Energy Optimization of Wireless Sensor Networks Using LEACH, SEP and MIEEPB Techniques

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Abstract- Wireless Sensor Network has over the years remained a major research focus in the telecommunication sector. Wireless Sensor Networks (WSNs) are large networks made of numerous sensor nodes with sensing, computation, and wireless communication capabilities. WSNs are deployed in several sensing systems for monitoring and controlling environmental and physical processes. Energy consumption of the network nodes has remained a major challenge faced by WSNs, as this tends to limit the lifespan of the network. In this work, MATLAB was used as a simulator to analyze and compare the energy optimization performance of three wireless sensor network protocols which include; Mobile Sink Improved Energy-efficient PEGASSIS-based Routing Protocol (MIEEPB), Stable Election protocol (SEP) and Low-energy Adaptive Clustering Hierarchy (LEACH). The simulation was focused on showing the number of sensor nodes alive and evaluating the lifetime of the network using the percentage of dead nodes, which are important indicators for measuring the performance of each protocol. The MIEEPB demonstrated better performance than SEP and LEACH protocols.

Keywords: Wireless sensor network, network lifetime, LEACH, SEP, MIEEPB, nodes.

I. INTRODUCTION

Wireless sensor networks have become a major research area due to modern advancement of technology. It is a group of sensor nodes used to sense and transform information. They are used for remote sensing and are applied in many industrial areas such as military, health, surveillance, etc. where they are placed in different locations to monitor the environment and inform the base station unattended.

According to (Puccinelli et al, 2007), in designing the sensor network protocols, energy consumption is of critical consideration in order to prolong the lifetime of the network. The longevity of the network is reached in part with the reduction of energy consumption due to the fact that sensors have limited energy sources, which usually cannot be reloaded once the network is deployed. Hence, the protocol for improving the network’s energy consumption takes into consideration factors such as path selection for information gathering and transmission, distance between sensors, network topology etc. for its design.

Several protocols have been proposed to improve the energy optimization problem faced by WSNs. This paper therefore presents a comparative study of three of these protocols, namely; mobile sink improved energy-efficient PEGASSIS-based routing protocol (MIEEPB), stable election protocol (SEP) and low-energy adaptive clustering hierarchy (LEACH).

Background

Wireless sensor networks are composed of many nodes, which gather data from the environment using a sensing module, and communicate with other nodes and base station through wireless technologies. They come in various topologies and the most common of them is the hierarchical topology.
Definition of terms:

i. **Source nodes** are nodes that pick up information from the environment and send to the base station.

ii. **Routing node** receives data from one or more nodes, and transmits them to other nodes adding its data.

iii. **WSN routing** is the needed mechanism required to carry out data transmission from one source to destination.

iv. **Network lifetime** is the time between startup of WSN until the moment that one node or a percentage of them is unable to transmit data to the base station.

**Clustering protocol:** According to (Heinzelman et al, 2000), clustering techniques aim at gathering data among other group of nodes, which elect heads among themselves. In (Khan M.A et al, 2012), the role of the elect heads is to aggregate data and report refined information to the base station or sink. Its basic objective is to make the network more efficient, improve fault tolerance, load balancing and scalability.

**II. REVIEW OF RELATED WORKS**

In a work done by (Vidhumitha, M.Usha, 2015), the main aim of the authors was to analyze the performance of several protocols classified as chain-based routing protocols which is one of the hierarchical routing protocol types by going deeply in describing these protocols mechanism and models. In addition, they examined the behavior of PEGASIS protocol with its genesis and its later improvements based on the number of dead nodes and how this can be affected on the network lifetime. PEGASIS follows the chain based approach and greedy algorithm according to (Khan, et al 2012). The sensor nodes organize themselves to form a chain or it uses the greedy approach. If any of the nodes die in between, then the chain is reconstructed to bypass the dead node. One leader node is assigned and that node will transmit the data to the base station (BS) (Jun, 2008). Authors in (Sonali et al, 2007) developed a simulation mathematical model using Poisson distribution to determine the sleep-mode nodes in WSN. This model was imposed on a range of data routing and clustering algorithm present in literature and results indicated a significant improvement in lifetime using it. The authors utilized the sleep-mode nodes as relays in transferring data from a transmitter to receiver for boosting energy efficiency in the network. At every round of data transfer, not all source nodes necessitate sending data to sink and hence tune itself to sleep mode. This Simple geometrical property in modeling is used in the mathematics involved for choosing the most practicable sleep-mode node to relay the data.

In (Latif et al, 2016), the work focused on analyzing the optimization strategies of routing protocols with respect to energy utilization of sensor nodes in Wireless Sensor Network (WSNs). The authors addressed some energy limitation constraints with respect to maximizing network lifetime using linear programming formulation technique. To check the efficiency of different clustering scheme against modeled constraints, they selected four cluster based routing protocols; Low Energy Adaptive Clustering Hierarchy (LEACH), Threshold Sensitive Energy Efficient sensor Network (TEEN), Stable Election Protocol (SEP), and Distributed Energy Efficient Clustering (DEEC). To validate their mathematical framework, they performed analytical simulations in MATLAB by choosing number of alive nodes, number of dead nodes, number of packets and number of channel head (CHs), as performance metrics as done by (Sonali, 2007).

To check the efficiency of different clustering scheme against modeled constraints in (Kanchan, (2015), three cluster based routing protocols are selected; Low Energy Adaptive Clustering Hierarchy (LEACH), Threshold Sensitive Energy Efficient sensor Network (TEEN) and Stable Election Protocol (SEP). To validate the results, analytical simulations were carried out using
MATLAB by choosing various performance metrics. It was proved that TEEN protocol performed better in terms of spreading overall network lifespan. Low-Energy Adaptive Clustering Hierarchy (LEACH), proposed by author in (Shio, 2010) is one of the pioneering clustering routing approaches for WSNs. The basic idea of LEACH has been an inspiration for many subsequent clustering routing protocols. The main objective of LEACH is to select sensor nodes as CHs by rotation, so the high-energy dissipation in communicating with the BS is spread to all sensor nodes in the network.

III SIMULATION PARAMETERS

1. LEACH PROTOCOL

In this work, we considered hierarchical routing protocol, which performs energy efficient routing and contributes to the overall system lifetime of WSNs. The LEACH protocol has two major phases of operation, which include the set up phase and the steady state phase.

i. **Set up phase:** This phase basically groups the sensor nodes into clusters. During this phase, each node decides whether to become a cluster head or not. In (Latif K, M et al, 2016), an advertisement packet consisting of base station ID, location, energy etc is sent to neighboring nodes asking them to join the cluster. The other nodes on the other hand consider the packet with the highest energy to join a cluster. The selection process is carried out using an algorithm below;

\[
T(n) = \begin{cases} 
  p & n \in H \\
  1 - p \cdot [r \mod (1/p)] & 0, \text{ otherwise}
\end{cases}
\]

Where “p” is the percentage of the number of clusters in the network. “H” is the group of nodes that have not been elected cluster heads in round “r” and “r” is the election round. Random numbers are constantly generated by the nodes and are compared with the threshold figure, T(n). Nodes with number lower than the threshold is made the cluster head. Once the cluster heads have been selected, they create a TMDA (time division multiple access) schedule for the cluster member nodes to prevent intra-cluster collision during transmission of data.

ii. **Steady state phase:** This phase starts with data transmission by the individual member nodes to their corresponding cluster heads. All other nodes are kept in sleep mode according to the TDMA schedule, thus minimizing the energy dissipation in these nodes. When all the data has been received, cluster heads aggregate these data and send to the BS.

2. SEP (Stable Electron Protocol): In LEACH as discussed above, all nodes have the same initial energy (i.e. homogenous network), which guarantees that all nodes must be made cluster heads at least once. The SEP protocol is more appropriate for a heterogeneous network where sensor nodes have different energy levels. In the SEP protocol, there are two categories of nodes namely;

i. Normal nodes

ii. Advanced nodes

Normal nodes have less energy than the advanced nodes and so, it uses the fact that advanced node must take greater responsibility to become cluster head in (Puccinelli D, M. Haenggi, 2007). The probability to become cluster head is therefore based on the ratio of energy of each advanced nodes to initial energy of normal nodes. Hence, there is an addition of energy factor and advanced nodes.
The initial energy associated with the advanced node will be more with a factor of $\alpha$. i.e. $E_0 \cdot (1 + \alpha)$.

The total network energy = $n \cdot (1 - m) \cdot E_0 + n \cdot m \cdot E_0 \cdot (1 + \alpha) = n \cdot E_0 \cdot (1 + \alpha \cdot m)$ (4)

where $m$ is the advanced nodes fraction. Hence, the total energy of the system is increased by $1 + \alpha \cdot m$ times.

3. **MIEEPB (mobile sink improved energy-efficient PEGASSIS-based routing protocol)**

In MIEEPB, a mobile sink is used by specifying the sojourn time and sojourn location. Mobile sink node divides WSN area into regions and considers that in each round the sink node will complete one course around the given number of sojourn locations. It is a multi-chain model that incorporates sink mobility, leading to smaller chains and reduced load. The multi-chain concept reduces the distance between connected nodes and saves energy.

\[
T_{nrm}(n) \begin{cases} 
\frac{P_{nrm}}{1 - P_{nrm} \cdot \left( \frac{1}{P_{nrm}} \right) \mod \frac{1}{P_{nrm}}} & \text{if } n_{nrm} \in G' \\
0 & \text{otherwise}
\end{cases}
\]

\[
T_{adv}(n) \begin{cases} 
\frac{P_{adv}}{1 - P_{adv} \cdot \left( \frac{1}{P_{adv}} \right) \mod \frac{1}{P_{adv}}} & \text{if } n_{adv} \in G'' \\
0 & \text{otherwise}
\end{cases}
\]

The initial energy of nodes, $E_0$ is 0.5 J

Data aggregation energy, $EDA$ is 5 pJ

### Table 1: System Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network size</td>
<td>100m x 100m</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Number of Rounds</td>
<td>10000</td>
</tr>
<tr>
<td>Base Station</td>
<td>(50, 50)</td>
</tr>
<tr>
<td>The initial energy of nodes, $E_0$</td>
<td>0.5 J</td>
</tr>
<tr>
<td>Data aggregation energy, EDA</td>
<td>5 pJ</td>
</tr>
</tbody>
</table>
Probability of cluster heads, $P$ 0.1  
Alpha, $\alpha$ 1  
Percentage of advanced nodes, $m$ 0.5  
$m_0$ 0.4

IV. SIMULATION RESULTS

![Graph of protocols based on number of dead nodes](image)

**Fig 1:** Comparative graph of protocols based on number of dead nodes

V. RESULT/DISCUSSION

Figure 1 shows the number of dead nodes for each protocol at every given number of rounds. It was observed that SEP had the highest number of dead node, followed by LEACH and MIEEPB.

Figure 2 shows the number rounds for which these percentage of nodes for each protocol dies. For example 25% of nodes were dead as at 1505 rounds for the SEP protocol. Similarly, for the MIEEPB protocol it can be seen that at 1900 rounds, 50% of the nodes were dead. It was observed that at 100% of the dead nodes, MIEEPB made 4333 rounds, followed by LEACH (3740 rounds) and then SEP (3384 rounds). This also has indicated that the MIEEPB protocol has the best lifetime efficiency amongst others.

From table 2, it can be seen that the life span of the LEACH protocol is more than the SEP protocol by 10.5%. Also the MIEEPB protocol, which is a chain-based protocol, has more lifetime efficiency than LEACH and SEP protocols by 15.8% and 28% respectively.
VI. Conclusion

The routing protocols of WSN are very important in terms of improving the network’s performance generally as shown in this work. From the graphs and table above, it can be deduced that the most improved chain-based cluster protocol used in this research, which is the MIEEPB demonstrated better performance than SEP and LEACH. However, for a homogenous network, the LEACH protocol performed better than the SEP protocol in terms of energy consumption and network lifetime.

Table 2: Results

<table>
<thead>
<tr>
<th>Protocols</th>
<th>SEP</th>
<th>LEACH</th>
<th>MIEEPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP</td>
<td>-</td>
<td>10.5%</td>
<td>28%</td>
</tr>
<tr>
<td>LEACH</td>
<td>-</td>
<td>-</td>
<td>15.8%</td>
</tr>
<tr>
<td>MIEEPB</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
References


