, since they consume more energy in the cluster head node and once head node dies all other nodes associated with it becomes isolated. In [7], an enhancement over the LEACH protocol was proposed. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is a near optimal chain-based protocol. The PEGASIS protocol, a chain of sensor nodes is formed and leader node is selected for each round randomly. A leader of a particular round collects the data, fuses the data and sends the data to the base station. Although clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about the energy status of its neighbors in order to know where to route its data. Such topology adjustment can introduce significant overhead, especially for highly utilized networks.

To overcome the shortcomings of LEACH and PEGASIS, P-LEACH is proposed. In P-LEACH, the cluster formation technique of LEACH has used in the chain based architecture of PEGASIS. The Fig. 1 shows the architecture of P-LEACH. As a result, the system will have a higher lifetime, low energy consumption, and unlike PEGASIS, can also deal with a dynamic system. This protocol uses an energy efficient routing algorithm to achieve the proposed results. ss

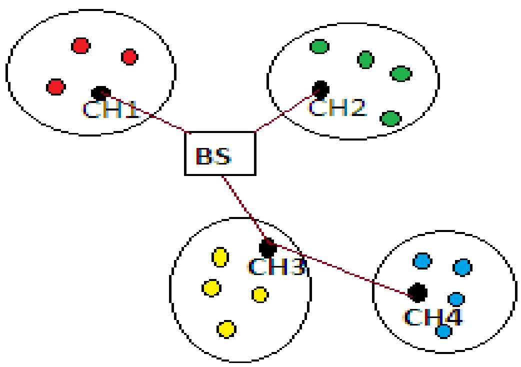

Fig. 1. Architecture of P-LEACH

In multi-hop routing with the LEACH protocol to prolong the lifetime of WSN is implemented based on Received Signal Strength Indicator (RSSI). It introduces the concept of equal clustering in which any node reaches the BS in an equal number of hops. This reduces energy consumption. But using a direct communication protocol, it requires a large amount of transmission power and thus drains the battery. This results in a reduction in network lifetime.

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A. Algorithm

The P-LEACH protocol can be well explained using the algorithm. The steps involved are as follow:

Step 1: Initializing the Network (Nodes (N), Base Station (BS), Location L (x,y), Energy(E))

Step 2: Cluster Head Selection

Step 3: Giving and receiving messages internally

Step 4: Chain Formation and selecting a leader

Step 5: Transferring the Data

Step 6: Change of Cluster Head

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In the algorithm, all the nodes (N) send their location L(x,y) and energy (E) information to Base Station (BS) in step-1. BS receives location (L) and energy (E) from nodes N1, N2, N3, N4, N5, N6 and so on, of each cluster. For Cluster Head Selection in step2, BS selects a node Ni with the maximum remaining energy ' ' as the Cluster Head (CH) for each Cluster. In Step 3, once the BS selects the Cluster Head, it informs every node in the network about the selection of the CH. Nodes send an acknowledgment message back to the BS informing the BS that it has successfully received the information.

In step 4, a CH with maximum energy and minimum distance from the base station is selected as the Leader, so as to contact the BS directly. Hence, the minimum path from source to destination is drawn. In step 5, the data is transferred through the path drawn. First, the data of each node is sent to the CH of the cluster. Now the CH gathers the data from all the nodes and forwards it to the next CH in the chain. In step 6, IF loop is implied if the energy of the cluster head goes below the expected energy level. If CH fails to maintain the same maximum energy, then the node with the second highest maximum energy is selected and declared as the CH as per the step 2.

This ensures the successful working of the Cluster Head in the Cluster-Chain-based architecture of the P-LEACH routing protocol. As the Fig. 2 represents P-LEACH algorithm flow chart. At Initialization stage, the REQ messages are sent by the Base Station to every Node. The Nodes then are equally divided into Clusters depending on sensing range and form the Cluster ID and table.

The node with maximum energy is selected as the Cluster Head. The next selected cluster head node is with the higher energy. The leader with lease distance from the base station is selected based on its location. The chain formation is based on distance and energy of every node. Then the data transfer takes place.

III.SOFTWARE IMPLEMENTATION

The software tool used here is the Network Simulator Version 2, widely known as NS2, is simply an event-driven simulation tool that has proved useful in studying the dynamic nature of communication networks. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2.

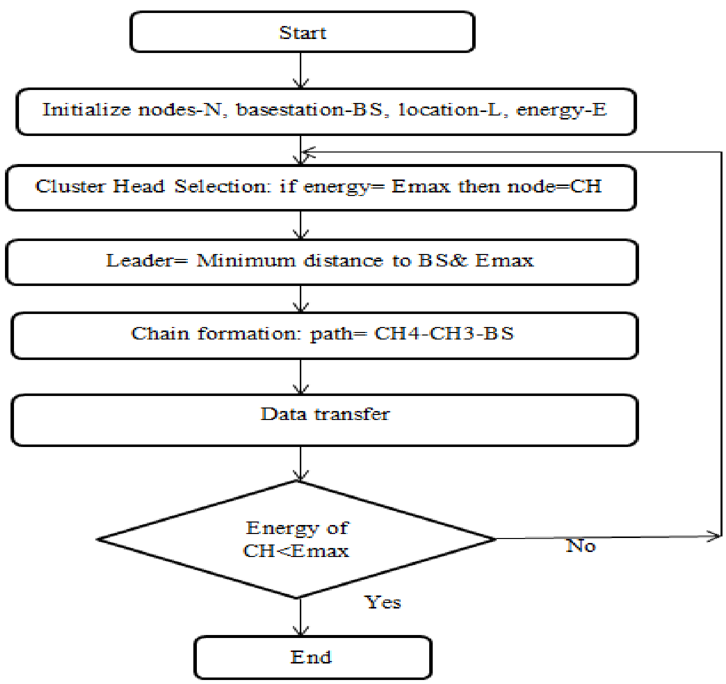

Fig. 2. P-LEACH Algorithm Flow Chart

In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behaviors. Due to its flexibility and modular nature, NS2 has gained constant popularity in the networking research community since its birth in 1989.

NS2 is an open-source simulation tool that runs on Linux. NS2 provides users with an executable command ns which takes on input argument, the name of a Tcl simulation scripting file. It is a discrete event simulator targeted at networking research and provides substantial support for simulation of routing, multicast protocols and IP protocols, such as UDP, TCP and RTP wired and wireless (local and satellite) networks. It has many advantages that make it a useful tool, such as support for multiple protocols and the capability of graphically detailing network traffic. Additionally, NS2 supports several algorithms for routing and queuing. LAN routing and broadcasts are part of routing algorithms. Queuing algorithms include fair queuing, deficit round-robin and FIFO. NS2 started as a variant of the REAL network simulator in 1989. REAL is a network simulator originally intended for studying the dynamic behavior of flow and congestion control schemes in packet-switched data networks.

A. Simulation Setup

The simulation parameters such as simulation area, number of nodes, the energy node, channel type and packet size are tabulated in the tabular column table 1 Simulation Parameters. The scale of grid networks fluctuates from 50 nodes to 160 nodes. Each node generates a packet at the beginning of each time slot based on a predefined probability which is the packet generation probability. As the state of a node is determined by the number of packets in its buffer, the packet generation probability directly affects the state of each node. Then, the action selection of each node will be indirectly affected. The expiry time of a packet is based on exponential distribution. The average size of a packet is 512 bytes.

All network nodes start the simulation with an initial energy that is equal to 1 joule and an unlimited amount of data to be transmitted to the base station. Each node uses its limited reserves of energy during the simulation, which causes the depletion. Any node which has exhausted its energy reserve is considered dead. The expected outcomes for the data transfer such as energy consumption, an end to end delay, throughput, packet delivery ratio and lifetime are evaluated and compared with the existing protocol.

Table. 1 Simulation Parameters

Parameters	Value
Simulation area	300x300m
Number of nodes	50, 80,100, 160
Channel type	Wireless Channel / Two Ray Ground Model
Energy of node	1J
Packet size	512 bytes

B. Graphical Representation

The various steps performed in the course of simulation process are discussed one by one as follow.

The desired number of nodes are created. Here 100 nodes are created and the sink node is placed in the middle of the simulation scenario. The sink is indicated in violet color and the sink node sends the broadcast message to all other nodes. Energy calculation is done and clusters are formed. CH selection process is carried out and primary and secondary cluster heads are chosen where blue and red color are the primary and secondary cluster heads. Nodes send the joint request to the corresponding cluster head. Cluster Head (CH) then accepts the request. The cluster member transfers the message to the CH. CH receives and aggregates the message which is sent to the sink. The Fig. 3 shows the color differentiated clusters that different clusters are displayed with different colors and the cluster heads are in the black.

The graph for the energy consumption which compares the proposed P-LEACH protocol and gossip routing protocol is shown in the Fig. 4 Energy Consumption. Energy consumption may be defined as the amount of energy or power used. From the graph, it is inferred that the energy consumption for the proposed method shows reduced energy consumption than the existing method.

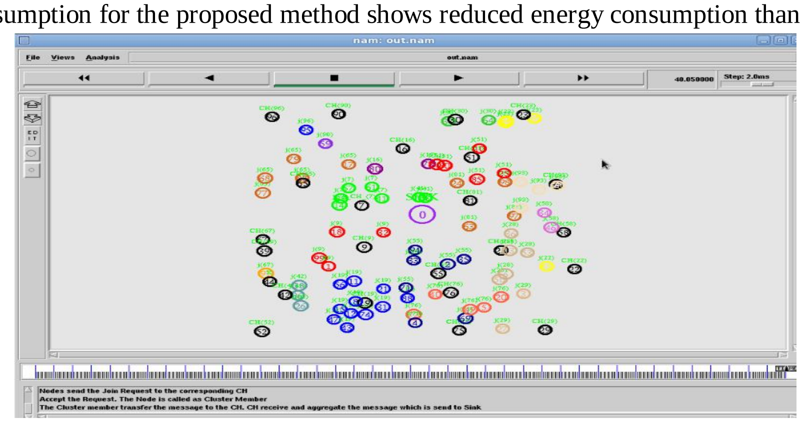

Fig. 3. Colour Differentiated Clusters

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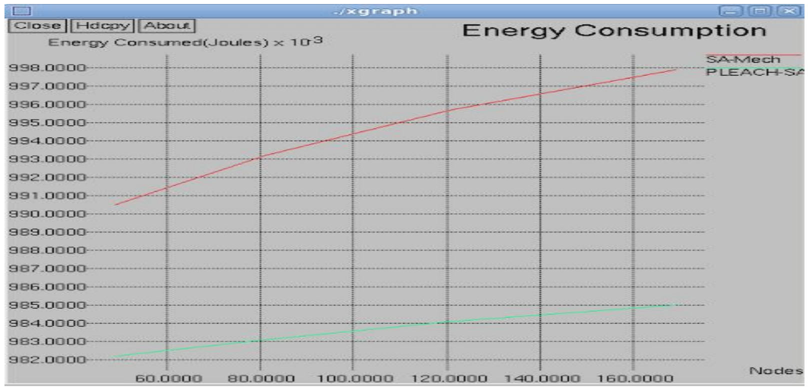

Fig. 4. Energy Consumption

The graph for the throughput which compares the proposed P-LEACH protocol and gossip routing protocol is shown in the fig. 5 throughputs. Throughput may be defined as the rate of successful message delivery over a communication channel. Throughput is usually measured in bits per second (bit/s or bps). From the graph, it is inferred that the throughput for the proposed method shows improved throughput than the existing method.

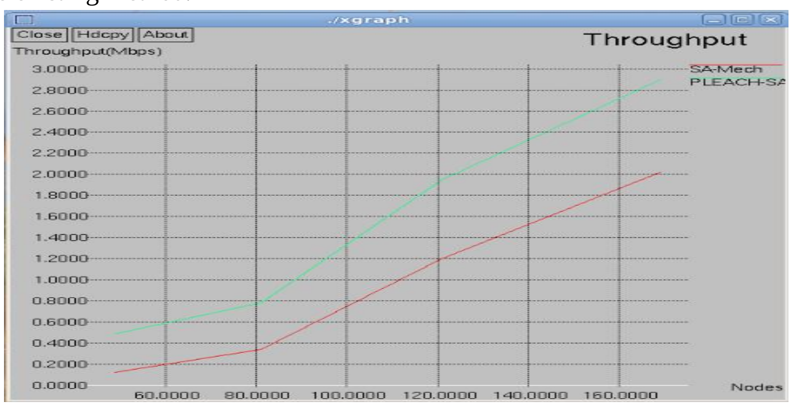

Fig. 5. Throughput

The graph for packet delivery ratio is shown in the fig. 6 Packet Delivery Ratio. The calculation of Packet Delivery Ratio (PDR) is based on the received and generated packets as recorded in the trace file. Packet Delivery Ratio is calculated using awk script which processes the trace file and produces the result. From the graph, it is inferred that the packet delivery ratio for the proposed method shows reduced loss of packets than the existing method.

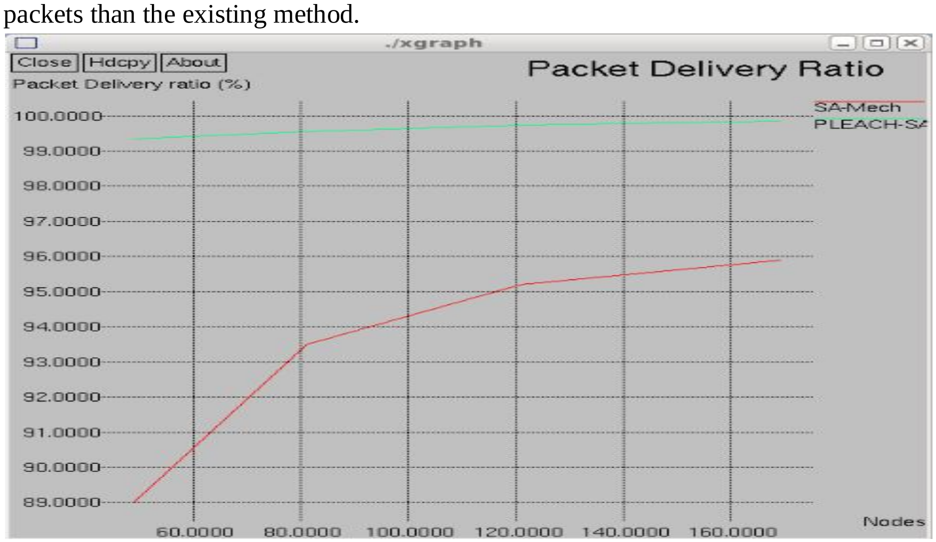

Fig. 6. Packet Delivery Ratio

The graph for the end to end delay which compares the proposed P-LEACH protocol and gossip routing protocol is shown in the fig. 7 end to end delay. The end-to-end delay is one of the most critical and fundamental issues for wireless sensor networks. The end-to-end delay is one of the most critical and fundamental issues for wireless sensor networks. From the graph, it is inferred that the end to end delay for the proposed method shows reduced delay than the existing method.

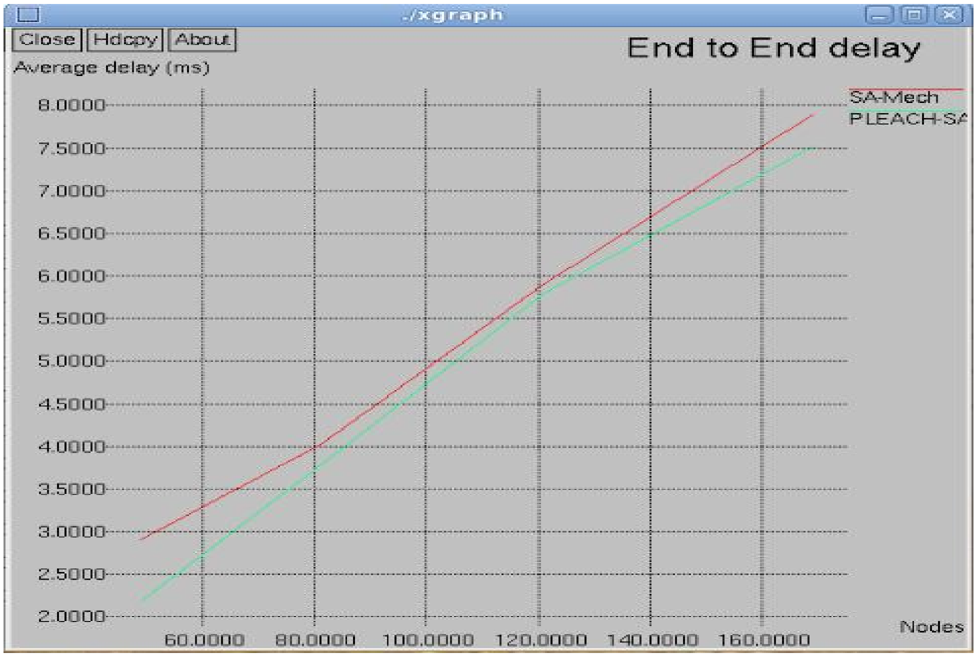

Fig. 7. End to End Delay

Thus the proposed method is simulated using NS2 and the graphs are generated as a comparison between the gossiping routing protocol and P-LEACH protocol. The simulated results are discussed in detail. The proposed method utilizes less energy compared to the existing and the throughput is also increased. The packet delivery ratio is improved and loss of the packet is minimized compared to the existing method. The end to end delay is also reduced. Thus the proposed method is more efficient than the existing method.

IV. CONCLUSION

A brief introduction about wireless sensor networks is thoroughly discussed. Scheduling is thoroughly detailed by explaining the different types of scheduling mechanism. Self-adaptive sleep/wake-up scheduling approach is explained in detail along with the algorithm used where it proposed an alternative approach based on game theory and the reinforcement learning technique. P-LEACH Routing Protocol for improving energy efficiency in the Self-Adaptive sleep/wake-up scheduling approach in wireless sensor networks is proposed and incorporated. The performance of P-LEACH routing protocol is compared with the existing gossiping routing protocol in the self-adaptive sleep/wake-up scheduling approach. With simulation, it is observed that P-LEACH protocol performs much better than the gossiping routing protocol in terms of energy consumption, throughput, packet delivery ratio and an end to end delay. The Network Simulator 2 is used for the software implementation and for evaluating the performance of the protocol. Based on the simulation results, it is determined that the proposed P-LEACH routing protocol performs better than the gossiping routing protocol in terms of energy and lifetime of the network. The simulation results validate that the proposed approach could extend the network for WSNs applications.

V. FUTURE SCOPE

The proposed approach has been evaluated in static networks. In the future, this can be extended to open and mobile networks, where nodes can dynamically enter into or leave the networks and they may move around in the networks. Such openness of networks and mobility of nodes will introduce new challenges. In the proposed approach, a node's approximation of another node's behavior is based on their past interactions. If the network is highly mobile, neighbors of each node may always change. Thus it may be difficult to converge in this situation. This issue can be solved in the future work. Also, the malicious nodes detection and removal will be performed in the future work.

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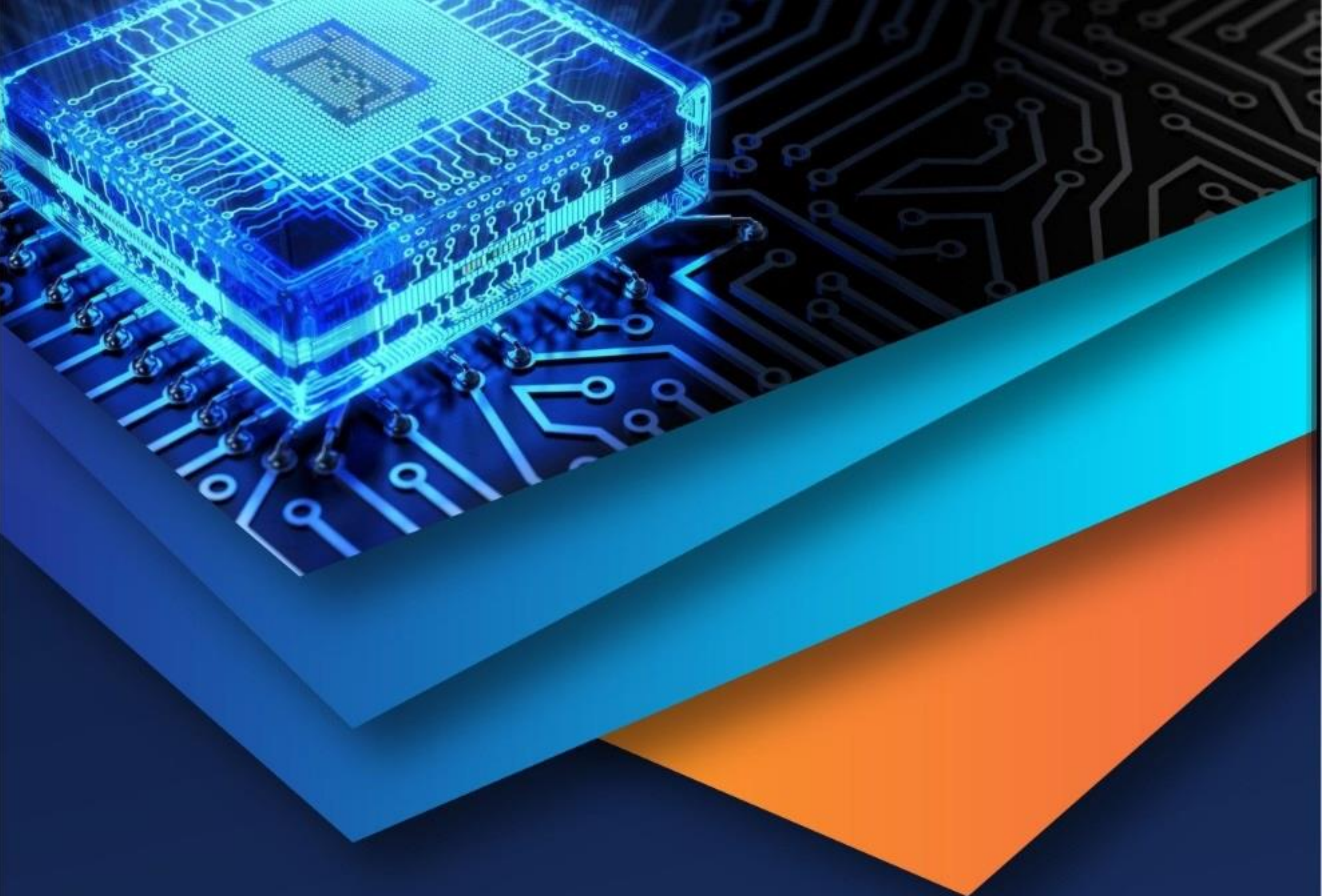

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