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Network coding based energy efficient LEACH protocol for WSN

G. M. Tamilselvan [a, *], K. Gandhimathi [b]

[a] *Department of EIE Bannari Amman Institute of Technology Sathyamangalam, Tamilnadu, India*
[b] *Department of CSE P. A. College of Engineering and Technology Pollachi, Coimbatore, India*

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Abstract: Wireless Sensor Network (WSN) consists of low cost tiny sensor nodes with limited energy resource, so it is a tedious task to develop energy efficient routing schemes that enhances the network lifetime. In WSN, clustering is used to improve the efficiency of finite energy resource. LEACH protocol is one of the widely used clustering techniques in WSN. So, in this paper, an energy efficient LEACH protocol is designed with network coding for WSN. Initially, the clusters are formed with the LEACH protocol, where it uses the residual energy metric and drain rate to select the cluster heads. Since network coding is an optimal technique to enhance the network performance by minimizing the number of transmissions, it is incorporated into the LEACH Protocol, where it has been applied at the cluster head levels. Furthermore, the next level of network coding is processed at a node by selecting any of the nodes as a master node. The simulation results show that the proposed scheme performs better than the EE-LEACH and LEACH protocol in terms of network lifetime, packet delivery ratio.

Keywords: WSN, energy efficiency, LEACH, bottleneck zone, network coding, network lifetime

1. INTRODUCTION

Wireless Sensor Network (WSN) consists of an enormous number of small size sensor nodes and base station (BS). The sensor nodes are built with sensors (temperature, light, humidity, radiation, etc.), microprocessor, memory, transceivers, and power supply (Liang, Huang & Lin, 2008). A highly developed and exceptionally superior communication protocols are required to realize the available and prospective application for WSNs. WSNs are application specific, where the design constraints of WSNs change based on the application. Consequently, the design constraints of the energy efficient routing protocol change from one application to another (He, et al., 2006). For instance, the design constraints of energy efficient routing protocols designed for environmental applications are not similar in many aspects from those designed for military or health applications (Lédeczi, et al., 2005). However, energy efficient routing protocols for all Wireless Sensor networks, in any case of the application, required to improve the network lifetime and reduce the by and large energy utilization in the network (Verdone, Dardari, Mazzini & Cont, 2007). Network lifetime is a serious concern in the design of WSNs. In many applications, replacing or recharging sensors is sometimes impossible. Therefore,

* Corresponding author.
E-mail address: tamiltamil@rediffmail.com (Tamilselvan G.M).

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many energy efficient protocols have been proposed to increase the network lifetime. It is very much complicated to investigate network lifetime because it depends on numerous factors, like network architecture and protocols, data collection initiation, lifetime definition, channel characteristics, and the energy consumption model (Chen & Zhao, 2005). For all energy efficient routing protocols, energy utilization during communication is the most important energy depletion parameter; the number of transmissions should be reduced as much as possible to achieve prolonged battery life. For these reasons, the energy consumption parameter is a top priority (Norouzi & Sertbas, 2011).

Some of the researches study the energy efficient routing protocols. (Aslam, Phillips, Robertson & Sivakumar, 2011) The taxonomy of routing protocols in WSN is reviewed. The protocols are classified as location based protocols, data centric protocols and hierarchical protocols. In this work hierarchical protocols that organize the WSN into a set of clusters is mainly concentrated. In recent times, the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is the most often used hierarchical protocol for sensor network clustering. So as to attain the optimal energy consumption, the LEACH uses the random rotation technique for cluster head selection (Heinzelman, Chandrakasan & Balakrishnan, 2002). Most of the researchers make changes or incorporate new concepts in LEACH protocol to make it more energy efficient. The presented solution is equally valid LEACH to increase the network lifetime by considering the shortcoming related with it.

Moreover, Network Coding is a well-known scheme to enhance the performance of the wireless network. It works by mixing the packets at the intermediate nodes. Thus, it minimizes the amount of data transmissions and hence it minimizes the redundant transmission (Katti et al., 2008). The amount of packet transmission is directly proportional to the energy consumption, where every single data transmission consumes energy. So, this paper enhances the performance of the LEACH protocol by incorporating the network coding. The network coding is implemented at two levels of nodes, namely cluster head level and master node level.

The rest of the paper is organized as follows: The next section presents the recent related works for energy efficient WSN. The Proposed routing scheme with LEACH protocol has been given in the subsequent section, followed by the simulation results and discussion. Finally, this research work is concluded with the analysis of results.

2. LITERATURE REVIEW

Some related researches study the energy efficient clustering protocol for WSN. A clustering technique, namely EECS is proposed for WSN. Based on the residual energy this approach selects the cluster head by means of local radio communication. Additionally, a load balanced method is presented to equally share the loads among the cluster head level (Ye, Li, Chen & Wu, 2005).

An energy efficient clustering scheme, namely GAECH algorithm has been proposed for network lifetime improvement in WSN. This scheme uses an optimization technique, namely Genetic Algorithm. This scheme uses different kinds of metrics such as HND, FND and LAND and it has been involved to create a fitness function. The GAECH forms the reliable clusters that are well balanced to maximize the stability with network lifetime (Baranidharan & Santhi, 2015).

A novel energy efficient routing scheme, namely EEREG is proposed for WSN based on the evolutionary game. First a mathematical code has been given to optimize the size of clusters and then an evolutionary game model is implemented at each node to stop the anarchism at the time of cluster head selection (Lin, Wang, Lin & Deng, 2015).

A distributed cluster head scheduling algorithm for the existing LEACH protocol has been proposed, where it considers the received signal strength and energy level of the node. WSN architecture with two tiers is supported by this scheme, where they can select the cluster head and gateway nodes at each of the tiers. It avoids frequent cluster head selection by considering the energy level and RSSI (Kannan & Raja, 2015).

An energy-efficient LEACH (EE-LEACH) Protocol, which considers the residual energy of the nodes to select the cluster head is proposed for WSN (Arumugam & Ponnuchamy, 2015). The data aggregation is carried out at the cluster head level and then the relay nodes are selected based on the energy level.

An energy efficient clustering algorithm called as DE-LEACH is designed for homogeneous WSN. This scheme considers the energy level and the distance between the nodes to select the cluster heads (Kumar, Prateek, Ahuja & Bhushan, 2014).

A Fuzzy Logic Cluster Formation Protocol (FLCFP) is proposed for energy efficient WSN, where they use the fuzzy logic system to aid in the clustering process (Mhemed, Aslam, Phillips & Comeau, 2012). The metric used to select the cluster heads are energy level, the distance between the nodes and the distance between the node and a sink node. With the help of these parameters, this scheme reduces the energy consumption in WSN.

3. ENERGY EFFICIENT LEACH PROTOCOL USING NETWORK CODING

Energy Efficient LEACH Protocol using Network Coding (EENC-LEACH) is designed to enhance the network lifetime of WSN by addressing the energy issues of sensor nodes. Initially, the EENC-LEACH protocol forms the clusters based on the energy level and its drain rate. And then the network coding is applied at each cluster head to reduce the redundant data transmission. Additionally, a master node is used in this process to apply further network coding at that node.

4. ENERGY MODEL

The radio energy dissipation model is illustrated in figure 1. In order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting a k-bit message over a distance d, the energy expended by the radio is derived.
A simple energy model has been presented for the energy consumption of sensor nodes. Energy depletion during packet transmission can be computed with the Equation (1) and (2):

$$E_{transmission} = k * E_{elec} + k * \varepsilon friss * d^2 \ if \ d \leq d0 \quad (1)$$

$$E_{transmission} = k * E_{elec} + k * \varepsilon amp * d^4 \ if \ d \geq d0 \quad (2)$$

Where E_{elec} denotes the energy dissipated by radio dissipation. $\varepsilon friss$ is the energy dissipated in the amplifier while $d \leq do$ and εamp is the energy dissipated in the amplifier while $d \geq do$. The E_{elec} depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. $\varepsilon friss$ and ε_{amp} depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. For the experiments described here, both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (friss) model is used; otherwise, the multipath (amp) model is used.The energy dissipation during the packet reception is given by Equation (3):

$$E_{reception} = k * E_{elec} \quad (3)$$

5. CLUSTER HEAD SELECTION WITH THE MODIFIED LEACH

In this section, the cluster head selection which employs the modified LEACH protocol in the network is proposed. For cluster head selection, the same procedure is followed as in the common LEACH protocol. The cluster heads have to spend extra energy for aggregating data and performing long range transmission to the distant base station. The LEACH protocol selects cluster heads periodically and drains energy uniformly by role rotation. Each node decides itself, whether or not a cluster head distributed by a probability. Under the homogeneous network, LEACH performs well, but its performance deteriorating in case of heterogeneous network. In this research work, a heterogeneous system is considered, where 10% of the nodes contains more initial energy than

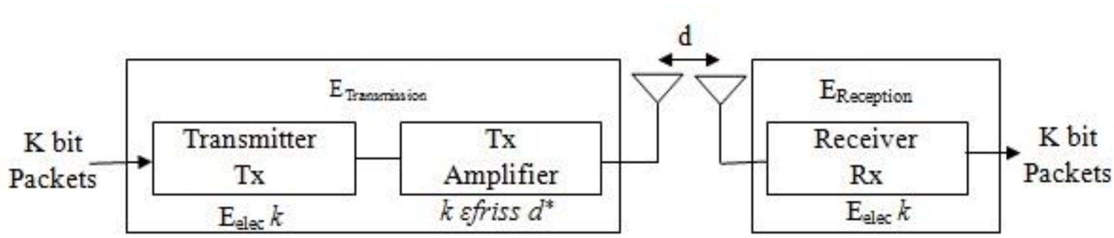

Fig. 1. Radio dissipation Model.

the other nodes in the WSN. The modified LEACH overcomes the weakness of LEACH that is the communication distance between the nodes. The cluster head consumes excess energy than the other nodes while transmitting the data on behalf of its cluster members. Hence it reduces the lifetime of the network. So the energy of the node must be considered while selecting the cluster head.

In this work, along with residual energy, the draining rate of the energy level is considered because some nodes may drain their energy faster than other nodes even though it has more energy level. The modified LEACH protocol selects the cluster head by modifying the threshold equation of the cluster head selection in the existing LEACH protocol and it is given in the following equation:

$$T(n) = \begin{cases} \frac{P}{1-P((r)mod(P))}\left[\frac{RE-DR}{ARE-ADR}\right] \; if\ n \in G \\ 0, \quad otherwise \end{cases} \tag{4}$$

Where P is the anticipated percentage of cluster head, r is the present round, and G is the number of nodes which are not selected as a cluster head in the previous round (1/P). RE is the residual energy of nodes. ARE is the average residual energy of the nodes in the network, which are not selected in previous cluster head selection. DR is the draining rate of the node. ADR is the average draining rate of the nodes in the network, which are not selected in previous cluster head selection.

The cluster head selection is made based on the draining rate of the node. Based on the current and the previous energy level, the node draining rate can be calculated and it is given as follows:

$$D_r = \frac{(RE_p - RE_c)}{(T_c - T_p)} \tag{5}$$

Here D_r indicates the node draining rate, RE_p is the previous residual energy of a node, RE_c indicates the current residual energy of a node, T_c indicates the current time, T_p indicates the previous time. At the time of steady state phase, the selected cluster head created a TDMA schedule and allocates a time slot for every data transmission. After completing the data transmission the network come back to setup phase to select the new cluster heads.

6. NETWORK CODING AT CLUSTER HEAD (CH) AND MASTER NODE

The network coding is applied into LEACH protocol, where the network coding is applied on the cluster head. The cluster head selection with the modified LEACH protocol verifies the energy level and the draining rate and it aids to increase the cluster head lifetime and it also aids to enhance the network lifetime. At the cluster head level the network coding is applied to maximize the coding opportunities and minimize the number of data transmission.

To exchange one packet, a traditional routing network needs more transmissions depend on the network topology while, with network coding, only the minimum number of transmissions is needed, and saved time can be used to transmit new data, thus increasing network throughput. In fact, with the shared nature of the wireless medium and multihop data flows, network coding leads to larger bandwidth savings. Because of the network coding based technique, maximum number of neighbors will be benefitted. Therefore, the number of transmissions will be reduced. Here, the cluster head can send coded packets to its neighbor nodes.

The procedure of the cluster head node for packet transmission contains two queues namely Transmit Queue (T-Queue) and Reception Queue (R-Queue). On the packet reception the node puts the packet in the R-Queue. While the node has been processed, then the node will simply discard the packet. Else the packet has been processed by the node further. If the node is a cluster head, then it will encode the packet by processing the EXOR operation. The cluster head encodes the packet in two ways: If it has the packet P_i in the T-Queue, then it takes the packet from the heads of the R-Queue and takes the packet P_j from the head of the T-Queue and EXOR these two packets

$$P_n = P_i \oplus P_j \tag{6}$$

Otherwise the node waits for the next packet P_{i+1} from the R-Queue then EXOR those two packets from the R-Queue

$$P_n = P_i \oplus P_{i+1} \tag{7}$$

A suggestion is given in the proposed algorithm to use the role of the master node along with the cluster head to reduce redundant data transmission by performing the network coding at the master node. Rather than forwarding the data directly to the sink node, the cluster heads will send their data to the particular zone in which it belongs. The nearby clusters will form a zone. Since it is assumed that the clusters are not homogeneous, so the cluster head, which handles the minimum number of cluster member, will be elected as the master node for that particular round. So the network lifetime can be improved further. The master node encodes the packet in two ways, as described already. The packet decoding is carried out at the sink node, where it receives the encoded packet from the master nodes. The sink node checks the IDs of native packets one by one, and corresponding packet is obtained from its packet pool.

The algorithm for the proposed scheme can be briefly explained as.

Step 1: Get the Number of Nodes
Step 2: Check for energy level and drain rate
Step 3: Form the cluster based on energy level and drain rate
Step 4: Select the cluster head, which has more energy and drain rate
Step 5: Apply network coding by implementing EXOR operation between packets to avoid the redundant data transmission
Step 6: Select the Master node from the cluster
Step 7: Perform network coding at the master node to reduce number of data transmission
Step 8: The packet decoding will be carried out at the sink node
Step 9: The sink node checks the IDs of native packets one by one

7. SIMULATION AND RESULTS

In order to evaluate the proposed approach, the NS2 simulator is used. The used simulator parameters are listed in the table 1. The performance of the EENC-LEACH is compared with the existing protocol such as EE-LEACH and LEACH. The packet size is considered as 128 bytes, while the transmission rate as 250 kbps. The size of the simulation area is 1200m×1200m and the heterogeneous nodes are deployed over it with a sink node. The metric used to evaluate the performance of these protocols are Packet delivery ratio and network lifetime.

Table 1. Simulation Parameters

Parameter	Value
Simulation Type	NS2 simulation
MAC type	802.11
Simulation time	1000 seconds
Initial Energy of two types of nodes	4 joules, 2 joules
Application type	CBR (Constant Bit Rate)
Protocol	DSR
Network Size	1200×1200
Number of Nodes	30, 50, 70,100, 120

8. PERFORMANCE METRICS

Packet Delivery Ratio: The ratio of amount of packets arrived successfully at the sink node to the amount of packets generated at the source node.

$$Packet\ Delivery\ Ratio = \frac{\sum Number\ of\ packet\ recieved}{\sum Number\ of\ packet\ sent} \quad (8)$$

Network Lifetime: Network lifetime is the time duration till it reaches a point that the maximum number of nodes will be dead after a long run of simulations.

9. DISCUSSIONS

The analysis of packet delivery ratio with respect to simulation time is given in figure 2. The packet delivery ratio is increased when the number of nodes increased in the network. But it may decrease when there is a wrong selection in cluster head nodes.

The proposed EENC-LEACH protocol selects the cluster head based on the draining rate and residual energy and makes the stable clusters in the network when compared to LEACH and EE-LEACH. The EENC-LEACH attains 95 % packet delivery ratio, while EE-LEACH, LEACH attains 85% and 80% respectively.

The analysis of Network lifetime with respect to the number of nodes is shown in figure 3. As the number of

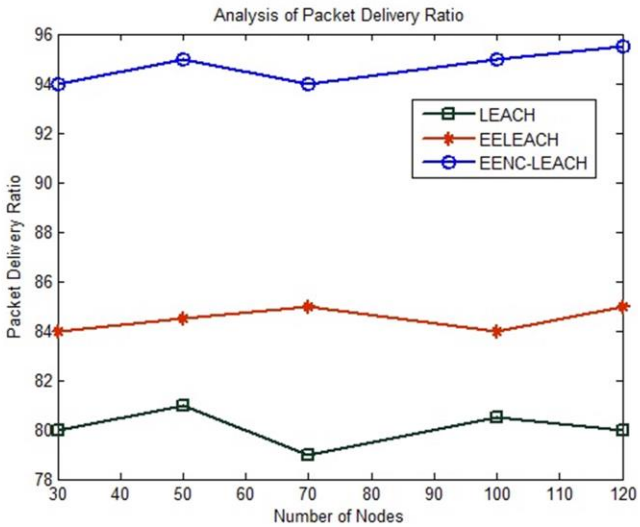

Fig. 2. Packet Delivery ratio with respect to simulation time.

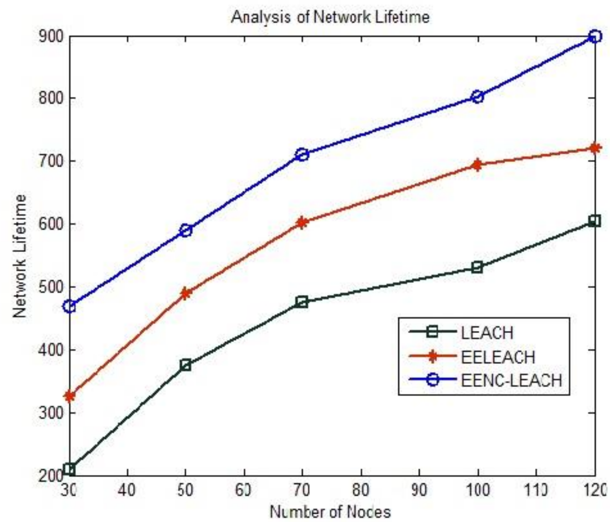

Fig. 3. Network Lifetime with respect to number of nodes.

nodes increases in the network, the network lifetime gets increases significantly due to the presence of a number of nodes for data transmission.

The proposed EENC-LEACH reduces the energy consumption by performing the network coding at the cluster head and master node level. The EENC-LEACH acquires 900 Sec for 120 nodes, while EE-LEACH and LEACH attains 720 Sec and 605 Sec respectively. Normally in any scenario number of nodes will be even in the hundreds. So it is apparent from the results that when the number of nodes is increased, the network lifetime gets increased. If we consider the network size with 30 nodes, the EENC-LEACH acquires 480 Sec, while EE-LEACH and LEACH attains 320 Sec and 220 Sec respectively. In any application, hundreds of sensor nodes are involved and more power will be saved collectively.

CONCLUSION

In this paper, an energy efficient LEACH protocol with Network coding is proposed for WSN. The existing LEACH protocol is modified in the cluster head selection by involving two metrics such as residual energy and drain rate. Afterwards the network coding is applied at the cluster head level. In order to reduce the energy consumption further, master nodes are introduced by forming the zones (group of clusters).In the master nodes, the network coding is incorporated into the LEACH protocol to reduce the number of data transmission in the network. At sink level, the packet was decoded with the native packets. The simulation is performed with the NS2 tool and it is found out that the proposed EENC-LEACH protocol performs better than the existing LEACH and EE-LEACH protocol in terms of network lifetime and packet delivery ratio.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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