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A Review on Leach: An Energy Efficient Protocol in Wireless Sensor Networks

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ABSTRACT
Wireless sensor networks (WSNs) are networks that comprise of many cheap, low power devices with sensing capability, limited processing and wireless communication capacity. Energy saving is the essential issue in designing efficient wireless sensor networks. The energy consumption of the sensor nodes determines the lifespan of the network. LEACH is a clustering technique that extends a network's lifetime by minimizing the energy consumed and creating efficient energy distribution within the network. In this paper, we review Low Energy Adaptive Clustering Protocol (LEACH) which is a hierarchical protocol which provides solution to energy consumption issues of wireless sensor networks. We analyze several modifications made to LEACH to further curb the energy consumption.

KEYWORDS: *Cluster, Cluster Head, LEACH, M2M, Routing protocol*

1. INTRODUCTION

WSN is an inter-connection of devices that houses sensors with capabilities to detect and respond to some type of physical or environmental input such as pressure, temperature, light, sound, heat etc. the output of these sensors are usually electrical signals that are transmitted through wireless links for onward processing and utilization. These networks are highly distributed and self-organized D. Estrin et al. (2001), Mr. Ankit Gupta et al. (2012). WSN explores different topologies for its communication, these topologies could be star, tree or mesh and the different types of WSN are mainly categorized based on environmental deployment and purpose, which are; Terrestrial, Underwater, multimedia and mobile WSN just to mention a few. The application of WSN technology is endless in areas such as health, transportation, IoT, environmental monitoring, security etc. Wireless sensors are usually tiny in nature but fitted with sensing and computing circuits, a radio transceiver and power element, M. A. Matin et al. (2012). The primary energy source for WSN is a battery with finite life span, so for efficient utilization of the nodes there arose the need for protocols that would ensure efficiency energy utilization of the nodes which will in turn extend the life span of the network.

The two major areas where strategy could be employed to combat this energy efficiency challenge are physical layer and MAC layer. The physical layer technique deals with designs of circuitry for power storage and dissipation and the quality of materials while the MAC layer involves protocols that coordinates the operation of the devices in the network to achieve the intended purpose Zhihua Lin, et al. (2020).

2. LEACH PROTOCOL

LEACH protocol is a self-organizing protocol that aid efficient utilization of energy. It is hierarchical in characteristics where the parent node of one cluster could be the child node of another cluster as shown in figure 1.1. The position of cluster heads is rotated based on some defined parameters such as residual energy, distance of the node from the sink, position in the cluster etc. It distributes the load in a network and it is assumed that each node in the network has a transmitter with capability of reaching the sink directly. LEACH features in both centralized and decentralized clustering protocol where the activities of the nodes in the network are coordinated by the sink and the nodes respectively Juma W. et al. (2018).

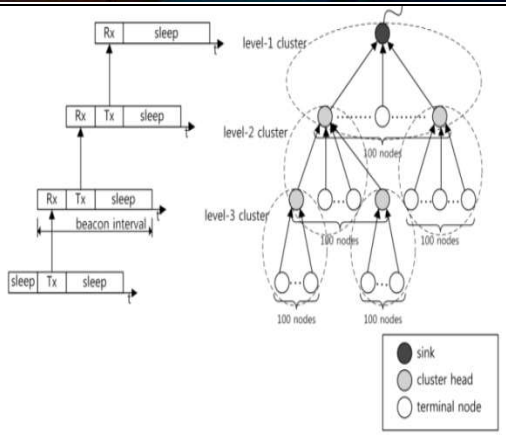

Figure 1.1 LEACH Cluster Network. Ieryung Park. *et al.* (2014).

LEACH has two phases that describe its operation; the set up phase and the steady state phase, Prabhat Kumar et al. (2012). The cluster is set up and cluster head selection is done under the set up phase whereas the sensor nodes sense their areas and send relevant generated packets to their Cluster Head (CH) in steady state phase. LEACH protocol has several rounds of communication which rotates the responsibility of CH to further balance the energy in the network. A CH is randomly selected. All the nodes in the network pick a number randomly between 0 and 1. The node that select a random number that is less than the threshold for node n then that node becomes the CH for that round. The value for the threshold T (n) can be calculated using the formula.

$$T(n) = \begin{cases} \frac{P}{1-P\left(r.\mathrm{mod}\frac{1}{P}\right)}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases}$$

Where; P = the desired percentage of the CH node.

r = the number indication the current round of communication.

G = set of nodes that have not been selected as CH node in the previous 1/P rounds.

When CH has been selected successfully, it broadcasts a beacon message to other member nodes. Based on the received signal strength of the beacon message, other nodes decide to which cluster they will join for the current round and send a membership message to their respective CHs. After the exchange, the cluster formation completed.

In the steady state phase, the CHs create TDMA schedule for all the member nodes in their respective clusters. The set of slots assigned to the nodes of a cluster are called frames; Hicham O. et al (2019). The duration of each frame differs according to the number of cluster members of the cluster. When these member nodes generate or sense data they forward to their respective CHs based on the assigned time slot and shut down their radio after successful transmissions. The CHs aggregate the data from the member nodes, compress and forward to the sink. After a predetermined time, the network moves to a new round. This process is repeated until all nodes in the network are elected CH at least once all through the previous rounds. After which the round is reset to back to 0 then the process starts all over again.

The transceiver consumes more of the dissipated energy in the sensors Meenakshi S. et al. (2012). The transceiver is made up of transmitting and receiving circuits embedded in the nodes and the sink. The transmitter circuit uses more energy compared to the receiver circuit. The different power dissipated by the receiver and transmitter is calculated by the following formulas:

Transmitting: Divya Prabha. *et al.* (2018).

$E_{TX}(k,d) = E_{TX} - \{(E_{elec} * k) + (E_{mp} * k * d)\}$ (2)

$E_{TX}(k,d) = E_{TX} - \{(E_{elec} * k) + (E_{fs} * k * d)\}$ (3)

$E_{TX-}(k,d) = \varepsilon fs * d^2 * k \ if \ d < d0$ (4)

$$\varepsilon fs * d^4 * k \ if \ d \geq d0$$

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}} \quad (5)$$

Receiving: Divya Prabha. *et al.* (2018).

$E_{RX}(k) = E_{RX} - (E_{elec} + E_{DA}) * k$ (6)

Where, E_{elec} = denotes amount of Energy consumption per bit in the transmitter or receiver circuitry.

E_{mp} = Amount of energy consumption for multipath fading.

E_{fs} = Amount of energy consumption for free space.

E_{DA} = Data aggregation energy.

Where k is the message size and d is the distance.

The novel LEACH has some advantages and disadvantages. These merits and demerit have geared different researches toward improving the protocol's performance in different metrics. Below are some of these advantages and disadvantages.

Advantages: Prashant Maurya *et al.* (2016).

1. LEACH is a completely distributed approach.
2. It does not require any global information of network.
3. It is a powerful and simple routing protocol.
4. It uses random rotation of Cluster-Head, which provides each node to become a cluster head node in a round.
5. It uses TDMA so that each node can participate in rounds simultaneously.
6. Each sensor node communicates only with associated cluster head (CH). It provides localized co-ordination and control for cluster setup and operation.
7. Only a cluster head node (CH) aggregates the data collected by the nodes to minimize the data redundancy.

Disadvantages: Prashant Maurya *et al.* (2016).

1. In LEACH Protocol only cluster head (CH) is responsible for sending data to base station (BS) directly. So, failure of CHs leads to lack of robustness.
2. Single Hop Routing technique is used in LEACH Protocol, which needs high energy for data transmission from CH to BS directly in case of large network.
3. Selection of CH in any round is random and does not consider energy level of node, which can lead to drainage of a particular node.
4. Dynamic clustering technique is used in LEACH which results in extra overhead like selection of CHs and advertisement.

For the purpose of this paper, we review the different modifications made on different variants of LEACH employed to tackle energy waste due to contention for channel access for network performance through measured metrics such as throughput, packet loss and energy efficiency.

3. LEACH VARIANTS

There are several variants of LEACH protocol based on deployment and node behavior in a given network.

3.1 LEACH-C (CENTRALIZED LEACH)

C-LEACH as it is famously called is a centralized clustering algorithm. The information obtained about the location and energy level of each node in the setup phase is used by the sink to compute the average energy level of the network. The sink runs a simulated annealing algorithm for nodes whose energy level is higher than the threshold to select the CH nodes. The node whose ID matches the advertised ID from sink is selected as CH Gnanambigai J. et al. (2012). The steady state phase is the same as for the novel LEACH. Due to the centralized technique, the sink has the overall knowledge of the network coverage area; hence less energy would be consumed by the entire network. It performs more data transfer per unit of energy. This centralized scheme makes it not suitable for larger network.

3.2 GRID LEACH

The deployment of sensors in this variant of LEACH is done in a grid format; Alireza Firuzbakht. Et al. (2013). The network is separated into independent grids with virtual grids. The node inside the grid with zenith energy level which is also close to the center of the cluster and sink is selected as CH. The data is sensed by a virtual square and forwarded to CH which is then aggregated and transmitted to sink. In this variant, sensor energy is conserved by making the transmitting node only to be the active mode while other nodes will be in sleep mode.

3.3 MULTI-HOP LEACH

The Multi Hop LEACH is akin to novel LEACH protocol except the direct data transmission

to sink. When the desired data is collected by CHs from their cluster nodes, they will transmit them serially through other CHs to the sink. So therefore, the distance between the nodes gets decreased which then conserved energy for data transmission. By raising the number of hops, the lifetime of the network will be improved efficiently Gnanambigai J. et al. (2012). The main tradeoff in this technique is the delay that occurs in the transmission.

4. MODIFICATIONS OF LEACH FOR EFFICIENT ENERGY UTILIZATION

Enhancement of LEACH by application of Radio Frequency through embedding active, ready and sleep communication modes whithin the network was done by Navdeep K. et al. (2016). The active mode was used only to sense data, the ready mode was used to sense and also transmit data from node to the sink whereas the node in sleep mode reduces the energy consumed and also balances the energy loads of the CHs. The term RFID-LEACH was coined as a name for their proposed method. They experienced challenge with clock synchronization which was one of the properties of RFID. This problem was tackled using contention avoidance algorithm (RTS/CTS). This technique described a scenario where CH node send request to send (RTS) packets containing a nonse feed to all its cluster members (CM), the CMs would adapt their clocks to the feed and reply with clear to send (CTS) to achieve synchronization. The RFID-LEACH scheme was simulated on NS2 and graphical results showed better performance than LEACH and RFID protocols in terms of throughput, efficient energy utilization, less end-to-end delay and overhead in the network.

A similar work on a variant of LEACH, where they introduced two new techniques to the novel protocol; the cluster head replacement scheme and dual transmission levels to aid efficient energy utilization Ms. Neha Bhadu, et al (2017). MODLEACH as the protocol was termed does not take into consideration the influence of parameter p which defined the probability of becoming the CH; instead, a mathematical analysis was done to select a nominal value of p. The estimated value of p was also varied and the impact was measured through simulations on MATLAB. MODLEACH performed better than LEACH in terms of network lifetime and packets exchange with base station.

Another work which proposed network efficiency by introduction of vice cluster head, the algorithm allowed one node in the cluster to be selected as VCH in case the CH dies. When this happens, cluster nodes data will always reach base station in an efficient way and no need to elect a new CH for that round of transmission Sasikala S. D. et al. (2015). K-LEACH as the technique was called employed Kmedoids clustering algorithm for uniform clustering, Euclidean distance and Maximum Residual Energy (MRE) was used to select the CH. This modification to CH selection reduced energy consumption by 33% compared with LEACH. This technique has advantages like efficient transmission of data to sink, improved network lifetime and lower energy consumption K. Kishan et al. (2012).

Most of the modification of LEACH focused on cluster head selection methods, inter cluster head communications etc. An improved work on LEACH channeled its effort towards intra-cluster communication in a hierarchical clustering network. The novel LEACH has two stages of operation; the set up state and steady state. IBLEACH in a quest to improve the performance of LEACH introduced a new state between the set-up and steady state called pre-steady state; Ahmed Salim et al. (2014). The main purpose of this new state was to calculate the cluster workload i.e., the aggregation of the sensed data from cluster members and send to the sink in one frame, then elect a CH that can handle the aggregated processes through all frames in that round; Tong M., et al. (2012). This helped to distribute cluster load overhead over the cluster members. This technique improved network lifetime and balanced energy consumption.

H-LEACH described the modification of LEACH which the cluster heads are fixed and chosen dynamically. This protocol utilized the node location coordinate and clusters the area on the basis of this information; Abdul Razaque et al. (2017). It used the maximum energy of the node to select a CH instead of threshold utilized by LEACH. The lifetime of a CH node could be estimated through the number of rounds. Simulation results indicated better performance than Hybrid Energy Efficiency Distributed (HEED).

EEE LEACH an Energy Efficient Extended LEACH is an energy efficient protocol that increase

energy utilization through creation of multilevel clusters and reducing the radio communication distance. This multilevel clustering protocol involves two layers of cluster formation aside having similar one layer formation between the nodes and the sink; Wairagu G. et al. (2009). The formation of clusters and selection of CHs is achieved in the first layer. Then the cluster members transfer their sensed data to their CHs. Using the fuse mechanism, the CHs aggregate the data received from their cluster members. In the next layer, Master Cluster Heads (MCHs) are selected. The CHs locate the nearest MCHs by calculating the distance between them then transfer their aggregate data to the respective MCHs. Meenakshi S. et al. (2012). In the similar fashion, the MCHs accept data from their nearest CHs, aggregate all received data, convert them into a compress format and forward them to the sink.

DD-LEACH (LEACH with Distributed Diffusion) was designed as an improved LEACH Protocol. This technique utilizes multi-hop routing of data from sensor nodes to sink. Nodes and CH serve as relay nodes to forward packets from other nodes towards the sink. In DD-LEACH Protocol data acumulation is done at multiple levels R. K. Kodali et al. (2016) Firstly, data aggregation is carried out at CH level. The CH collects the data from member nodes. While forwarding data to sink, all the median CHs also perform data aggregation at their different levels. In DD-LEACH energy consumed is alleviated through multi-hop routing communication.

LEACH-A (Advanced Low Energy Adaptive Clustering Hierarchy); In this novel LEACH protocol, CH is responsible for sending data directly to sink which expends high amount of energy than other member nodes in the network. M. Usha et al. (2016). In advanced LEACH, a technique called mobile agent is used to process data. This LEACH variant protocol is defined as a heterogeneous energy inclined protocol developed for the purpose of energy conservation, efficient data transfer, reducing the probability of node failure and for improving the time interval before demise of the first node. Hence, both the energy conservation and data transfer reliability is improved in LEACH-A. This scheme also uses synchronized clock, through which each sensor node gets the beginning of each transmission round. J. Gnanambigai1 et al. (2018).

There is an improved LEACH protocol referred to as MG-LEACH. This modified protocol divides the deployed nodes into sub-groups (G1…. Gk) based on locations of the nodes; where k is a real number. The numbers of groups in this modification are mainly dependent on node density. The groups formation is coordinated by the sink at the time of deployment and after every “r” rounds. Hicham Ouldzira et al. (2019). This is an extra step employed in their algorithm before setup phase and steady state phase called Set building phase. MG-LEACH has three steps. The build phase is utilized during time of deployment after each "r" rounds per sink, and the remaining two are the same as those applied in LEACH such as the set-up phase and steady state phase. This protocol offered better performance than LEACH in terms of energy conservation and efficient utilization. Jong-Yong Lee et al. (2019).

In the same vein of attempt to further reduce the energy consumed in an IoT related environment, this variant of LEACH modified the protocol by initiating a strict threshold for CH selection and retaining the CH position to serve for multiple rounds provided the node has enough residual energy to match up with the task. Siavoshi, S. et al. (2016). The proposed protocol also switches the power between the nodes in a cluster. This protocol focused on the growing demand for IoT devices which the novel LEACH is unable to cater for in terms of energy because of the frequent rotational duties of the CH. This rotation consumes energy. I-LEACH (short for IoT LEACH) maintains a node that has serve as CH in the previous round if the energy threshold value still meets the set criteria. Trupti Mayee et al. (2017). This way the energy wasted during routing information to the new CH in each round can be minimized. The extra energy consumed for the formation of new cluster due to new CH selection can also be mimimized. I-LEACH protocol outperforms LEACH by 67% increase in throughput and extending the lifespan of the network through successful 1750 rounds of communication.

The table 1 summarized the different approach of modification of LEACH, the methods, results, strengths and weaknesses

Table 1 THE DIFFERENT APPROACH TO MODIFICATION OF LEACH

S/N	REFERENCES	PROBLEM ADDRESSED	METHODOLOGY	RESULTS	LIMITATIONS	OPEN AREAS
1.	**Navdeep K., Ranbir S. (2016).**	Efficient Energy consumption, distributed overhead energy	Embedded active, ready and sleep modes using RFID.	The energy consumed was significantly less compared with LEACH even when the number of nodes connected to the AP increased.	Synchronization problem with the protocol because of the property of RFID.	Ways to improve the performance Through clock synchronization of the cluster heads and members
2.	**Ms. Neha Bhadu, Dr. Uma Kumari (2017).**	Energy consumption on radio communication by stations in IEEE 802.11 infrastructure WLAN.	Utilized efficient cluster head replacement and dual transmission levels as means to utilize energy efficiently.	Improved energy consumption and longer battery life for sensor nodes. Increase network life span.	Employed only in homogenous networks.	To be implemented in heterogeneous networks
3.	**Sasikala S. D., Sangameswaran N.,Aravindh P. (2015).**	Failure of selected Cluster Head in the network.	Introduction of Vice Cluster Head (VCH).	Extension of network lifetime in case of cluster Head battery being drained.	Establishment of Vice Cluster Head consumed more energy in the initial set up phase.	Improved technique in selection of Vice Cluster head that will consume less energy in the set up phase.
4.	**Ahmed Salim, Walid Osamy, Ahmed M. Khedr. (2014)**	Evenly distribution of energy in the network between nodes and the CH.	Used the set up phase. Pre-steady state and the steady state to achieve intra cluster communication.	Reduced rate of energy consumption and energy distribution between CH and Cluster members.	Pre-steady sate introduced complexity to the LEACH process and implementation problem.	Ways to execute pre-steady state with less complexity.
5	**Abdul Razaque, Satwic Mudigulam, Kiran Gavini. (2017)**	Life time of network and energy consumed per node	Selection of CH by considering residual and maximum energy of nodes, calculation of alive nodes after every round.	Improved energy consumed by individual nodes and lifetime of the network	Loss of nodes with energy below the threshold even when they are yet to die off completely	Ways to utilize nodes with energy below the threshold through assigning minimum energy consumption task.
6	**Meenakshi S., Kalpana S. (2012)**	Increased Energy efficiency	Used multilevel clusters through radio distance reduction to form MCH which aggregate data from CHs	Increased Energy efficiency and network life time.	Multiple levels of data aggregation that could affect data quality and integrity	Measuring the QoS of data received by the sink efficiently
7	**Hicham Ouldzira, Hajar Lagraini,**	Energy consumption	Division of the clusters into sub groups depending on	Improved energy conservation and	Added "set building state" as an extra step that	Ways for efficient memory

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5. OPEN AREAS

So many modifications have been made to LEACH in a quest to further reduce energy consumed and balance the load in the network but there are still areas that are yet to be integrated to LEACH. This novel protocol has potential to last long in the communication space, its unique way of organizing nodes give it an edge in longevity.

One of the basic operations of LEACH is the arrangement of clusters in layers where the child node of one cluster would be the parent node of another cluster, a cluster head in one cluster is a cluster member in another cluster. These are arranged in layers for ease of packet forwarding to the sink and energy distribution within the network. Contention window adjustment; a technique that devices use to curb contention and collision in communication could be explored in the LEACH space, this has the potential to enable effective Cross-layer communication especially when the number of nodes in one cluster increase astronomically. This would improve the transmission time Sharma M. *et al.* (2012) and throughput of LEACH protocol

6. CONCLUSION AND FUTURE WORK

In this paper, we reviewed the different modification made on LEACH with intention to further reduce energy consumption and improve

network lifetime. We explored the different areas of modification and techniques employed to achieve varying results on energy efficiency, the functionality of the modifications, area of application and comparison of the modification to the novel LEACH and other variants. More parameters could be adjusted to create other modifications that could resolve limitations of current modifications.

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