

Multi-Level Modleach for Wireless Sensor Networks

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Abstract

Main objective of this paper is to develop a Modified Low Energy Adaptive Clustering Hierarchy (MODLEACH) protocol with multiple levels of cluster Heads. Wireless sensor nodes sense the physical parameters like temperature, pressure, humidity etc and send the obtained data to the base station directly or in multiple hops using other neighbouring nodes in the network as intermediate relay stations. The network lifetime and efficiency depends on the protocol adopted by the network. Many protocols were developed recently, LEACH is efficient cluster based routing protocol and basis for many other protocols. Later MODLEACH protocol has been introduced, which overcomes the drawbacks of LEACH. MODLEACH has a drawback of reducing network lifetime due to excessive power consumption by the cluster head when it is far away from the base station and it dies faster. In our paper, we provide multiple levels of cluster heads, which helps the cluster heads that are far away from the base station to survive a little longer and hence increases the life time of the network. When compared to MODLEACH, multi-level MODLEACH is effective in terms of network lifetime and energy consumption.

Keywords: Cluster Head Formation, Multiple Levels, Network Lifetime, Routing Protocol, MODLEACH

1. Introduction

Wireless sensor networks are a combination of many sensors which sense and process the data and send this information to the base station or other sensor nodes by forming networks by adopting a particular routing protocol¹. These sensor nodes are generally small and very less expensive. These are deployed in the areas where a particular parameter is to be monitored and transmitted to the base station. Recently, the wireless sensor networks are undergoing bi-directional communication i.e. based on the data obtained from the sensor nodes, sensor activity can be controlled from the base station by sending the commands. The recent advancements in technology gave rise to the development of wireless sensor networks and it is widely used in almost all the fields. Hence, wireless sensor networks have become a multidisciplinary subject and find its application in almost all the areas like medical sciences, environmental monitoring, forest fire detections, landslides, earth quake detection, volcanoes monitoring, disaster management and industrial management etc. This can be better explained by taking an example of forest

fire detection. This concept can also be implemented in forest to detect the forest fires and prevent the damage to a greater extent. In order to detect forest fires, sensor nodes that detect the fire based on the temperature are deployed in the forest covering the entire forest area with equal spacing or randomly. Now these sensor nodes sense the data and transmit it to the base station. Whenever there is a forest fire it can be detected with the help of data received by the base station and action can be taken immediately and damage can be reduced to a greater extent. In the similar way, sensor nodes can be placed in the industries to maintain the physical parameters at the required level and prevent the damage to the machinery by avoiding fire accidents. However, these sensor network nodes are limited with respect to many design issues² like network lifetime, power consumption etc. Each node requires a power source for performing these tasks, which is achieved by installing a battery for every sensor node. These sensor nodes are generally installed in remote places where manual replacement of batteries is not feasible frequently. Hence, power consumption plays an important role in sensor networks.

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For increasing the network lifetime, implementing an efficient routing protocol is needed. Many protocols are developed recently for addressing different problems in wireless sensor networks. All the existing routing protocols in wireless sensor networks can be classified into the following basic types: direct transmission, hop to hop transmission and cluster based transmission methods. In direct transmission³, data is transmitted directly from the sensor node to the base station without any intermediate nodes. This provides data security but not suitable for the nodes which are deployed at large distances from the base station as it requires large amount of power to transmit packets to large distances. This protocol has the drawback of creating a communication gap in the areas far away from base station due to death of node because of excessive power consumption and draining of power source. In hop to hop technique, data is transmitted in multi hops through multiple nodes and finally to base station. This rectifies the problem arising in direct transmission method. A transmitting node first sees for the route to transmit data to base station and then transmits it to nearest available node. This also gives rise to a problem that is similar to direct transmission. In this method, the nodes that are near to base station die faster as all the traffic is directed through them. In cluster-based algorithms, all nodes in a particular network form clusters and elect one cluster head⁴. This cluster head receives and aggregates the data from other nodes and transmits it to the base station. It also transmits the data received from base station to respective nodes. This is a hierarchical routing algorithm. Instead of direct cluster head to base station data transmission, transmitting in multiple hops i.e. transmission takes place with other cluster heads as intermediate nodes and eventually to base station would enhance the network lifetime even more, when cluster head is far from the base station. Based on clustering technique, many protocols are developed. Some of them are LEACH, TEEN⁵, SEP⁶, DEEC⁷ and PEGASIS⁸ etc. Among them LEACH is prominent and gives rise to many other protocols.

2. Leach Protocol

Low Energy Adaptive Clustering Hierarchy also called as LEACH protocol is a cluster-based routing protocol⁹. In this protocol, all the sensor nodes sense the data and transmit this sensed data to a cluster head which is

clearly explained in the Figure 1. The cluster head then aggregates the data and transmits it to the base station as shown in Figure 1. Cluster head formation involves setup phase and steady state phase. In setup phase cluster heads are elected and they send an advertising message to all the other nodes. Based on the received signal strength from different cluster heads, each non-cluster head node chooses its cluster head and sends a join request to that particular cluster head. In steady state phase, cluster head prepares the TDMA schedule to its member nodes and sends it to them. A member node can send its data only in the time slot allotted to it in the schedule. Every sensor node generates a random number between zero and one. If the number is less than the threshold $T(n)$, then it is elected as the cluster head¹⁰.

$$T(n) = \begin{cases} \frac{P}{1 - p(r \bmod (\frac{1}{p}))}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

Where p is percentage of cluster heads and G is the set of nodes that have not been cluster heads for $1/p$ rounds.

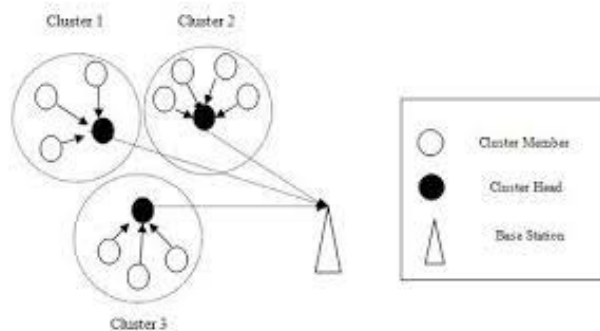


Figure 1. Leach data transmission process.

This protocol randomly picks up the cluster head and new cluster head is elected for every round by performing cluster head formation. This leads to unwanted overhead, which in turn leads to the wastage of limited energy. Once initially a cluster head is elected, it gets chance only after $1/p$ rounds. And in some cases there is a possibility that electing of new cluster head may not be necessary if the previous cluster head has not spent much of its limited energy. And sometimes there is a chance that some low energy node replaces the existing cluster head during next head formation. So, there is a need of cluster head replacement which is a bit efficient, where replacement of cluster head for every round is limited by taking into consideration the

remaining energy of existing cluster head. Also LEACH uses the same amplification energy for transmitting data irrespective of distance from source to destination, which causes energy wastage. This can be better illustrated with the help of an example. Transmitting a packet from node to cluster head with amplification level required by a cluster head to base station is wastage of energy. So, in order to save energy, we need to adopt a transmission mechanism which specifies different amplification energies required to communicate with cluster head or base station. To solve the above problems in LEACH, we introduce MODLEACH protocol with dual transmitting power levels and efficient cluster head replacement.

3. Modleach Protocol

Basically, by this approach, network lifetime can be improved by introducing two techniques. In LEACH protocol, cluster head is formed for every single round and once a cluster head is formed, it will get the chance of becoming cluster head only after next $1/p$ rounds. Here p is the probability of certain node to become a cluster head. Whereas in MODLEACH protocol, we set a threshold and if present cluster head has not utilized much of its energy within its tenure as cluster head and has energy which exceeds the required threshold energy level, it will continue as cluster head for the next round also. Thereby minimizing the energy wastage due to cluster head election process and routing packets to new cluster head. If the cluster head has lesser energy than the required threshold, then the cluster head is replaced in accordance with LEACH algorithm. Besides using efficient cluster head formation, it also uses dual transmitting power levels. Generally, transmission can take place in three ways:

- Intra-cluster transmission
- Inter-cluster transmission
- Cluster head to base station

Intra-cluster transmission is communication between sensor nodes and cluster head i.e. within the cluster. Inter-cluster transmission is communication between two cluster heads. And the othertype of transmission is between cluster head and base station. For all kinds of transmissions, LEACH protocol provides the same amplification energy levels. But, amplification energy requirement is not same for inter-cluster and intra-

cluster communication. Using lesser energy for intra-cluster communication when compared to inter-cluster communication saves a large amount of energy. The routing protocol switches it to low power level or high power level amplification based on whether the node acts as cluster head or as a cluster member respectively.

4. Proposed Model

In applications of wireless sensor networks, where nodes are randomly distributed over a large area, MODLEACH cannot be the effective way of routing the packets. Because, if the cluster head is far away from the base station (as the coverage area is very large), then transmission power increases significantly and the cluster heads that are far away from the base station die fast. In the other case, if we use multi-hop technique between cluster heads, then the cluster heads that are nearer to the base station die faster as all the traffic is routed through them. To overcome this problem, we introduce the concept of various levels in MODLEACH protocol. In the proposed model, Cluster heads are divided into multiple levels so that every cluster head transmit data to its next level i.e. n^{th} level cluster head transmit the received packets from $(n-1)^{\text{th}}$ level cluster head to $(n+1)^{\text{th}}$ level cluster head, instead of direct transmission to base station¹¹. In a two-level modleach (2L-MODLEACH), after collecting data from the member nodes, level-1 cluster head forwards the same to level-2 cluster head, which in turn aggregates the data and forwards it to the base station¹² as shown in Figure 2. In the Figure 2, $CH_{11}, CH_{12}, CH_{21}, CH_{22}, CH_{31}$ are the level-1 cluster heads which receive the data from member nodes and transmit it to the level-2 cluster heads. In Figure 2, CH_1, CH_2, CH_3 can be said as level-2 cluster heads.

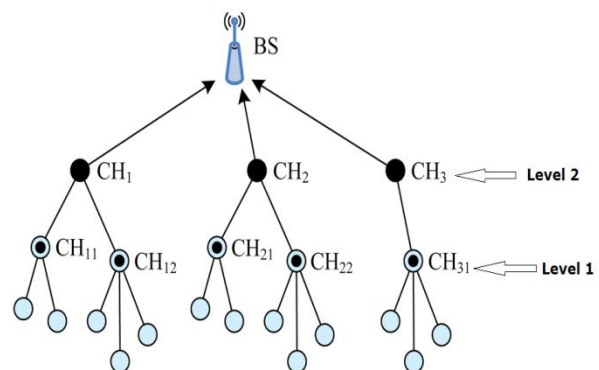


Figure 2. 2L-MODLEACH transmitting structure.

4.1 Selection Process of Cluster Heads in Multi-Level MODLEACH

As the network size increases based on the application, we can increase the number of levels in the multi-level MODLEACH protocol. In this multi-level MODLEACH protocol, level-1 cluster heads are elected in the same way as the MODLEACH protocol. After electing level-1 cluster heads, the cluster heads with maximum residual energy and proximate to the base station is elected as the level-2 cluster head. In addition to its present position as level-1 cluster head, it also acts as level-2 cluster head. Based on the residual energy remaining in the level-2 cluster heads and the nearest distance ones from the base station are elected as level-3 cluster heads.

4.2 Setup Phase

In this model, level-1 cluster heads are elected as per the MODLEACH protocol. After electing level-1 cluster heads, the leaf nodes receive the advertising message from all the cluster heads of level-1 and based on the received signal strength they join one of the cluster and send acknowledgement and its ID to that particular cluster head. Each level-1 cluster head records the leaf nodes IDs. Setup phase of level-2 cluster heads is similar to the level-1 cluster heads where level-1 cluster heads are treated as leaf nodes. Level-1 heads send their IDs and their associated member nodes to level-2 heads. This process continues till the last level and the final level cluster heads prepare the TDMA schedule for all the nodes based on the received information and broadcasts the message.

4.3 Steady State Phase

Based on the TDMA schedule, the nodes transmit the sensed data to their respective cluster heads in their allotted time slot. The nodes can be kept in sleep until their allocated time slot to save the energy. Level-1 cluster heads receive and aggregate the data from the leaf nodes and forward it to the level-2 cluster head. This process continues and finally the data is received by the base station. Significant amount of energy can be saved with this type of routing protocol.

5. Simulation Results

To simulate the proposed model, some of the assumptions

are considered. They are: The nodes with same initial energy are deployed over an area randomly and base station is provided with replenished source of energy. In this model, we have compared MODLEACH and two-level MODLEACH which comes under the multi-level MODLEACH and performance analysis is presented using MATLAB software. In order to analyze the performance we have considered few parameters, which are tabulated in Table 1. The parameters like area of sensor network, number of nodes, initial energy given to each node, packet size, energy dissipated etc. are considered as per the below given Table 1. In the Figure 3 and Figure 4, the performance analysis of MODLEACH, 2L-MODLEACH is made with respect to the dead nodes and packets transferred to the base station for number of rounds using MATLAB. Figure 3 shows number of dead nodes in the network as the number of rounds increases. Number of dead nodes indicates the network lifetime indirectly. As the number of dead nodes increases, the network lifetime decreases gradually. As the network lifetime increases efficiency of the network also improves. Figure 4 shows the packets of data transferred to base station as the number of rounds increases. The following parameters are used for the purpose of simulation: From Figure 3, it is clear that MULTI-LEVEL MODLEACH outperforms MODLEACH and number of dead nodes is less in MULTI-LEVEL MODLEACH i.e. 2L-MODLEACH when compared to MODLEACH. Also, number of dead nodes further decreases with the increase of level. From Figure 4, we can say that MULTI-LEVEL MODLEACH is better than the MODLEACH as number of packets to BS is high for 2L-MODLEACH and more information is received by BS when compared to ordinary MODLEACH. So, from the obtained results, it can be stated that multi-level MODLEACH has higher network lifetime when compared to LEACH and MODLEACH.

Table 1. Assumed Simulation Parameters

Parameter	Value
Routing protocols	MODLEACH, 2L-MOD-LEACH
Deployment area	500*500 m ²
Number of nodes	500
Packet size	25 bytes
Initial battery power	1J
Energy dissipated in Tx, Rx	50 nJ/bit
Nodes deployment	Random

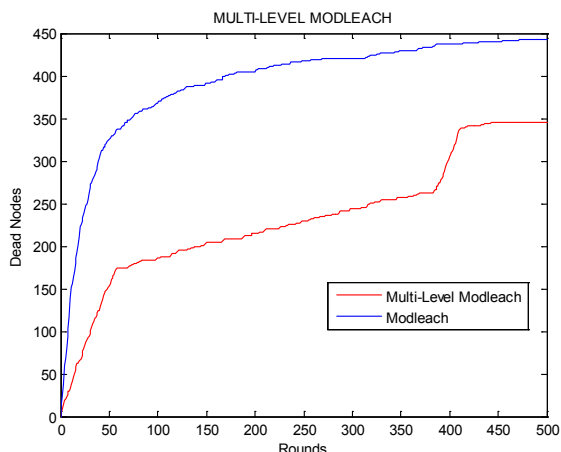


Figure 3. Number of rounds against dead nodes.

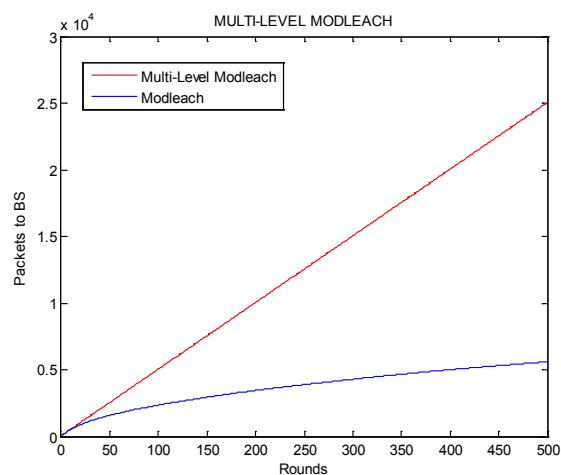


Figure 4. Number of rounds against packets to base station (BS).

6. Conclusion

An efficient protocol is proposed and the same is simulated using MATLAB software. MODLEACH

protocol outperforms MODLEACH and extends the network lifetime significantly. This protocol can be further enhanced by increasing number of levels and introducing soft threshold and hard threshold levels as per requirement of the application.

7. References

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