MACHINE-TO-MACHINE LEACH BASED CROSS-LAYER PROTOCOL FOR ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORKS

BY

ODEH Prince Olah
MENG/SEET/2017/7363

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING (M.ENG) IN COMMUNICATION ENGINEERING.

NOVEMBER, 2021

ABSTRACT

Wireless sensor network (WSN) consists of a group of sensor nodes that enables the monitoring of a variety of environmental information for various applications. In WSNs, it is very important to operate a sensor network for a long time to achieve the intended purpose. Low Energy Adaptive Clustering Protocol (LEACH) is a clustering technique that provides solution to the short life span of a network. It is a self-organized protocol that has been modified with different parameters and direction to achieve long life span of WSN. The demand for information and increase in deployed sensor nodes per area has created limitation for performance of WSN in terms of long life span and energy utilization. Most modifications on LEACH as a solution to energy efficiency in WSN did not capture solution to the effect of this increase. This work was carried out on the scenario of large number of nodes in an area and large number of nodes per cluster to achieve efficient energy utilization and distribution. It entails utilization of contention window (*CW*) adjustment for effective communication within clusters, efficient number of clusters based on deployed nodes and number of neighbors. This technique divides the nodes in a coverage area into clusters. These divided nodes sense data from the field and forward to their respective cluster heads that will in turn send to the upper parent nodes in the upper hierarchy till the packet gets to the sink. The intra cluster communication occurs between nodes in a cluster and cluster heads. The conventional means of intra cluster communication is through direct transmission since it is assumed that the nodes in a cluster are many, the cluster members would compete for channel access to forward their individual packets to the cluster heads. When the *CW* is small it leads to high collision and loss of data and degradation of the network performance when the *CW* is high It leads to waste of channel resources. Optimum contention window adjustment where the active number of nodes is taken into consideration when *CW* is selected for effective channel utilization and reduction of collision was utilized. The high demand of information has led to high number of nodes per coverage area which has become a problem for WSN with direct transmission. Contention Window LEACH (CW_LEACH) showed better performance and longer network lifetime. The total number of rounds of communication was increased by 16% when simulated on MATLAB. The total successful transmission was 2400. This ensured maximization of energy of the nodes through proper utilization of channel, less idle listening and over hearing. This method can be applied in IoT and devices on 5G.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

Acronyms	**Meaning**
BAN	Body Area Network
BS	Base Station
CH	Cluster Head
CM	Cluster Member
CW	Contention Window
DEEP	Decentralized Energy Efficient Cluster Propagation
DIDD	Double Increment Double Decrement
DTx	Direct Transmission
EEH	Energy Enhanced LEACH
EEHC	Energy Efficient Hierarchical Clustering
HEED	Hybrid Energy Efficient Distributed
IoT	Internet of Things
LEACH	Low Energy Adaptive Clustering Hierachy
LEACH-C	Centralized LEACH
MAC	Medium Access Control
MCH	Master Cluster Head
MILD	Multiplicative Increase and Linear Decrease algorithm
M2M	Machine to Machine
VCH	Vice Cluster Head
WSN	Wireless Sensor Network

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Wireless sensor network is simply an interconnection 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. The outputs of these sensors are usually electrical signals that are transmitted through wireless links for onward processing and utilization; Miao *et al.* (2016). It is a self-organized wireless network systems consisting of many low-cost and resource constraint sensor nodes. It can be comprised of hundreds or thousands of sensors, depending on the requirement of quality of service (QoS) and the capability to tolerate a fault, Jyoti *et al.,* (2014). These sensors are battery powered with computational capabilities and low in cost. WSN explores different topologies for its communication; these topologies could be star, tree or mesh. 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.

Over the years this technology has undergone several improvements through research in the different areas of applications which covers distribution, communications, data processing, interconnection and energy efficiency which is the focus of this research. Wireless Sensor Networks (WSN) are on high demand Zhang *et al.,* (2016). This is due to revolution in technology that needs independent processing, detection and activation of gadgets Patil *et* *al.*, (2016), applications of internet of things (IoT) Kumar *et al.*, (2016), body area network (BAN), wireless sensor network (WSN) and machine to machine (M2M) communication. However, to achieve better performance of the network, many researchers such as Wei *et el.*, (2015), Alkadeki *et al.*, (2015), Zhang *et al.*, (2016) have leverage on the use of Wireless Local Area Network WLAN to achieve communication in M2M. To do this, IEEE 802.11 standards remains important.

1.1.1 Physical deployment of devices in WSN:

Star Topology: This topology is the type of topology where each node connects directly to the gateway or sink. A single sink can send and receive packets from different remote nodes. In this topology the remote nodes are not allowed to send packets to each other. Communication between remote nodes has to be routed through the gateway or sink. This characteristic brings about low latency communications between the nodes and the sink.

Tree Topology: This topology is also known as cascaded star topology in which each node connects to a node that is placed higher in the tree and then to the sink. The main advantage of tree topology is that the network could be expanded easily and also detects errors easily. The disadvantage of this topology is that it depends heavily on the bus cable. If the bus cable breaks, the whole network will collapse.

Mesh Topology: The mess topology allows transmission from one remote node to another which is within its transmission range, and if a node wants to communicate with another node that beyond its transmission range, it uses another remote node as an intermediate node to forward the packet to the desired node. The advantage of this topology includes easy detection and isolation of fault in the network.

Nodes in the fields are connected to the central node called access point as shown in Figure 1.1. In other words they collect data from their environment and then relay it to the access point (AP) where necessary action is decided. The information could be temperature, pressure or any other environmental metrics.

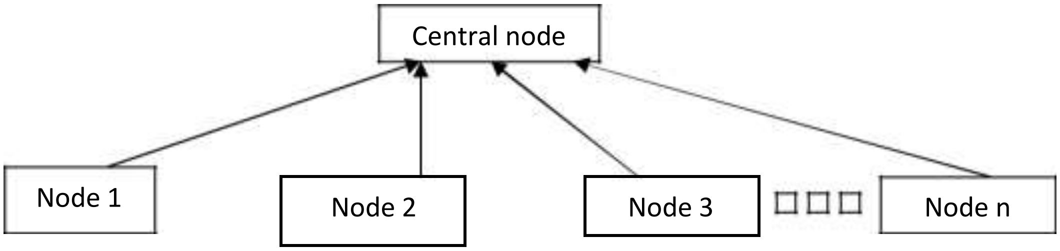


Figure 1.1 Node Communications in Wireless Network (Vojislav *et al.* 2015)

With the topology considered above (which is an equivalent of start topology), it is obvious that Nodes 1 to Node n will all contend for the channel resource to communicate with the central node. In this research, part of the focus is on improving the power safe mode of the nodes.

There are different ways nodes communicate in a network environment depending on the number of nodes, their states (active or inactive) or their position (mobile or static). The aim of deploying nodes to an environment is to extract relevant data from the environment for onward processing and utilization, in other to achieve this aim and maximize resources, multiple nodes are deployed at the same time and the method of deployment also differs. These deployed nodes do communicate with each other and with the sink. This gives birth to the term cooperative communication, which is a scheme that provide solution for effective communication among nodes in a network to achieve some objectives such as energy efficiency in the network; Vojislav *et al.,* (2015), efficient channel utilization, increase in network operation period, reduction in network interferences, expansion in coverage, transmission reliability, network throughput and network stability.

One of the major areas of cooperative communication which forms the basis of this research is clustering. This is the grouping of sensor nodes or communication devices to form clusters for the sole purpose of attaining efficient usage of network resources. Clustering technique help to utilize energy efficiently and reduce collision at the network access point. The access to the network gateway or sink is through the cluster head which also aggregate all the data from the cluster member nodes. Peng *et al.,* (2014). Clustering protocols define the topology of the hierarchical non-overlapping clusters of sensor nodes in the network. An effective clustering protocol ensures the creation of clusters that are described with the radius that is similar and perfectly positioned cluster head to serve all cluster members with equity. All nodes in the network that is clustered are linked to the selected cluster head. The cluster heads find their own appropriate routes to the sink in the network. When considering a sensor network that is covering a wide area, clustering approach will reduce complication in the network. (Sucasas *et al.,* 2016).

All the clustering protocols have elected to choose the cluster head first then the cluster members align accordingly based on some criteria. Border nodes join the nearest cluster and sometimes serves as gateway for inter cluster heads communication.

1.2 Statement of the Research Problem

The focus in LEACH and other clustering protocols has been on efficient energy utilization and channel access through effective energy distribution in clusters and effective communication between cluster nodes and cluster heads then cluster heads and sink. Little has been done on inter cluster communication through the use of border nodes as gateway or relay node and also few have considered intra cluster communication. The number of nodes in a cluster could vary depending on coverage area and total number of deployed nodes in the network. The aim of energy efficiency is defeated when the members of a cluster that contend to forward their packets to the cluster head is high. An M2M network might possess hundreds or thousands of nodes (devices) densely located over small or medium area due to the demand for information and growth of number of devices that extract or deliver the needed information Zhang *et al.,* (2012). When this happens, the number of nodes in a small cluster area will grow exponentially, the effective communication with less contention and energy waste due to idle listening between cluster nodes and cluster heads, child node and parent node will go a long way to determine life span of the node and indirectly the efficiency of the network. We propose optimum contention window adjustment for optimum selection of window period for active nodes for effective channel utilization, energy efficiency and reduction of packet loss due to collision.

1.3 Aim and Objectives of the Study

The aim of the research is to develop a machine-to-machine LEACH based cross-layer protocol for energy efficiency in wireless sensor networks. This would be achieved via the following objectives.

1. To develop a cross-layer contention window based LEACH protocol
2. To simulate the scenario with defined network parameters
3. To evaluate the overall network performance in terms of energy efficiency and distribution.

1.4 Justification of the Research

Since idle listening and overhearing during communication in WSN network is one of the major reason for more power waste Wei *et al.* (2015), which is also a problem with intra cluster communication with cluster heads due to the use of direct transmission (DTx). We propose optimum contention window adjustment based on active nodes in a round as solution to a large number of nodes in a cluster communicating efficiently with their cluster heads in a LEACH network to further reduced energy consumed during idle listening, overhearing and balance the load in the network. The contention window is adjusted strictly based on active nodes in the cluster. Based on our research, no method like this has been applied to hierarchical intra cluster communication.

1.5 Scope of the Study

The scope of this work is limited to enhancing the energy performance of a LEACH hierarchical clustering protocol through contention window adjustment based on active node in rounds of transmissions, analysis of results and comparison with the Novel LEACH protocol. This work provides solution to a scenario where the number of deployed nodes is high which brings with it the challenge of intra-cluster communication and effective power management. Optimum contention window adjustment is applied to manage the competing nodes for channel access through selection of window size based on the number of active nodes with packets in their buffer then the nodes multi-hop their packets through other nodes to the sink. The investigation carried out suggests that this technique display superior performance when the number of deployed nodes over a coverage area is very high.

1.6 Thesis Outline

This rest of this thesis is structured as follows; Chapter 2 has the Literature review that presents various techniques proposed by different researchers to combat the challenge of WSN short battery life and improve the performance of the networks, LEACH, modifications of LEACH. Chapter 3 presents Research Methodology and how the aim and objectives of this research was achieved. Chapter 4 has the presentation of result and discussion, Chapter 5 has the Conclusion and Recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Literature

In recent times, Wireless sensor networks (WSN) have expanded to accommodate a wide range of applications, such as monitoring or tracking targets in specific fields like active volcanoes, healthcare, precision agriculture, underground mining and transportation. WSN consists of cheap sensor nodes that collect real-world data, process it, and transmit it to the destination via radio frequency. The coverage and communication range of sensor nodes are limited by energy of the nodes. The largest energy consumer in wireless sensors is the transceiver Althobaiti & Abdullah, (2015); Odey and Daoliang, (2012). The effective use of the limited energy is the primary goal of the design of media access control (MAC) protocol for WSN Lakshmisudha & Arun (2013). The MAC protocol can manage the performance of the transceiver because they have the greatest impact on the communication mechanism. One of such MAC protocols is LEACH. It divides the coverage area into clusters Ankit *et al.,*(2012). A node is selected randomly as cluster head and this process is rotated to avoid one node serving as cluster head twice which could deplete its energy fast. The set up phase involve the forming of clusters and selection of cluster heads based on some parameters such as residual energy and previous selection. It uses a probability *1/p* to select the cluster head of a cluster, Vishal, (2018). The steady state the sensed data are transmitted to the cluster head which then aggregate and forward to the sink or base station. This protocol has the advantage of distributing energy overhead in the network and extending the life span of the network through efficient energy utilization Kajal *et al.,* (2013). So many researchers have channeled their efforts towards conserving energy in sensor nodes. In M2M, the reason for such research is to ensure that constrain resources like power is adequately managed. The quest for more energy utilization has led to creation of other variant or modified LEACH protocols that made progress to enhance the life span of the node in the network. In this section, related works as done by other researchers is fully discussed.

2.2 Machine-To-Machine Communications

Machine to machine (M2M) is the direct communication between devices using any communications channel, including wired and wireless without the intervention of sink or base station (BS). M2M communication can include industrial instrumentation, enabling a sensor or meter to communicate the information it records such as temperature, inventory level, etc. to application software that can use it. Nodes in a WSN can communicate with each other for the purpose of sharing information, location or acting as relay to forward packets to another node. Many researchers have leverage on this type of communication to proffer solutions to challenges in different areas of WSN.

In Wei *et al.,* (2015), in the quest for enhancement of energy efficiency in M2M, the authors worked on the sensor nodes for energy efficient utilization in M2M communications. The technique used to achieve the enhancement was Deep Sleep; this technique was divided into two categories, Energy-Aware deep sleep which provided high channel priority access to low energy nodes and allowing them to sleep longer. Controlled Access, which is the other part that reduces the number of active nodes and lowers contention for channel. With this research, the overall outage probability was reduced.

Furthermore, application layer loss rate and collision probability were reduced. In the application of deep sleep, nodes with energy less than threshold is made to sleep and given higher priority to transmit when they wake up. NS2 was used to simulate the result for the enhanced IEEE 802.11. The shortcoming of this research arises when the number of nodes increases exponentially; this reduces the efficiency and increases energy loss due to idle listening and collision of packets and contention.

Similarly Amjad *et al.*, (2017) considered the enhancement of M2M communication by applying visual sensor network so as to utilize visual information. However, energy efficiency within the visual sensor network remained an issue. Energy conservation was achieved via targeted threshold based optimization which had impact on the quality of information. This was however solved via the use of self-reconfiguration scheme for visual sensor nodes. This technique aids energy conservation in visual sensor network and maintains the quality of information generated by the network. With this scheme the result shows energy conservation of 59.21% more than conventional schemes.

In a related development, Ali and Rejeb, (2018) worked on energy conservation strategy for M2M differentiated services in 5G. Their work was channeled towards solving increased collision due to the increase in the number of nodes competing for the channel. As a result, the performance of the random access channel drastically reduced. With this, many nodes would experience outage due to fast depletion of energy. The strategy used was aimed towards increasing energy efficiency by reducing access attempt for M2M delay sensitive applications and delay tolerant ones. With this, access success probability and energy conservation was increased.

Likewise Ozcelik *et al.,* (2017), in the quest to solve energy efficiency in home M2M devices, proposed an integration architecture that can suit existing components. To achieve their aim, a long sleep algorithm schedule was applied to existing IEEE 802.11 power safe mode. The result showed efficient safe in the M2M communication.

Ali *et al.,* (2019) presented a resource algorithm allocation termed threshold controlled access protocol to solve problems in energy conservation in M2M communication in the technique used “uplink resource allocation”, devices make decisions of resource allocation based on battery status and related application power profile which lead to good quality of service in the network. The result of their work showed that the technique was less complicated and had better performance compared to literatures they reviewed.

Also Deshpande *et al.,* (2015) presented an improved M2M clustering method to enhance energy conservation. The results of this method were compared with the result of Low energy adaptive clustering hierarchy and energy aware multi-hop path hierarchy. Better performance was observed with the improved M2M clustering method.

Al-kaseem, (2016) presented a new clustering mechanism with smart sleep mode to prolong M2M network life time. Furthermore, the technique promotes better connectivity. Also, sink mobility was considered to provide load balancing and reduce end-to-end delay. With the use of MATLAB, smart sleep M2M protocol was simulated and the result showed energy conservation enhancement by 78% compared to existing algorithm reviewed. Also, there was an increase in packet sent to the sink by 82%.

Meanwhile, Shah and Shoaib, (2019) presented a simple an uplink centric approach to achieve improved energy conservation in M2M devices. Working on the existing architecture that involves massive number of ubiquitous devices, optimized slot aloha is used for M2M communication since previous aloha worked well for less traffic. The technique used adjusts the delay time for transmission slots mainly for small sensor devices used in M2M application. Energy efficiency was increased by 60% compared to other techniques and life time of 45% while keeping through put steady.

Twayej, (2017) presented a routing protocol which is a multilevel clustering multiple sink (MLCMS) with IPV6 protocol over Low Wireless Personal Area network (6LOWPAN) based on smart sleep mode. This was used to enhance life time of the node. In this technique, the whole field was divided into quarters with cluster heads. Result shows that MLCMS performed better than other schemes like modified low-energy adaptive cluster hierarchy (MODLEACH) protocol. The performance is 75% better than MODLEACH in energy efficiency. Life time of the node improve by 12%.

Yang *et al.,* (2017) used an energy efficient power control and time scheduling scheme in M2M communication with none-orthogonal multiple access (NOMA) and energy harvesting to enhance energy conservation in M2M communication. In this research, user equipments were configured as gateways of machine type communication devices. At the end of the research, energy conservation was achieved.

Shahwani, (2016) presented an energy efficient clustering technique in M2M based on affinity propagation (AP) to enhance energy conservation. The technique is based on head rotation among the most appropriate candidate for cluster heads. At the end of the research, the scheme gave a better energy conservation enhancement.

Azari *et al.,* (2016) presents scheduling based cooperation incentive scheme so as to enhance energy conservation. The scheme aids the nodes to organize themselves, create groups of machines and communicate with the base stations through group representatives. This scheme benefits from a novel programmer design that takes into account the level of cooperation of each node, compensates for the additional power consumption of the group representatives and maximizes the useful life of the network. Since the reuse of cellular uplink resources for intragroup communication will degrade the primary user Quality of Service (QoS), the analysis results were provided. These results were compared to the maximum allowed number of simultaneously active machine groups in a given cell and the QoS of the primary user. The simulation results showed that the proposed solution significantly prolongs the life of the network.

In a similar fashion, Miao *et al.,* (2016) came up with an accurate power consumption model, considering static and dynamic power consumption at the same time, and used this model to derive the service life of the network. In addition, the cluster size that maximizes the life of the network was determined and an energy-saving cluster head selection scheme was developed. In addition, they found feasible areas where clustering is beneficial in increasing the life-time of the network. The simulation results showed that the new scheme was superior to other schemes in terms of energy savings and significantly extends the life cycle of a single node and the entire M2M network.

2.3 Contention Window Adjustment

Bandwidth management has always been area of concern when it comes to effective utilization and resource allocation in IEEE 802.11. Most communication schemes that use random method such as carrier sense multiple access with collision avoidance (CSMA/CA) do have challenges with collision that leads to bandwidth capacity wastage, loss of data and degraded throughput Bianchi *et al.,* (1996). Distributed coordinated function is a good communication model deployed in infrastructure and ad-hoc systems. The DCF is based on CSMA/CA, provides two mechanisms, a default called the basic access mechanism, and an optional request to send and clear to send (RTS/CTS) mechanism. The short RTS and CTS control frames are used to reserve media before transmitting large data frames. During this period, if the channel is detected to be inactive and its back-off time has expired, the node will detect the medium and initiate frame exchange. The back-off time is the random delay time added before sending data, measured in the slot time, and the back-off time is the random value multiplied by the slot time. The random value is a pseudo-random integer in the interval [0, *CW* (Contention Window)]. In DCF 802.11, the minimum and maximum *CW* sizes (,) are fixed. The back-off interval initializes the back-off timer. The timer decreases when medium is free and freezes when busy. When the back-off timer expires, the node can start transmitting. After a successful transmission, *CW* is set to the minimum value. When a collision occurs, an exponential back-off mechanism is used. According to this mechanism, after each failed transmission, *CW* doubles and then the node performs a new fallback process. Once the maximum *CW* size is reached, CW will stay at the maximum until it is restarted. The value of *CW* depends on the number of frame transmission failures.

2.4 Exponential Back-off Algorithm

Back-off is a common solution to solve the contention problem between different nodes that want to transmit data at the same time. When a node enters the back-off state, it waits for an additional number of time slots randomly selected. In 802.11, a time slot has duration of 20μs, and the random number must be greater than 0 and less than the maximum value called the contention window (*CW*). During the waiting period, the node continues to check the medium to see if it remains idle or if it starts another transmission. At the end of its *CW*, if the medium is still idle, the node can send its frame to the CH. If during the contention window, another node starts to transmit data, the back-off counter is frozen, and when the channel returns to an idle state, the countdown starts again.

There is a problem with the *CW* dimension. For a smaller *CW*, if many nodes try to transmit data at the same time, some of them are likely to have the same back-off interval. This means that conflicts will continue to occur, seriously affecting network performance. On the other hand, for a large *CW*, if few nodes want to transmit data, they are likely to have a long back-off delay, resulting in a decrease in network performance. The solution is to use an exponentially increasing *CW* size. It starts from a small value (= 2) and doubles after each collision until it reaches the maximum value (= 1023). In 802.11, the fallback algorithm must be executed in three situations:

1. When the station detects that the medium is busy before transmitting the packet for the first time,
2. After each retransmission
3. After successful transmission

This is necessary in order to prevent a single host from wanting to transmit a large amount of data, occupying the channel for too long and denying access to all other stations. When the station decides to transmit a new data packet after a period of inactivity and the media idle time exceeds Distributed Inter Frame Space (DIFS), the back-off mechanism is not used. This is shown in Figure 2.1

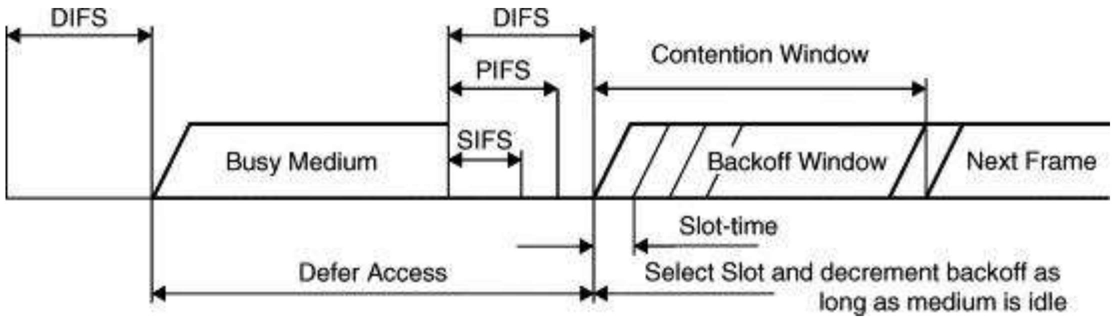


Figure 2.1 Transmission cycle (Gnanambigai *et al*. 2018)

The transmission time for a data frame = $(\mathrm{PLCP} + \mathrm{DR})\mu s$ (2.1)

Where:

PLCP = the time required to transmit the physical layer convergence protocol (PLCP)

D = frame size

R = channel bit rate

Packet transmission time = $\mathrm{BO} + \mathrm{DIFS} + 2\ \mathrm{PLCP} + \mathrm{DR} + \mathrm{SIFS} + \mathrm{AR}\mu s$ (2.2)

Where:

A = ACK frame size

BO = Back-off time

DIFS = Distributed inter-frame space

SIFS = short inter-frame space

Performance loss highly depends on the packet size and data rate, but the possibility of a 30% loss is higher. The smaller the data packet, the greater the impact of CSMA/CA on network performance. To evaluate the performance impact of CSMA/CA, it is important to understand how the various spaces between frames are defined. The 802.11 standard defines the following four inter-frame spaces to provide different priorities.

1. Short inter-frame space (SIFS): Used to separate transmissions belonging to a single dialogue (such as fragment-ACK), and it is the minimum interval between frames. There is always at most one station to transmit at any one time, so it takes precedence over all other stations. This value is set in each PHY and is calculated in such a way that the broadcast station can return to receive mode and be able to decode the incoming data packets. For 802.11 DSSS PHY, the value is 10μs.
2. Point Coordinate inter-frame space (PIFS): Used by AP to access media before any other station. This value is SIFS plus a slot time (that is, 30μs).
3. Distributed inter-frame space (DIFS): It is the space between frames used by stations that want to start a new transmission. It is calculated as PIFS plus the time interval (i.e. 50μs).
4. Extended Inter-frame Space (EIFS): This is the longest inter-frame space used by a station that receives an unintelligible packet. This is necessary to prevent the station (which cannot understand the duration information of the virtual carrier sense) from conflicting with future data packets belonging to the current dialogue.

Energy efficiency in a communication system is usually measured as the energy required to transmit one bit.

CW adjustment helps in handling collision. Researchers have manipulated this technique in various ways to achieve communication with less collision and loss of data. The parameters considered are active nodes, size of data, duration of transmission and retransmission attempts just to mention a few. Exponential back off algorithm have been explored extensively in applying optimum *CW* for successful data transmission. Below are some related works in the area of *CW* management for effective communication.

The research by Bharghavan *et al.*, (1994) showed that the number of competing nodes strongly affects the optimal *CW* size, and they proposed a multiplicative increase and linear decrease (MILD) algorithm. However, when the number of nodes is large and the number of active nodes suddenly changes from high to low, a decrease in throughput performance is observed. The size of the contention window is multiplied by 1.5 when a collision occurs, and the interval is reduced by one when the transmission is successful. The disadvantage of MILD is that it cannot adjust its *CW* fast enough due to its linear reduction mechanism.

A simple change for 802.11 is proposed by Wu *et al.* (2002) made the back-off counter oscillate around the optimal value. Whenever the retry counter reaches the limit, the *CW* is kept and not reset; after a successful transmission, the *CW* is set to the maximum value between the initial *CW* increased by one slot and the half of the actual *CW*; but when a transmission fails, the *CW* is set to the minimum value between the increased by one slot and the double of the actual *CW*.

The Fast Collision Resolution MAC protocol has been described by Kwon *et al.*, (2003). The protocol allows the latest successful nodes to use a smaller *CW* and some nodes can reduce their back-off timer exponentially when they continuously meet idle time slots.

The main concept of the Double Increment Double Decrement (DIDD) algorithm introduced by Chatzimisios *et al.*, (2005) focused on decreasing the *CW* gently and gradually after a successful packet transmission. The DIDD halves the *CW* instead of going back to in order to avoid potential future packet collisions.

Hu *et al.*, (2005) proposed a collision resolution scheme that allows the *CW* to adjust dynamically to incorporate the knowledge of the collision process via the standard mean and variance statistics. This helps avoid similar collision and system reset after failed retransmission.

Sylwia *et al.,* (2006) calculated the estimated values of and through simulations using α and β variables and θ constant. They considered the number of neighbors (nodes) in the 1-hop neighborhood and a coefficient of the remained energy (RE). The equations for and are described as:

$$= \times \times - \qquad (2.3)$$

$$= \times - + \qquad (2.4)$$

Where α, β and θ have values of; 14.0, 5.0 and 1215 respectively.

Table 2.1 Remained Energy Neighborhood Data (Sylwia *et al.* 2006)

Energy Level	Remained Energy (RE)	Nr = 2	Nr = 4	Nr = 6	Nr = 8	Nr =10
100%	0.55	10	26	41	57	72
85%	0.65	13	31	50	68	86
65%	0.75	16	37	58	79	100
45%	0.80	17	40	62	85	107
25%	0.85	19	43	66	90	114

Mahmoud *et al.,* (2008) went further on *CW* calculations to estimate the optimum contention window for active nodes in an 802.11 based wireless networks. They introduced a technique called Neighborhood Backoff Algorithm. They adapted the *CW* according to the number of active nodes in order to reduce collisions. *CW* size for each node was carefully selected according to the number of contending nodes. Through simulations with 2 to 30 nodes and *CW* varied from 5 to 300 slots, they arrived at expression for optimum *CW* as;

$$=8\times 5\ -5 \qquad (2.5)$$

Using this technique helped reduce collision and maximize channel utilization.

Renzheng *et al.,* (2017) worked to improve throughput through less collision in wireless 802.11ah amendment with a technique they termed; Adaptive Contention Window Scheme. This scheme deviated from the conventional back-off algorithm that utilizes a minimum contention window at the beginning of the back-off process and doubles it each time a collision occurs. Their scheme chose an optimum contention window *CWopt* based on the number of nodes at the beginning of transmission. When the transmission was successful the *CW* decreases to half, when there is a collision it sustains the value of the *CW*.

$$\approx \sqrt{(2\ )} \tag{2.6}$$

N is the number of stations in the network,

Tc is the average time to detect the collision of each station.

In another research, Changsen *et al.*, (2016) improved the Exponential Backoff Algorithm through Self Adaptive Contention Window Factor Update for 802.11 DCF. They used theoretical analysis to device an intelligent technique that can adaptively adjust the CW updating factor to achieve the maximal throughput during run time. This reduces the number of collisions, improves the channel utilization and retains the advantages of the binary exponential back-off algorithm, such as simplicity and zero cost.

Whereas, Radha *et al.,* 2020) employed adaptive listening in MAC to save energy. They effectively used the frames in MAC which are sleep and listen periods as a decision model for contention window adjustment. The listen period make use of synchronization. Neighboring nodes gain access to the medium through contention. They select slot for transmission, if no data during that slot then the particular node chose, the node can proceed to transmit. This is called winning the contention. Hence collision can be taken care by this method.

Myung *et al.*, (2018) used optimal collision probability to form Adaptive Contention Window Control (ACWC). This scheme maximize throughput with N nodes in a network when the transmission probability T_N is approximately.$C*/N$

2.5 Classification of Clustering Protocols

Clustering protocols are broadly classified into two groups; namely: Centralized clustering protocol and decentralized clustering protocol.

In centralized clustering protocol, sensor nodes in the network present their individual characteristics such as residual energy and position in the network to the sink. Through established sequence of operation the sink works out the following parameters: number of clusters, size of clusters and location of cluster heads. The sink goes further in assigning of duty to individual nodes. In other works the sink helps in coordinating the nodes and setting up the network for effective communication. The sink makes all the major set up decisions and it does so by utilizing data provided to it by the nodes in the network. Heinzelman *et al.,* (2012). There are two major examples of centralized clustering protocol; The Low Energy Adaptive Clustering Hierarchy {LEACH-C} Heinzelman *et al.,* (2000) and Power-Efficient Gathering in Sensor Information Scheme {PEGASIS}, (Lindsey S. *et al.,* 2002).

While in decentralized clustering protocol the sink doesn’t coordinate the cluster set up and other management in the network. Clusters are formed without help from the sink. This is more energy efficient because of the absence of overhead energy cost burden on the sink for coordination of the cluster activities. Each node advertises itself to other nodes and after consideration of certain criteria like position, residual energy a cluster head is selected. Examples under this technique are; Hybrid Energy Efficient Distributed Clustering (HEED), Younis *et al.* (2004), Low-Energy Adaptive Clustering Hierarchy (LEACH), Energy Efficient Hierarchical Clustering (EEHC) Kumar *et al.,* (2009) and Decentralized Energy Efficient Cluster Propagation (DEEP).

2.6 Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol

This protocol is self-organizing and coordinates nodes in the network. It is hierarchical in characteristics where the parent node of one cluster could be the child node of another cluster. The position of cluster heads is rotated based on some defined parameters such as residual energy, maximum energy, and threshold energy. 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 *et al.,* 2017).

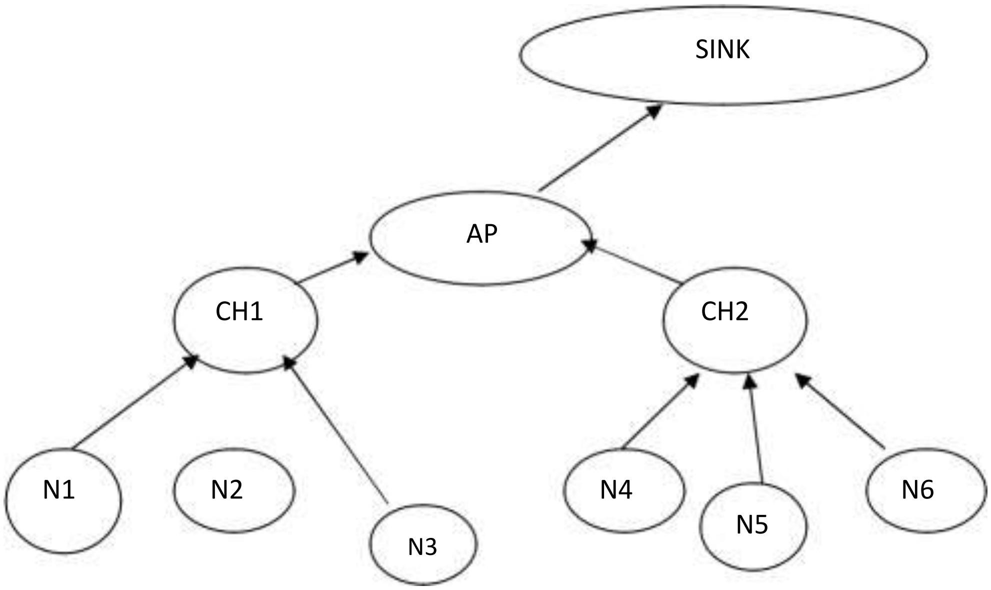


Figure 2.2 Topology of M2M Nodes With LEACH Protocol (Juma *et al.,* 2017).

All nodes will send data to the cluster head (CH) which will then send the aggregated data to the sink through the access point. Usually, each node uses stochastic algorithm so as to determine whether it becomes the cluster head based on the assumption that each node’s radio is strong enough to communicate to the sink trough the access point and to the cluster head. However it is important to note that if a single node remains cluster head the probability of outage will be high. This is the reason why the cluster head selection has to rotate. Furthermore, nodes selected as cluster heads cannot be cluster head for *p* rounds. Where *p* is the desired percentage of cluster head. Therefore, every node has 1/*p* probability of being cluster head. This cluster heads then create a schedule for nodes to transmit their data. Each of these nodes communicates with the cluster head using TDMA according to the schedules created. With this they will only turn on their radio when they are to transmit. This will however increase energy efficiency. Therefore, the application of this protocol to an M2M network will improve the overall performance of the network.

2.7 Modifications to LEACH

Enhancement of leach by application of Radio Frequency by embedding active, ready and sleep communication modes in the network was done by Sharma M. *et al.,* (2012) The active mode was used only to sense data, the ready mode was used to sense and also transmit data from the node to the sink or base station where as the node in sleep mode used for saving the energy consumption and also balances the energy loads of the cluster heads. 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 RTS packets containing a NONCE feed to all its cluster members, the cluster members would adjust their clocks to the feed and reply back with CTS to achieve synchronization. The RFID-LEACH technique 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.

While Neha *et al.,* (2017) worked 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. MODLEACH as the protocol was termed does not take into consideration the influence of parameter *p* which defined the probability of becoming the cluster head; 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. Sasikala *et al.,* (2015). 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. 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.

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 upstate and steady state. IBLEACH, Ahmed *et* *al.,* (2014), in a quest to improve the performance of LEACH introduced a new state between the set-up and steady state called pre-steady state. 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. 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 within the area on the basis of this information, Abdul, (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).

While EEELEACH 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 *et al.*, (2009). In the first layer CHs are formed where the cluster member nodes transmit their data to their respective CHs and by using the fuse mechanism the CHs aggregate the received data. In the second layer, Master Cluster heads (MCHs) are formed. After the formation of these MCHs, the CHs search the nearest MCHs by calculating the distance between them and transmit their aggregate data to the respective MCHs. Meenakshi *et al.,* (2012). In the similar fashion, the MCHs received data from their nearest

CHs, aggregate all received data, transformed them into a compress format and forward them to the sink.

DD-LEACH (LEACH with Distributed Diffusion) was designed as an improvement over LEACH Protocol. This technique uses 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 aggregation is done at multiple levels Kodali and Sharma, (2013). First data aggregation is done at CH level. The CH collects the data from member nodes. While forwarding data to sink, all the intermediate CHs also perform data aggregation at each of their respective levels. In DD-LEACH energy consumption is reduced by using multi-hop communication.

LEACH-A (Advanced Low Energy Adaptive Clustering Hierarchy); In the novel LEACH protocol, Cluster Head is responsible for transmitting data to sink directly which consumes high energy than other member nodes in the network. M. Usha *et al.* 2016. In advanced LEACH, the data is processed by using a technique called mobile agent. Advanced LEACH may be defined as a heterogeneous energy protocol is developed for the purpose of energy saving, reliable data transfer, decreasing the probability of node's failure and for increasing the time interval before the death of the first node. Hence both the energy saving is improved and reliable data transfer in LEACH-A. This also use synchronized clock, through which each sensor gets the starting of each round (Gnanambigai *et al.* 2018).

There is an improved Leach protocol called MG-LEACH. In this modified protocol the deployed nodes are divided into sub-groups ($G_1 \ldots G_k$) depending on the locations of the nodes; where k is a real number. The numbers of groups in this modification are mainly dependent on node density. These groups are created by the sink at the time of deployment and after every “x” rounds. Hicham *et al.,* (2019). This was an additional step used in their proposed algorithm before setup phase and steady state phase and known as Set building phase. MG-LEACH consists of three steps, the build phase is used at deployment time and after each "x" rounds per sink, and the remaining two are the same as those used in LEACH such as the Installation Phase and steady state phase. This protocol offered better performance than LEACH in terms of energy conservation and efficient utilization. (Jong-Yong *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 introducing a strict threshold for cluster head 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 *et al.,* (2017). This way the energy wastage during routing information to the new CH in each round can be controlled. The extra energy consumed for anew cluster formation due to new CH can also be controlled. I-LEACH protocol outperforms LEACH by 67% increase in throughput and extending the lifespan of the network through successful 1750 rounds of communication.

Handy *et. al.*, (2015) explored LEACH with deterministic cluster-head selection to enhance lifetime of the network. This protocol reduces energy consumption of wireless micro-sensor networks by using a deterministic cluster heads election algorithm. The deterministic cluster head selection algorithm uses reduced threshold value of the mean time threshold equation as indicated by equation 2.7:

$$(\ ) = \frac{\qquad}{1-(\ (\ \frac{1}{\quad}\ )} \times \frac{-}{-} \qquad (2.7)$$

Where _ is the current energy level and _ is the initial energy level of node.

Loscri *et. al.*, (2016) presented Two-Level LEACH(TL-LEACH) protocol which uses two types of CHs in the network as first level CHs and second level CHs. Each sensor node can decide to be a primary (second level CH) or secondary (first level CH) or simple node (SN) in the network. First level CH decides which second level CH it will join; similarly each simple node also decides which first level CH it will join. Data transfers from first level CH to the sink via second level CH. This reduces the probability of data loss when the CH in a cluster dies.

Kodali & Aravapalli, (2018) explored Multi-Level LEACH as extension to TL-LEACH. It includes 3LLEACH (Three Level LEACH) and 4L-LEACH (Four Level LEACH) protocols. Working of 3L-LEACHand 4L-LEACHis same as TL-LEACH, but only difference is number of levels increases between two different level CHs. The lower level CH forwards aggregated data to the upper level CHs. Aggregation is performed at each level CHs and energy consumption is reduced because of multi-hop communication. The tradeoff of this protocol is QoS of data delivered.

Yassein *et al.*, (2009) used V-LEACH (Vice LEACH) protocol which has an alternative cluster head Vice-CH along with active CH in each cluster. Vice-CH becomes CH to avoid isolation of cluster nodes from network in case CH dies. It insures the availability of cluster nodes and does not select a new CH each time when the CH dies. It has the advantages of efficient transmission of data to the sink, high network lifetime and low energy consumption.

It is an improvement over the V-Leach which has tried to remove the shortcoming of V-LEACH by increasing the network lifetime Naveen *et al.* (2012). In this method, initially the Vice Cluster Head is elected along with the cluster heads based on the energy and the distance parameters. When the cluster head dies, it is replaced by Vice Cluster Head and at the same time new Vice Cluster Head will be selected. It means the cluster head will stay over the life of network. The decision of the Cluster head and Vice Cluster head is taken on the basis of Energy, Distance and Remaining Energy of the sensor nodes. This algorithm provides better network lifetime than V-LEACH.

Xiangning & Yulin, (2007) discussed Energy LEACH (E-LEACH) as an enhancement of LEACH by considering the residual energy of each node in the process of selection of CHs. It uses a better way to select CHs after first round but dissipates enough amount of energy to calculate residual energy of each node.

Chen & Shen, (2007) discussed ME-LEACH Protocol which uses shortened communication distance between sensor nodes to improve load balancing. The direct communication between CHs and sink reduces capability of larger WSNs. This is mostly used for smaller networks for better results on performance.

Chen & Shen, (2008) introduced a Large-scale WSNs (MELEACH-L) protocol as an extension to MELEACH in which size of each cluster is controlled and CHs are separated from backbone nodes by constructing back bone tree. Channel assignment problem among neighbor clusters and the cooperation among CHs during data collection is also been solved in this protocol.

Kim & Chung, (2006) considered LEACH-M (Mobile LEACH) protocol with same threshold formula which was used in LEACH protocol. To avoid the unavailability of node during data transmission phase it uses TDMA scheduling to confirm whether a mobile node is in communication range of CH or not. CHs sends REQDATA-TRANSMITION message at starting point of each TDMA slot. If two successive TDMA frames are missed by the node then node considers itself as out of range and is removed by the member list of CH.

Kumar *et. al.*, (2008) proposed LEACH-ME (Mobile Enhanced) protocol as an enhanced version of LEACH-M by selecting the less mobile nodes as CHs relatively to its neighbors. Each node broadcasts their IDs and estimates the distance to all other nodes. Now each node calculates mobility factor according to:

$$(\ ) = \frac{1}{-1} \times \sum_{=0}^{-1} (\ ) \qquad (2.8)$$

Where ( ) is the mobile factor based on remoteness of node **i** to all other nodes, **N** is the number of neighbors of node **i** and **d** is the distance of node **i** from its neighbors **j**. Nodes with least mobility factor and higher energy level are selected as CHs.

Hong *et. al.,* (2009) discussed threshold based cluster head replacement for wireless sensor networks (TLEACH) to enhances the network lifetime by minimizing the number of cluster head. The minimum number of CHs is selected by using higher threshold of residual energy. T-Leach reduces the heads election amount and replacement cost.

Abdulsalam & Kamel, (2010) proposed weighted LEACH (W-LEACH) for handling continuous, uniform and non-uniform data flow or data stream using data stream aggregation algorithm. It uses centralized approach to control non-uniform network. While selecting the CHs, nodes have their weight metrics which can be decided by residual energy level and density of nodes (number of surrounding nodes) measured. A node with higher density will be weighted as higher node.

Tong & Tang, (2010) suggested LEACH-B (Balanced-LEACH) protocol which enhances LEACH by finding the optimal number of CHs which can be selected by using residual energy of nodes. Minimum and optimal number of CHs is selected from the list of candidate CH nodes which are arranged in decreasing order of residual energy. By using optimal number of clusters LEACH-B ensures cluster balancing which saves energy consumption.

Liu & Ravishankar, (2011) designed LEACH-GA protocol using a genetic algorithm-based clustering technique to improve energy efficient protocols. Each node sends its node ID, location information and CH decision based on optimal percentage **C** to the sink. The sink applies genetic algorithm operations on received information to find out the optimal threshold probability and broadcast it for cluster formation.

Bakr & Lilien, (2011) introduced LEACH-SM protocol as an extension to LEACH by considering an efficient management of spares. It adds an extra phase to LEACH called the spare selection phase that follows the setup phase and is followed by the steady state phase.

The decentralized energy-efficient spare selection technique is used to select spare parts which run in simultaneously on all nodes and in all clusters to make a decision about spare which maintains the above-threshold target coverage. All spares go asleep if not in use to conserve energy.

Yektaparast *et al.*, (2012) explored cell-LEACH protocol. In cell-LEACH protocol a cluster is divided into seven sections which are called cells. These seven clusters are divided using one central cell of hexagonal shape and other six cells at each face of central hexagonal shape with their own cell heads which can communicate to each other directly. Cluster head is chosen among all nodes of seven cells of a single cluster and cell heads forwards the aggregated cell data to CH. These clustering and celling is static and hence remain there for network lifetime. The only thing which changes is cell heads and cluster heads.

Gajjar *et al.*, (2012) proposed Improved-LEACH protocol which enhances the LEACH protocol by considering the remaining energy level of node during CH selection process with its distance from the base station. The steady state phase starts only if the sensed value of a node is greater the threshold value fixed or set by the user at the application layer. The network area is divided into four quadrants and base station is considered in one quadrant. All CHs of other quadrant uses two hop communication but CHs of those quadrant in which BS is located will communicate directly to BS.

Whereas Quynh *et al.*, (2012) explored energy and load balance LEACH (EL-LEACH) protocol with a modified CH selection function in which it considers the residual energy of node and distance between two CHs to avoid data redundancy. It uses an immediate cluster selection scheme if two cluster heads are close to each other in which a non CH node situated away from other CH node with highest energy level and will become a CH node.

Meanwhile Wang *et al.,* (2012) suggested Multi-hop LEACH protocol to solve quick energy drainage problem of CH in single hop communication in case of large-area network. Intra-cluster communication takes place between CH and its cluster member nodes where CH receives data from all member nodes at a single-hop distance and aggregates and transmits the data directly to the BS or through intermediate CHs. Multi-hop inter-cluster communication takes place when the distance between the CH and the BS is large and the CH uses intermediate CHs for sending data to the BS.

In a related development Pawar & Kasliwal, (2012) designed an Enhanced LEACH Protocol (En-LEACH) by using modified cluster head selection phase and modified data transmission phase. It considers the energy parameter at the time of cluster setup phase. The probability function of becoming a cluster head is modified as ratio of node’s energy level and aggregate energy of the cluster in the network. At the time of data transmission from cluster head. Each cluster head checks its energy level before sending data to base station. If energy level of cluster head is less than the threshold value then cluster head does not forward the data to base station and waits for the next round. By waiting for next round it avoids the probability of failure of cluster head.

In LEACH-F Heinzelman *et al.,* (2000) clusters that are formed once are fixed. Then, the cluster head position rotates among the nodes within the cluster. The advantage is that there is no set-up overhead at the beginning of each round due to re-clustering. To build clusters LEACH-F uses the same centralized concept of LEACH-C algorithm. The method lacks scalability since fixed clusters do not allow new nodes to be added and the lifespan of such network is very less because it never adjusts the clusters as nodes die.

Performance of cluster-based hierarchical routing protocol depends on the selection of optimal numbers of CHs. In order to distribute energy equally in the network and to increase the network lifetime, Xu *et al.* (2012) devised the idea of selecting the optimal number of sensor nodes as CHs and varying the round time in every round. They have considered the energy dissipation of the transmission of an entire network, instead of the individual sensor nodes. The selection of the CH in each round of the E-LEACH protocol considers two additional constraints: the first one is the residual energy of sensor nodes and the second one is energy consumption for sending data to the BS. The main advantage of considering these two constraints is to distribute energy across the network uniformly. So, the sensor node is selected as a CH based on higher residual energy and minimum energy consumption for transmitting data in the E-LEACH protocol. In order to send sensed data from CHs to the BS efficiently, E-LEACH protocol uses the minimum spanning tree for the shortest path among CHs. The CH with highest residual energy is selected as the root node of the minimum spanning tree. The E-LEACH protocol is highly scalable and more energy efficient compared to basic LEACH but it suffers from delay and control packets overhead.

HLEACH method is proposed by considering the concept of minimizing the communication distance between nodes to conserve energy Meenakshi *et al.*, (2012). It employs the same clustering approach as LEACH during initial phases and later it extends LEACH by further clustering the cluster heads and nominates one of the cluster head, which then acts as the Master Cluster Head (MCH), to forward data to the base station. In

HLEACH finally only one MCH is involved to transmit all compressed data to base station, so central point of failure situation may occur when the MCH will be dead.

Energy harvesting is essential in some applications of WSN, especially when sensor nodes are placed in non-accessible areas like battlefield for such kind of applications, Thiemo *et al.* (2004) proposed sLEACH, in which solar power is used to improve lifetime of WSN. In solar-aware centralized LEACH cluster heads are selected via BS using LEACH-C. BS normally selects solar powered nodes through maximizing residual energy. In sLEACH nodes transmit their solar status to BS along with energy level. Nodes with higher energy are selected as CH. Performance of sensor network is increased when number of solar-aware nodes is increased. Life time of sensor network depends on the duration of sun. This is the energy harvesting time. If sun duration is small, CH handover is performed in sLEACH. If the node serving as CH is running on low battery and another node in a cluster sends data with flag, then its solar power is increased. Thus the latte node becomes the CH in place of the first serving CH. The new CH is selected during steady state phase enhancing the lifetime of the network.

Table 2.2 Summary of Related Works

S/N	REFERENCES	PROBLEM ADDRESSED	METHODOLOGY	RESULTS	LIMITATIONS	OPEN AREAS
1.	**Navdeep *et al.*, (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.	**Neha *et al.*, (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 *et al.*, (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 *et al.*, (2014)**	Evenly distribution of energy in the network between nodes and the CH.	Used the set up phase. Pre-steadystate and the steadystate 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-steadystate with less complexity.
5	**Abdul *et al.*, (2017)**	Life time of network and energy consumed per node	Selection of CH by considering residual and maximum energy of nodes, calculation ofalive 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 *et al.*, (2012)**	Increased Energy efficiency	Used multilevel clusters through radio distance reduction to form MCH which aggregate data from	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

			CHs			
7	**Hicham *et al.*, (2019)**	Energy consumption and efficient utilization.	Division of the clusters into sub groups depending on location and node density	Improved energy conservation and efficient utilization.	Added “set building state” as an extra step that could consume memory	Ways for efficient memory management to meet the node requirements
8	**Trupti *et al.*, (2017)**	Energy consume by devices inan IoT related environment	Introduced a strict threshold for CH selection and retaining the CH for more rounds if the energy threshold condition is still met	Increased throughput by 67% and extendied the lifespan of the network through successful 1750 rounds of communication.	Suffers signal loss due to pathloss and fading	Ways to improve the incurred losses
9	**Udin *et al.*, (2018).**	Irregular formation of clusters and the total number formed.	Allowed Sink to select CH, maintain regular clusters and ensured evenly distribution of nodes	Improved node lifetime and energy loss due to randomness of nodes in novel LEACH	When the sink is disconnected the whole network will fail	For further research will analyze the others quality of service (QoS) such as node alive, energy consumption, data received sink, energy efficiency,

						and throughput.
10	**Dwi *et al.*, (2019).**	Energy wasted by cluster member nodes sending data to CH in far position	Used Reinforced Learning RL to select a cluster node that will relay message of other member nodes to the CH.	Lengthen the network live, increase the received packet in the sink and decrease energy use.	Reduced data QOS because of multiple transfer of data	Areas to improve data quality at the end of multiple transfers.
11	**Daewon *et al,*. (2015).**	Energy consumption and packet delay associated number of nodes connected to an AP.	Performance analysis and extensive simulations	The energy consumed was significantly less compared with continuous active mode even asthe number of nodes connected to the AP increased.	The packet delay increased slightly asthe number of nodes increased.	Ways to improve the performance of packet delay with large number of nodes connected to the AP.
12	**Pranav *et al.* (2016).**	Energy consumption on radio communication by stations in IEEE 802.11 infrastructure WLAN.	Opportunistic power save mode algorithm.	Improved energy consumption and longer battery life for mobile devices.	The performance of OPSM degrades with increasing number of stations.	To design a generic policy for the STAs that works better for higher round trip propagation delay (RTPD).
13	**Hsiang-Ho *et***	Energy harvesting for	Implementing energy harvesting	Improved energy		Combination of the

	***al.*, (2016).**	machine-to-machine communication	modules on wireless network infrastructure: Solar, wind, pressure etc.	efficiency; reduce overall outage probability, application layer loss rate & collision probability.		different parameters of deep sleep to optimize the performance & energy consumption
14	**Muhammad *et al.*, (2019).**	Improving energy efficiency through effectively dealing with idle listening.	Systematic combination of downclocking, frame aggregation and contention window control.	The mechanism increased performance of the system through reduction of Idle listening.	It focused solely on one area of energy wastage which is Idle listening.	Improving on this method to achieve higher performance in terms of energy per bit and throughput.
15	**Mao Shengli *et al.* (2015).**	Application of network simulation base on clustering algorithm.	Distribution of content to nearest server bringing content close to user to avoid contention	Improvement of content delivery and comparison with C/S mode	Very large in size and requires large specification to run	Improving on channel scheduling algorithm and studying of optical Burst switched network

Energy-Efficient Hybrid Clustering Communication Protocol (EEHCCP) divides the communication process into several rounds. Each round composed of setup and steady-state phase. In each round, EEHCCP rotates cluster heads based on the residual energy of the nodes. EEHCCP incorporates both static and dynamic formation of clusters and selects either of these methods based upon control parameter known as Average Cluster-Member Energy (ACME). In the very first round of EEHCCP, each node sends its ID, location, and energy information to the sink, the sink then selects the desired number of cluster heads, determined apriori, and their associated cluster members Rohit *et al.* (2018). The CH selection is based on the location and energy status of all the nodes. The sink first divides the network into k-cluster using k-mean clustering, where k, is equal to the desired number of cluster heads. The sink then finds the highest residual energy node for each cluster and appoints them for the job of cluster heads. At last, the sink forgets the cluster formed using k-mean clustering and then, performs re-clustering for chosen cluster heads and determines cluster members for each cluster head using minimum distance criterion so as to minimize the within-cluster sum of squares. The k-mean clustering was used just to find initial CHs and not the initial clusters. The k-mean ensures good distribution of CHs which also helps to distribute the energy consumption in the network.

All these literatures show how much have been explored towards the enhancement of energy conservation. However none has used the technique in this research. This justifies the reason for this research.

Table 2.2 shows the summary of some researches done on M2M communication, Contention window adjustment and Modifications to LEACH.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

This chapter presents the method used for the realization of the research objectives and achieving the aim. This comprises of both the hardware and software tools used for the research and the methods used for the implementation of the set objectives.

3.1 Tools

The tools listed below were used for the realization of the aim of the research:

3.1.1 Software

Windows 10 Pro, MS-Word, Foxit PDF Reader, MATLAB (R2018a), OMNET++

3.2 Methodology for Achieving the Stated Objectives

This section presents the detailed techniques used for the realization of the research aim. This include LEACH protocol adoption and modification, formation of network scenario, application of contention window adjustment and optimum contention window selection and evaluation of the proposed protocol performance and comparison with the novel LEACH. The work flow is summarized by the block diagram in Figure 3.1.

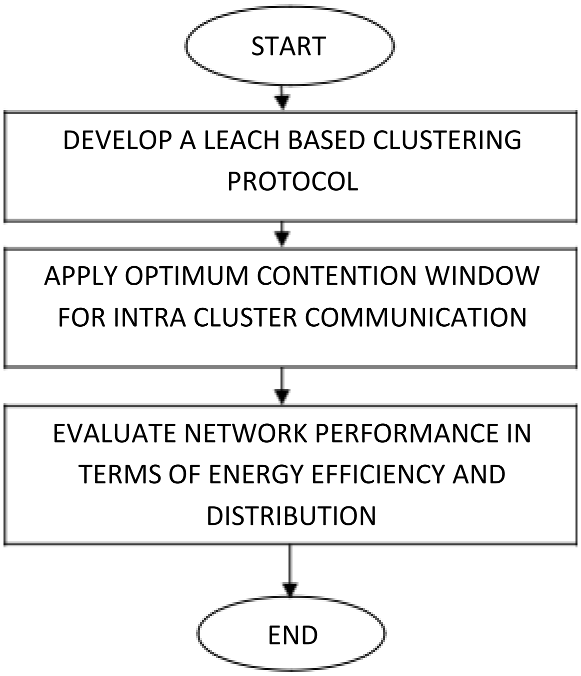


Figure 3.1 Work Flow Diagram of Research Methodology

3.3 Methodology for Objective One

In this section we develop the protocol by describing the mode of communication in a covered area, the parameters considered, the metrics measured, modifications made and the step by step working principle of the technique. This gives the overall description of our improved protocol.

3.3.1 Direct Transmission (DTx)

The conventional set up for wireless sensor networks is such that all the deployed nodes in the field of interest send packets of data directly from the field to the sink. The attempt by different nodes to send at the same time give rise to issues of collision, packet loss, energy wasted due to idle listening and over hearing. The scenario presented below shows all the nodes in a targeted coverage area and the intended sink. All the nodes extract useful data and forward to the sink. The attempt by all the nodes to communicate with the sink or base station leads to collision, loss of date and short life span of the network due to node battery depletion and energy overhead. This method of transmission is known as direct transmission, Pedro *et al.,* (2010) expressed in Figure 3.1. There is no intermediary node between the sending node and the sink; in the case of this scenario the CH. The nodes remain in active state when transmitting to CH and listen to the channel part of the time then sleeps for the other part when it has no packet to send. No energy is expended by the nodes on receiving data since it does engage in cross node communication. The bulk energy of the node is expended when transmitting to the CH and the amount expended is largely determined by the nodes location from the CH and the data size transmitted. This protocol is least efficient when it comes to energy efficiency, throughput and latency (Meenakshi *et al*., 2012).

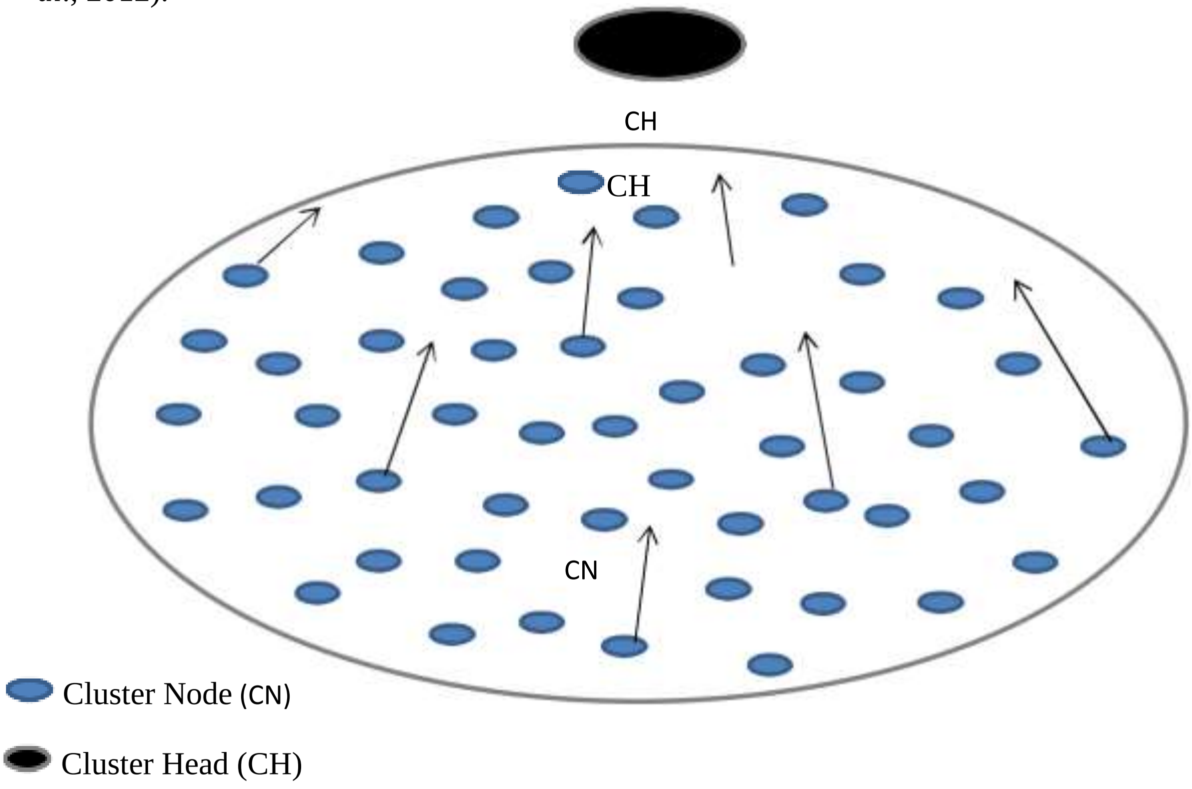


Figure 3.2 Direct Transmission in Wireless Communication Network (Meenakshi *et al*., 2012)

3.3.2 Operation of CW-LEACH

Contention Window LEACH (CW-LEACH) clustering protocol divides the deployed nodes into multiple clusters which become sub groups of the main area of coverage. These divided nodes collate data and forward to selected cluster heads that will in turn send to the upper parent nodes in the upper hierarchy and so on till the packet gets to the sink. Inter cluster heads communication is handled by border nodes which acts as relay. The intra cluster communication occurs between nodes in a cluster and cluster heads. Cluster members compete for channel access to forward their individual packets to the cluster heads. The conventional means of taking random back off times (IEEE standard 802.15.4-2011, IEEE Computer society, 2011) between contention window time slots do little to curb idle listening and overhearing within clusters when the nodes are of a good number. Short contention window when the nodes are more leads to more nodes wasting energy listening to the channel and more contention window slots and less active nodes leads to less utilization of battery life of the nodes and channel. We introduce the optimum contention window size for active nodes to ensure maximization of energy of the nodes through proper utilization of channel, less idle listening and over hearing. The contention window varies proportionally with the number of active nodes. The different levels of hierarchy in CW-LEACH is shown in Figure 3.3

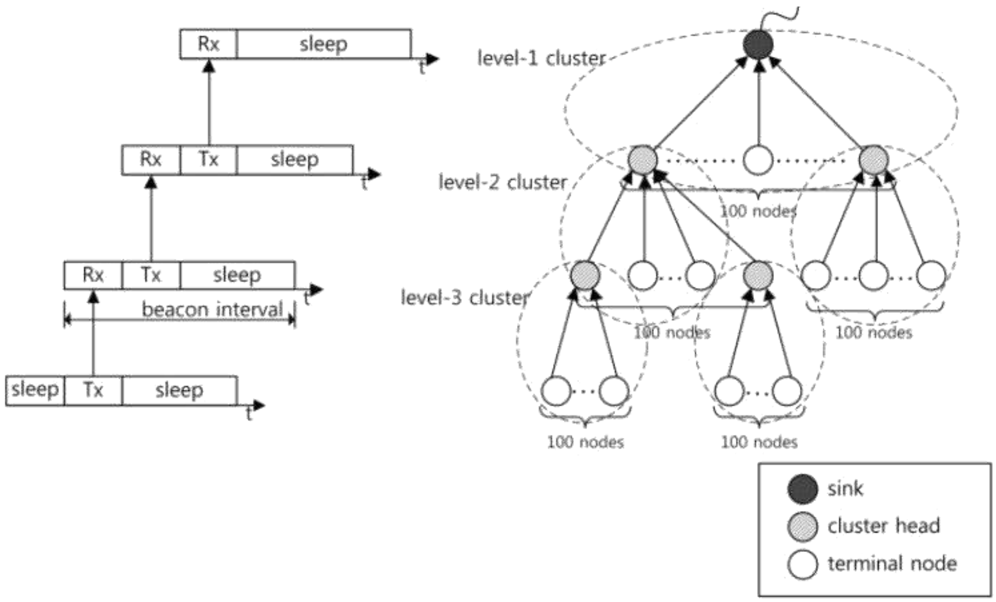


Figure 3.3 Level Cluster Network for CW-LEACH (Ieryung *et al.* 2014)

3.3.3 Set-up phase

The set-up phase is subdivided into little number of tasks. It is responsible for organizing SN in the deployment area, cluster formation by traditional LEACH technique and electing CH. Then it initiates TDMA scheduling for generating time instances for sink traversal. Each SN in a cluster picks a number randomly between 0 and 1. The node that select a random number that is less than the threshold for node n then the node becomes the CH for that round. The threshold value T (n) of node can be calculated using the expression:

$$( ) = \{ \begin{array}{ll} 1-(\cdot \ 1) \qquad - & , \text{if} \in \\ 0, & h \end{array} \tag{3.1}$$

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, the CH broadcasts an advertisement message to other nodes. Based on the received signal strength of the advertisement, other nodes decide to which cluster it will join for this round and send a membership message to its CH. After the exchange, the cluster formation becomes completed. When the number of clusters are few, energy consumption of cluster heads will increase and cause early death of those cluster heads; when the number of cluster heads is excessive, it will cause transmission data overload of the sink node, which will affect the entire network energy consumption, thus shortening the life cycle of the WSN. The optimum number of clusters formed based on the number of nodes and coverage area is given by:

$$=\sqrt{\ } \qquad \frac{}{{}_{2}} \sqrt{\frac{\epsilon}{\epsilon \qquad -{}^{4}}} \tag{3.2}$$

Where N is the number of sensor nodes and M is the area of the sensor network.

∈ is the amplifier energy of the free space radio model and ∈ is the amplifier energy of the multi-path radio model.
dtoBS Indicates the average distance between CHs and the sink.

The last task executed in the set up phase is calculating of the number of neighbors each node has. This is done by calculation of the neighborhood radius. This information helps each node effectively utilize the CW adjustment and optimum CW selection for energy distribution and channel utilization. The expression for calculating the neighborhood radius is given by:

$$_{h} = \sqrt{\frac{\times}{_{\times}}} \qquad (3.3)$$

Where $_{h}$ is the neighborhood radius,

× is the area of nodes deployed and

K is the number of clusters.

3.3.4 Steady state phase

The steady-state phase starts with initializing the mobility of the sink node. The sink collects data from the SNs of each cluster. The sink waits for the stipulated amount of time which is taken care by time division multiple access (TDMA) scheduling. Once the waiting time is over then TDMA enables time-out session which redirects the sink to move to the next cluster. After completion of data collection from all clusters the sink returns to ready mode. i.e. waiting for CHs to aggregate and forward data of their cluster members.

3.3.5 Energy model

The transceiver consumes more of the dissipated energy in the sensors (Meenakshi *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:

3.3.6 Transmitting circuit equations:

$$E_{TX}\_(k, d) = E_{TX}\_\{ (E_{elec} \times k) + (\in \quad \times k \times d)\} \tag{3.4}$$

$$E_{TX}\_(k, d) = E_{TX}\_\{ (E_{elec} \times k) + (\in \quad \times k \times d)\} \tag{3.5}$$

$$E_{TX}\_(k, d) = \in \qquad \times d^2 \times k \text{ if } d < d0 \tag{3.6}$$

$$\in \quad \times d^4 \times k \text{ if } d \geq d0$$

$$= \sqrt{\frac{\epsilon}{\in}} \tag{3.7}$$

3.3.7 Receiving circuit equation:

$$E_{RX}\_(k) = E_{RX}\_(E_{elec} + EDA) \times k \tag{3.8}$$

Where,

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

$\in$ = Amount of energy consumption for multipath fading.

$\in$ = Amount of energy consumption for free space.

EDA = Data aggregation energy.

Where   is the message size and   is the distance.

3.3.8 Average energy

The Average energy of the network is given by:

$$= \frac{\Sigma \; =1}{} \qquad (3.9)$$

Where E_i is residual energy of i^{th} node and

N denotes the number of sensor nodes in the network.

Recall Equations

$$\overset{=}{=} \qquad \overset{*}{*} \qquad \overset{*}{-} \qquad \overset{-}{+}$$

Where α, β and θ have values of; 14.0, 5.0 and 1215 respectively.

$= 2$

$= 1023$

$\approx 8.5 \; - 5$

The minimum contention window size is 2 and the maximum is 1023 according to 802.11 standard and 20μs per slot. It is necessary to select a contention window size based on the active nodes in the cluster. The scenario for this work is that with higher number of nodes per cluster, the probability of collision will be high because of the number of nodes that would compete to forward data to the cluster head. When this happens, the other contending nodes would normally start from the minimum contention window then doubles the figure till the channel is free or till the data is dropped when the window gets to the maximum. In our technique, the contention window size does not start from the minimum rather it starts from the minimum but exceed the optimum (CW) by one step after calculating the number of active neighbors using equation 10. This optimum selection increases the chance of successful transmission and reduces the number of packets dropped when the nodes are unable to send.

During the set up phase information on cluster size, members and number of neighbors are exchanged in the network. The nodes that have data in their buffer to send pick the limit of the minimum required contention widow size to send their packets then double their slots each time the channel is busy but won't exceed the calculated value for CW*opt* by more than one step and reset to minimum when transmission is completed. This is replicated over other clusters. Long CW leads collision and loss of data when the number of nodes is large.

The energy consumed per cluster is aggregated to get the total energy consumed by the network.

$$E = E + E + E + E + E \qquad (3.10)$$

The efficiency was measured based on throughput delivered to cluster heads and the latency was measured by the number of successful transaction and collision of packets.

3.4 Methodology for Objective Two

A network scenario of 1000 nodes and area of 100m ×100m is considered. The coverage area has 10 clusters which results to 100 nodes per cluster and 10 cluster heads. We assumed equal distribution of nodes in the cluster and area. Three layers of child parent relationship. When there is collision free communication between cluster nodes and cluster heads the overall energy consumed in the network would be reduced. The total energy consumed is the aggregate of the energy utilized in the individual clusters.

The clusters are *I*,*j*,*k*,*l* and *m* each with 100 nodes.

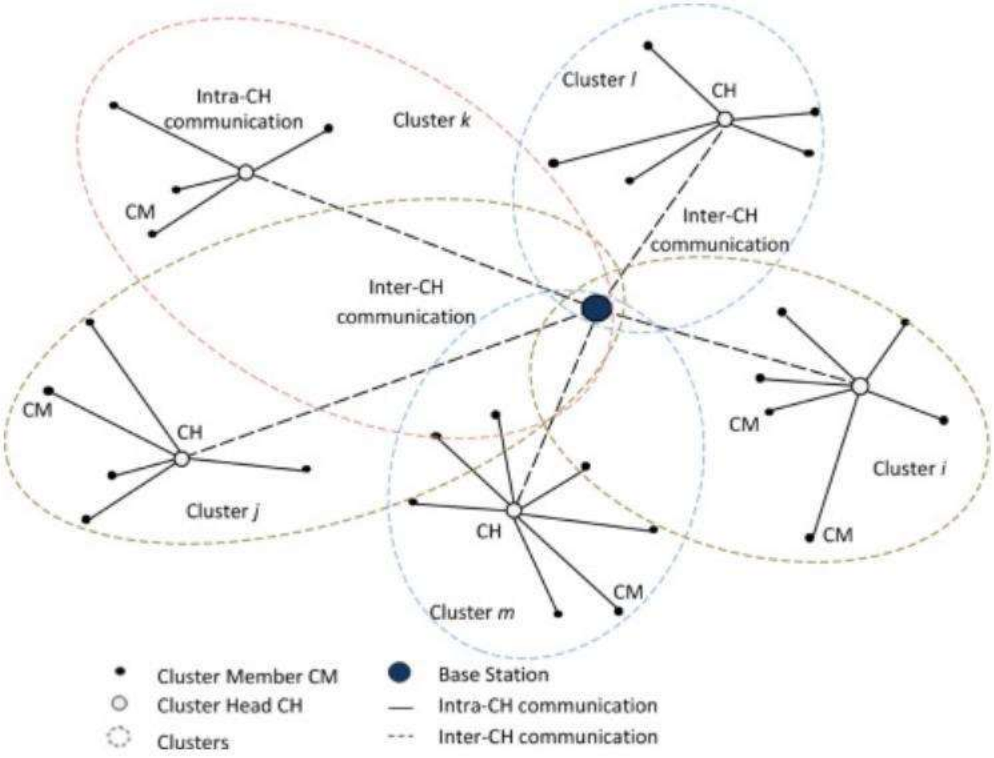
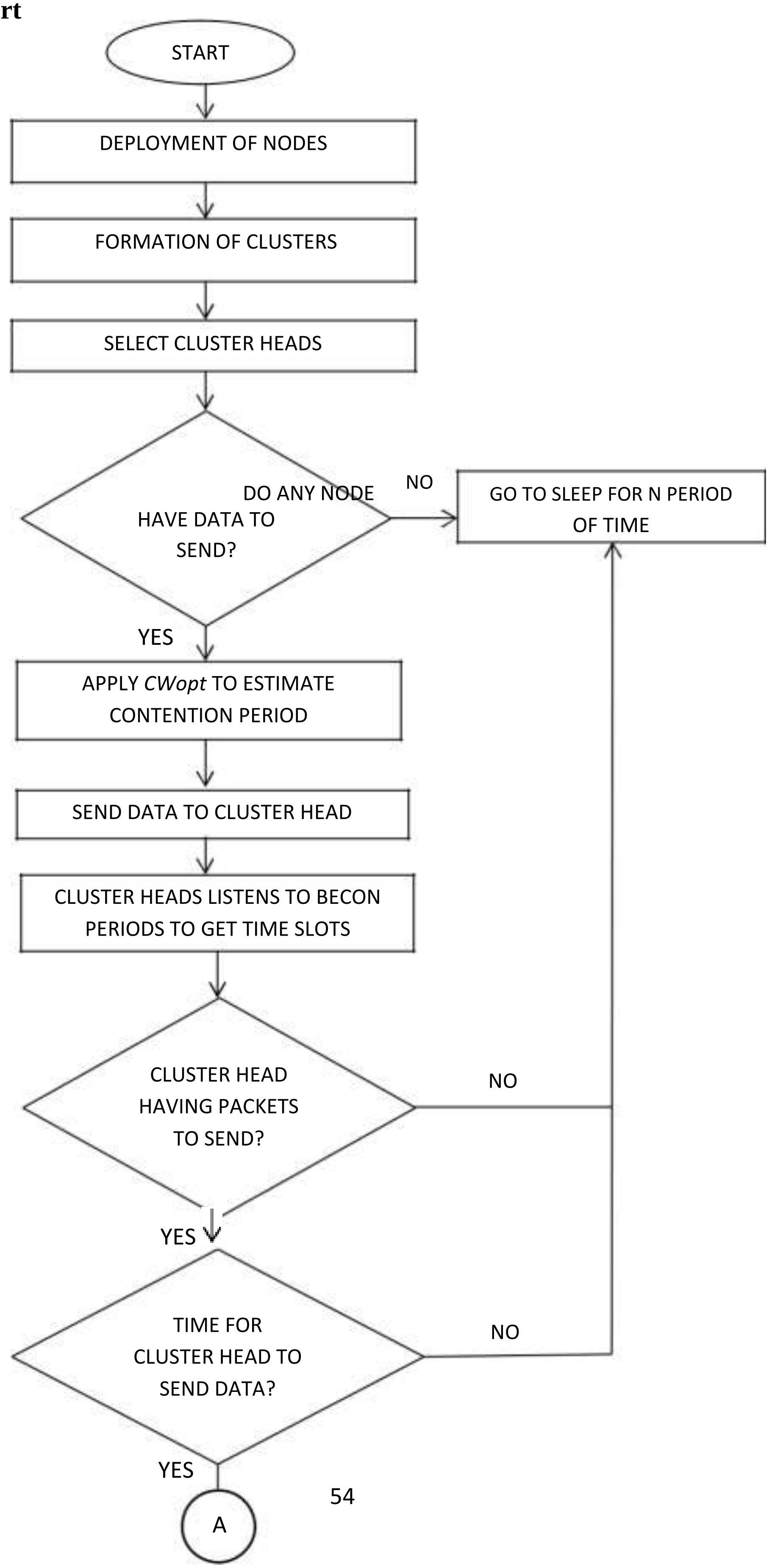


Figure 3.4 Clustering Wireless Sensor Network (Ankit *et al.*, 2012)

3.4.1 Flowchart



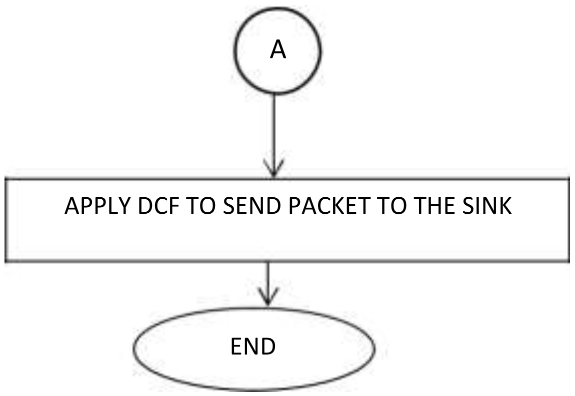


Figure 3.5 Flow Chart for Contention Window LEACH (CW-LEACH)

The diagrammatic representation of Figure 3.5 shows the step by step execution of the technique. When the nodes are deployed, they form clusters by exchanging information about their location and distance from each other. Part of this shared information is used to select cluster heads for each cluster for the first round of communication. This CH task is rotated among the nodes until every node has served as CH then the cycle is repeated till all the nodes in the network die. Each node in a cluster forward generated data to the CH applies contention window adjustment for optimum performance and reduction of collision among the competing nodes for channel access. Then the CHs apply time division multiple access (TDMA) to forward the collated data from their respective clusters to the sink for onward processing and utilization.

Table 3.1 Simulation Parameters

S/N	Parameters	Value
1	M×M	100m × 100m
2	N	1000 nodes
3	Sink Node	50m × 200m
4	E_o	2 J
5	E_{elec}	$50\times10^{\wedge -9}$ J/bit
6	E_{Tx}	$50\times10^{\wedge -9}$ J/bit
7	E_{Rx}	$40\times10^{\wedge -9}$ J/bit
8	EDA	$5\times10^{\wedge -9}$ J/bit
9	E_{amp}	$100\times10^{\wedge -12}$ J/bit/m^2
10	P	0.05
11	Packet size	4000 bits
12	E_{fs}	$20\times10^{\wedge -12}$ J/bit/m^2
13	Number of rounds	100-4000

3.5 Methodology for Objective Three

The network performance was evaluated in this section with focus on energy efficiency and distribution. The number of successful transmission and number of rounds the nodes go in sending data to their respective CHs before the end of their life describes the performance of the network overall performance based on the aforementioned parameters.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

In this section the simulation results obtained analysis of the results and comparison with novel LEACH to show improvement were shown.

4.1 Results of Simulation

Figure 4.1 showed the random deployment of the nodes in a coverage area of 100m by 100m. The position of the sink is at 50m by 200m. The nodes are in blue color and the sink is in red color. It is assumed that every single node has a radio with capability to reach the sink directly from any location on the network. The sink has receiving power to accommodate aggregated packets from all nodes serving as CHs. Another assumption made is that the clusters will have equal number of nodes for the purpose of this simulation. To demonstrate the effectiveness of our method we took a constant packet of 4000 bits which is quite large for a WSN node as the data size to be passed around in the clusters. We have been able to achieve objective one through successful deployment of nodes and formation of clusters. Selection of CHs for a round and TDMA advertisement message shared.

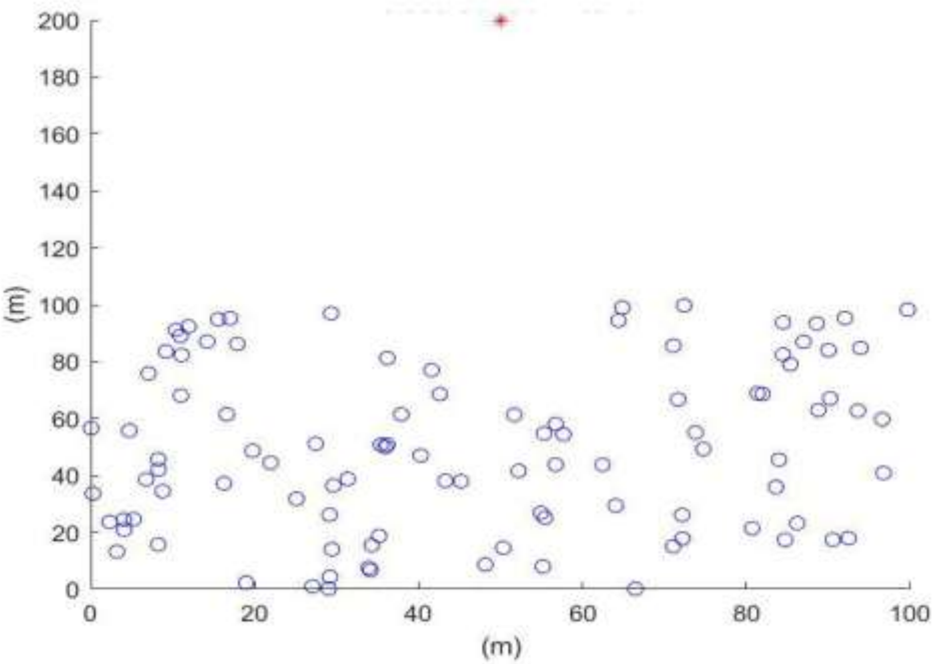


Figure 4.1 Random Deployment of Nodes

Objective two was achieved through simulation of the network scenario with defined network parameters. The parameters selected are based on required distance to the sink and capability to send data of 4000 bits. The aim of achieving energy efficiency and effective measurement of performance has warranted us to simulate one cluster and replicate the result across other clusters. The results obtained from the simulation showed the different performance of the network in terms of operational nodes against rounds of communications, operational nodes against transmission and average energy consumed per transmission.

4.1.1 Operational nodes per round of communication

Figure 4.2 showed the progress of rounds of communication and the number of live nodes. The relationship between live nodes and rounds of operational is inversely proportional in nature. As the number of rounds increases the number of operational nodes reduces because some nodes tend to die out after serving as CH for number of rounds thereby loosing energy in the process. LEACH without contention window adjustment as shown in Figure 4.2 went a total of 2301 rounds before all the nodes in the network die out while CW-LEACH went on for 2929 rounds. The technique showed better performance when compared with the novel LEACH using the same parameters.

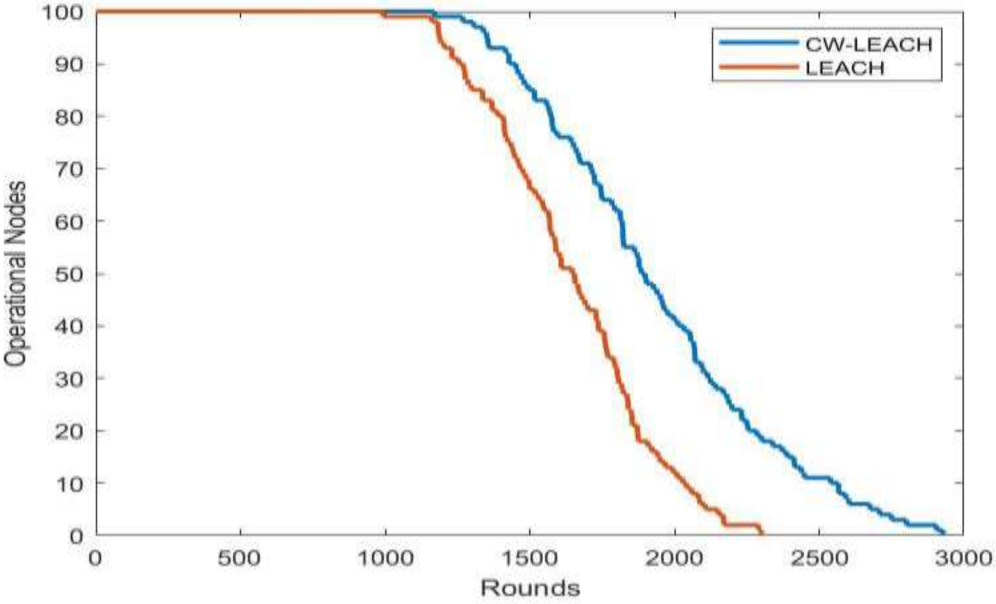


Figure 4.2 Operational Nodes per Round of Communication

4.1.2 Operational nodes per transmission of communication

Analysis of figure 4.3 showed the performance of the nodes in terms of number of transmissions. This communication between nodes and CH then CH to sink was accounted for on the figure. This covered the communication when the CH was rotated among the nodes in the cluster. The relationship between operational nodes and transmissions is inversely proportional and seen in the graph. When the number of transmissions increases the number of operational nodes reduces. Some nodes die out after going through multiple transmission and contention window adjustment aid the total number of nodes to service more transmissions. The results of Figure 4.3 also depict transmissions performance of the nodes before all the nodes reach the end of life. The novel LEACH protocol without CW adjustment went a total of 1978 transmissions successfully while the number of successful transmissions with contention window adjustment for CW-LEACH stood at 2400 before total collapse of the network.

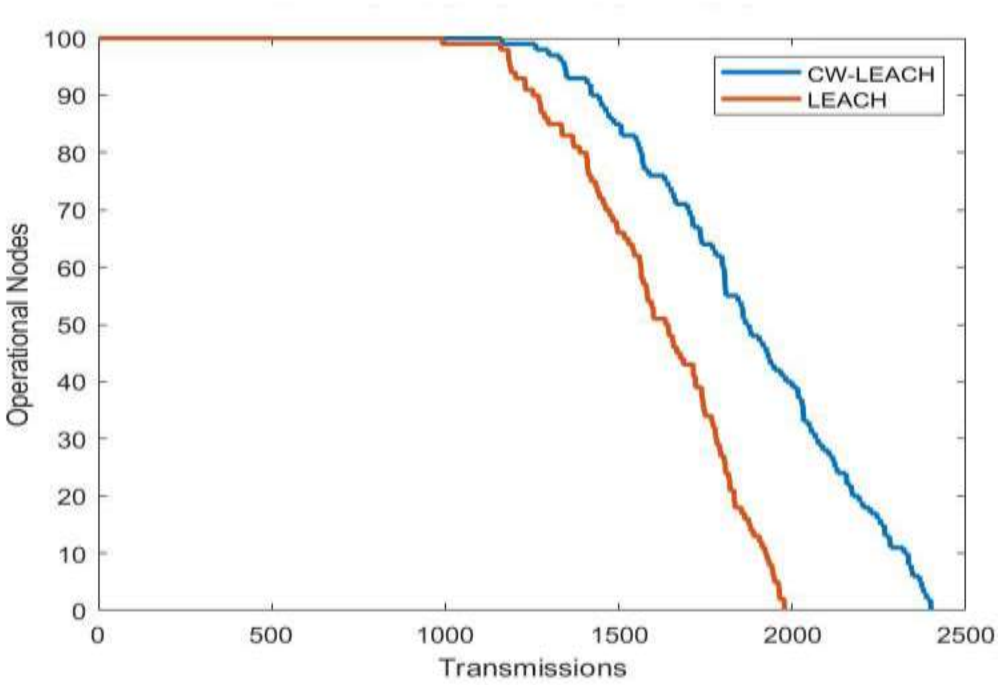


Figure 4.3 Operational Nodes per Transmission of Communication

4.1.3 Energy consumed per transmission of communication

Energy consumption is an important parameter in WSN and also the aim of the research which to improve on the efficiency and distribution. Here we measured the energy consumed per transmission of the nodes, the period of peak energy consumption and lowest point. This gives an overview of the energy performance of the network. This energy performance tracks the high and lows of the energy consumed during rounds of transmissions. This tracked the lifetime of operational nodes, the energy distribution and efficiency. When the energy distribution is well balanced in a WSN the network life time increases and deployed nodes are efficiently utilized.

In Figure 4.4 was observed that the energy consumed per transmission in a LEACH algorithm without contention window adjustment. The energy peaked at 0.33J and was least at 0.10J.

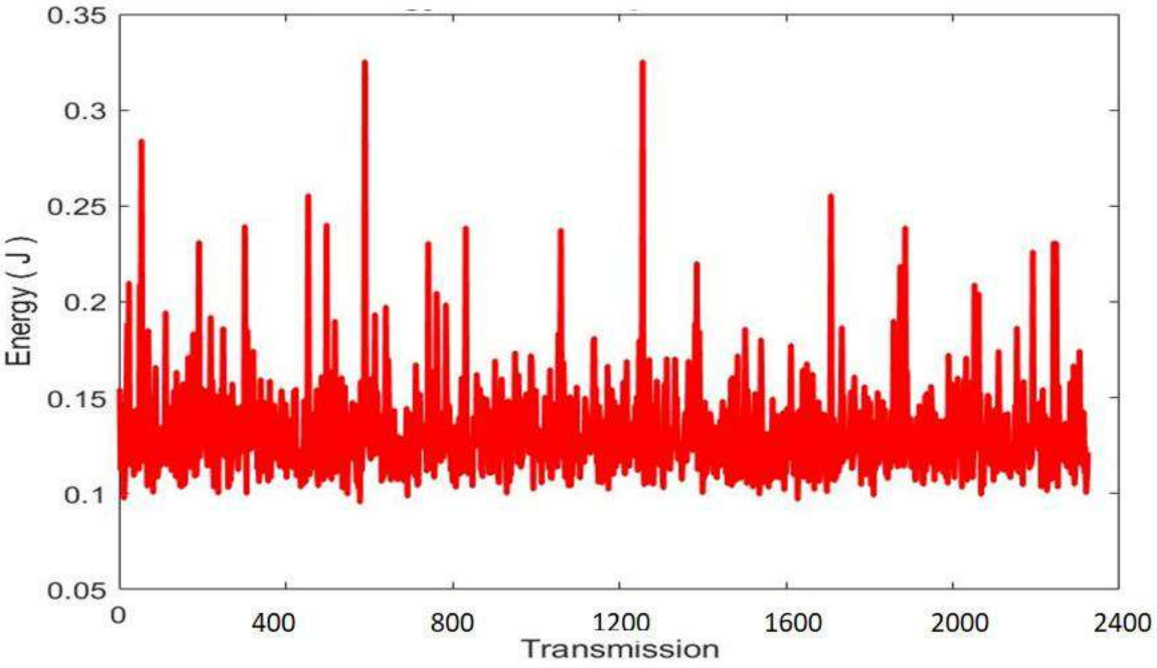


Figure 4.4 Energy Consumed Per Transmission for Novel LEACH

Whereas CW-LEACH had energy consumption peaked at 0.23J and was least at 0.09J which is shown in Figure 4.5. This indicates better performance of CW-LEACH over novel LEACH protocol.

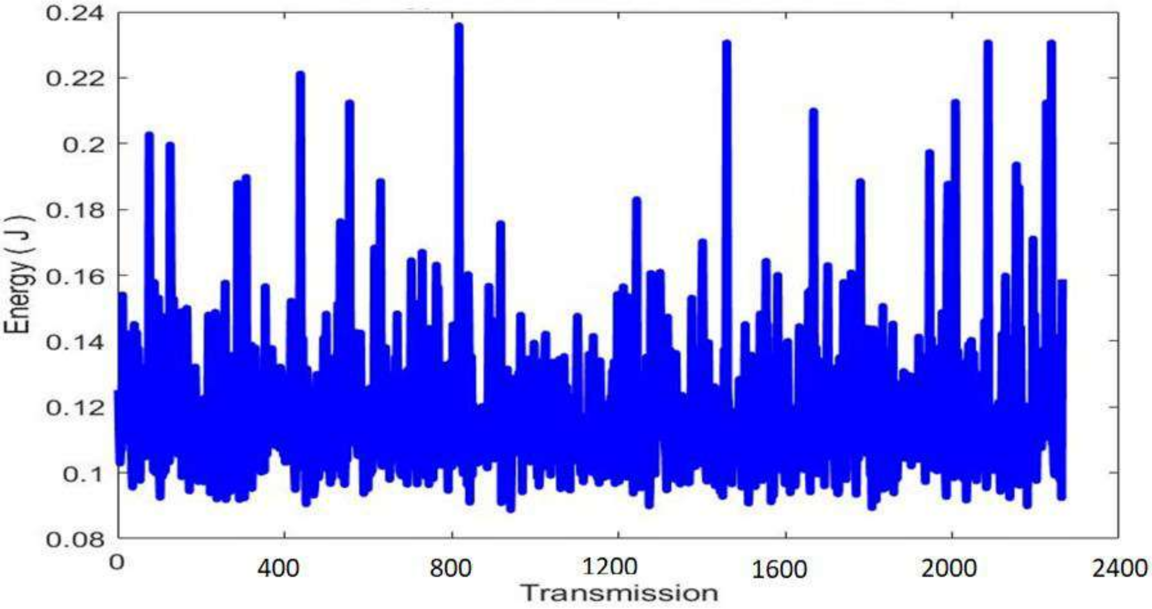


Figure 4.5 Energy Consumed per Transmission for CW-LEACH

4.2 Discussion of Results

The performance of LEACH protocol with contention window adjustment which was tagged CW-LEACH has displayed improvement though more energy efficient utilization and distribution. The intra cluster communication which is the communication between CH and member nodes is crucial in determining the life span of a sensor network. When there is high energy consumption in one cluster due to collision, the effect is rippled through the entire network and when each cluster maintains energy consumption within a good threshold the network becomes more efficient.

The first objective was achieved the network was successfully developed with contention window adjustment protocol merged with principle of operation of novel LEACH protocol to curb the effect of collision when the number of deployed nodes is high and the number of cluster formed and nodes in a cluster are also high. The parameters were well defined and effective in carrying out simulation to test the new protocol. The performance of the new protocol when the number of live nodes was plotted against number of rounds of communication indicated efficient utilization of energy. When compared with LEACH protocol, all nodes in the cluster were communicating over one thousand rounds of communications. The record for the first death of node was at the 993rd mark for LEACH protocol while CW-LEACH went further 178 rounds before it lost its first node as displayed in Figure 4.3. The total rounds the CW-LEACH went before all the nodes in the cluster died off was 2929, when compared with the novel LEACH that went 2301 rounds of communication the percentage improvement stood at 27.3%.

For the number of transmissions, the LEACH protocol had the first node died at 1015 transmissions while CW-LEACH had first node died at 1168 transmissions. The total transmission the LEACH protocol achieved was 1978 whereas CW-LEACH achieved a total of 2400 transmissions before all the nodes in the cluster died.

These numbers have shown that CW-LEACH protocol has improved the energy distribution and efficient energy utilization in the sensor node network.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Energy efficiency has been the target improvement of LEACH protocol from the onset but growth of demand for more information in the different fields of application has limited the solution provided by this novel protocol. Our technique which has potential to cater for growing demands in WSN and the need to keep energy consumption at efficient level, reduce energy wasted on idle listening and efficient channel utilization. CW-LEACH improved the total number of rounds the nodes could go before dying out, this number stood at 2950 as against 2250 rounds on the novel LEACH. This signifies an improvement of 16%. The total number of transmissions carried out by operating node increased from 1950 to 2400. Energy consumption was kept at a reasonable value all the lifespan of the nodes in the network and the average energy consumed was less than 0.25J at the peak of operation.

5.2 Contribution to Knowledge

From literatures, a lot of modifications have been done on LEACH in a quest to further reduce energy consumed and extend the lifespan of a network. A new trend of growing number of deployed nodes on the field because of increased demand for data has become a new problem in the WSN family. This research has proven that the growing needs would be satisfied through the CW-LEACH modification. This is our contribution to the research community on LEACH in WSN.

5.3 Recommendation

LEACH protocol has spent up to 19 years in the research community and has improved over time to provide solution in different aspect of WSN. The research space calling for the attention of LEACH is the mobile environment, 5G and IoT. These are growing technologies that could do with the organizational qualities of LEACH and mode of operation and could prove to be an important protocol that could provide solution to some challenges in interconnected devices like interference, pathloss, fading high data traffic.

5.4 Publication

Prince Olah Odeh, Dr. S. Zubair, Dr. A. U. Usman and Dr. S. Bala (2021) “A Review o LEACH: An Energy Efficient Protocol in Wireless Sensor Networks” Proceeding for First Nigerian Society of Engineers National Conference, pp. 120-127.

REFERENCES

Abdul R., Satwic M., Kiran G., (2017) “H-LEACH: Hybrid-Low Energy Adaptive Clustering Hierarchy for Wireless Sensor Networks” International Conference on Systems Engineering and Modeling. 62–71.

Abdulsalam H. M., and Kamel L. K., (2010) "W-LEACH: Weighted Low Energy Adaptive Clustering Hierarchy aggregation algorithm for data streams in wireless sensor networks." pp. 1-8.

Ahmed S., Walid O., Ahmed M. (2014) “IBLEACH: intra-balanced LEACH protocol for wireless sensor networks” Springer; Wireless Network 20:1515–1525.

Al-kaseem, Bilal R. (2016). “Energy Efficient MAC Protocol with Smart Sleep Scheduling for Cluster-Based M2M Networks.” 227–32.

Althobaiti, A. S., & Abdullah, M. (2015). Medium access control protocols for wireless sensor networks classifications and cross-layering. [International Conference on Communication, Management and Information Technology (ICCMIT 2015), Prague, Czech Republic]. Procedia Computer Science, 65, 4–16

Ali, Anum, Ghalib A. Shah, and Junaid Arshad. (2019). “Energy Efficient Resource Allocation for M2M Devices in 5G.” 1–16. doi: 10.3390/s19081830.

Ali, Kaouther T., and Sonia B. Rejeb. (2018). “Energy Conservation Strategy for M2M Differentiated Services in 5G / HetNet.” 2–7.

Alkadeki, Hatm, Xingang Wang, and Michael Odetayo. (2015). “Improving The Performance Of IEEE 802.11 By A Dynamic Control Backoff Algorithm Under Unstaturated Traffic Load.” 7(6):45–53.

Amjad, Anas, Mohammad N. Patwary, and Alison Griffiths. (2017). “Energy Efficient Self-Reconfiguration Scheme for Visual Information Based M2M Communication.”

Ankit G., Sangeeta M., Monika G., Pankaj G. (2012) "Clustering Approach for Enhancing Network Energy using LEACH Protocol in WSN" International Journal of Wired and Wireless Communications Vol.2, Issue 1, ISSN: 2319-9512 e-ISSN: 2319-9520

Azari, Amin. (2016). “Energy Efficient Scheduling and Grouping for Machine-Type Communications over Cellular Networks.” International Symposium of Modeling and Optimization of Mobile Ad Hoc Networks 43:16–29.

Bakr B. A, and Lilien L, (2011) "LEACH-SM: A protocol for extending wireless sensor network lifetime by management of spare nodes." International Symposium of Modeling and Optimization of Mobile, Ad Hoc, and Wireless Networks. pp. 375-375.

Bao Zhenshan, Xue Bo, Zhang Wenbo. (2013) “HT-LEACH: An Improved Energy Efficient Algorithm Based on LEACH”, International Conference on Mechatronic Sciences, Electric Engineering and Computer (MEC).

Beiranvand Z., Patooghy A., and Fazeli M., (2013) “I-leach: An efficient routing algorithm to improve performance amp; to reduce energy consumption in wireless sensor networks,” in Information and Knowledge Technology (IKT), 5th Conference on, pp. 13–18.

Bharghavan V., Demers A., Shenker S, and Zhang L., (1994) MACAW: a media access protocol for wireless LANs”, in Proc. of the conference on communication archtectures, protocols and applications. pp. 215-225, ACM Press.

Bianchi G., Fatta L, and Oliveri M., (1996) Performance evaluation and enhancement of the CSMA/CA MAC protocol for 802.11 wireless LANs, in Proc. IEEE PIMRC, Taipei, Taiwan, pp.407-411.

Changsen Z., Pengpeng C., Jianji R., Xiaofei W., Athanasios V. V., (2016) “A backoff algorithm based on self-adaptive contention window update factor for IEEE 802.11 DCF” Springer. DOI 10.1007/s11276-015-1184-9

Chatzimisios P., Boucouvalas A. C., Vitsas V., Vafiadis A., Economidis A., Huang P., (2005) "A simple and effective backoff scheme for the IEEE 802.11 MAC protocol", invited paper, in Proc. CITSA’05, Orlando.

Chen H., Zhang C., Zong X., and Wang C., (2013) “LEACH-G: an Optimal Cluster-Heads Selection Algorithm Based on LEACH,” Journal of Software, vol. 8, no. 10, pp. 2660–2666.

Chen J., and Shen H., (2007) “MELEACH an energy-efficient routing protocol for WSNs,” Chinese Journal of Sensors and Actuators, vol. 9, pp. 035.

Deshpande, Kartik Vishal. (2015). “Clustering in M2M Communication.”

Gajjar, K. Dasgupta, Pradhan S., (2018) "Lifetime improvement of LEACH protocol for Wireless Sensor Network." International Conference on Advance Computing and Communication Systems. (ICACCS) pp. 1-6.

Gnanambigai J., Rengarajan N., Anbukkarasi K., (2018) “Leach and Its Descendant Protocols: A Survey” International Journal of Communication and Computer Technologies Vol. 01, No. 3, Issue: 18.

Handy M., Haase M, and Timmermann D, (2017) "Low energy adaptive clustering hierarchy with deterministic cluster head selection." in Mobile and Wireless Communications Network, 4th International Workshop, pp. 368-372.

Heinzelman W. B., Chandrakasan A. P., and Balakrishnan H., (2002) ‘‘An application-specific protocol architecture for wireless microsensor networks,’’ IEEE Trans. Wireless Commun., vol. 1, no. 4, pp. 660–670.

Heinzelman W. R., (2000) “Application-Specific Protocol Architecture for Wireless Networks” PhD Thesis, Massachusetts Institute of Technology.

Heinzelman W. R., Chandrakasan A., and Balakrishnan H., (2000) ‘‘Energy-efficient communication protocol for wireless microsensor networks,’’ in Proc. 33rd Annu. Hawaii Int. Conf. Syst. Sci., p. 10.

Hicham O., Hajar L., Ahmed M., Mostafa C., Abdelmoumen T., (2019) “MG-leach: an enhanced leach protocol for wireless sensor network” International Journal of Electrical and Computer Engineering (IJECE) Vol. 9, No. 4, pp. 3139~3145 ISSN: 2088-8708, DOI: 10.11591/ijece.v9i4.pp3139-3145.

Ho, C. K., Khoa, P. D., & Ming P. C. (2010). Markovian models for harvested energy in wireless communications. In IEEE international conference on communication systems (ICCS), pp. 311–315.

Hong J., Kook J., Lee S., (2009) “T-LEACH: The method of threshold-based cluster head replacement for wireless sensor networks,” Information Systems Frontiers, vol. 11, no. 5, pp. 513-521.

Hu J., Raymond C. D., (2005) “A statistics based design of MAC protocols with distributed collision resolution for Ad Hoc networks” , in Proc. MobiWac05, Hawaii.

IEEE standard 802.15.4-2011, IEEE Computer society, 2011

IEEE Computer Society LAN MAN Standards Committee, Amendment to

IEEE Standard 802.11: Medium Access Control (MAC) Quality of Service

Enhancements, IEEE Standard 802.11e, Nov. 2005.

Ieryung P., Dohyun K., and Dongsoo H. (2014) " MAC Achieving Low Latency and Energy Efficiency in Hierarchical M2M Networks with Clustered Nodes" IEEE Sensors Journal Sensors-10694 DOI 10.1109/JSEN.2014.2364055

Jong-Yong L. (2019) “Improvement of CH election in three-level heterogeneous WSN”, Indonesian Journal of Electrical Engineering and Computer Science, Vol. 13, No. 1, pp. 272~278.

Juma W. Raymond, Thomas O. Olwal, and Anish M. Kuren, (2018) “Cooperative Communications in Machine to Machine (M2M): Solutions, Challenges and Future Work”. DOI:10.1109/ACCESS.2018.2807583.

Jyoti S., Bhanu P. S., Subhadra B. S., (2014), “A Survey on LEACH-based Hierarchical Routing Protocols in Wireless Sensor Network” International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 3 Issue 6.

Kajal V. Shukla, (2013) “Research On Energy Efficient Routing Protocol LEACH For Wireless Sensor Networks” International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 2 Issue 3.

Kirkpatrick S., Gelatt C. D. J., and Vecchi M. P., (1983) “Optimization by simulated annealing,” Science, vol. 220, no. 4598, pp. 671–680.

Kim D. S, and Chung Y. J., (2006) "Self-organization routing protocol supporting mobile nodes for wireless sensor network." The Institute of Internet, Broadcasting and Communication, pp. 622-626.

Kodali R. K., and Sarma N., (2018) "Energy efficient routing protocols for WSN's." International Conference on Advance Computing and Communication Systems. (ICACCS) pp. 1-4.

Kumar G. S., Paul V., and Jacob K. P., (2018) "Mobility metric based leach-mobile protocol." International Conference on Advance Computing and Communication Systems. (ICACCS) pp. 248-253.

Kumar, P., Rajesh V., Arun P., and Ashish A., (2016). “Machine-to-Machine (M2M) Communications : A Survey.” 66:83–105. doi: 10.1016/j.jnca.2016.02.016.

Kumar D., Aseri T, and Patel R., (2009) ‘‘EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks,’’ International Journal for Computer Communication., 32, no. 4, pp. 662–667.

Kwon Y., Fang Y., and Latchman H., (2003) A Novel MAC protocol with fast collision resolution for wireless LANs, in Proc. IEEE INFOCOM.

Lakshmisudha, K., & Arun, C. (2013). Research on power optimization in physical and MAC layer of wireless sensor networks — A survey. In International Conference on Intelligent Systems and Signal Processing (ISSP) (pp. 262–267). Gujarat.

Lindsey S. and Raghavendra C., (2002)‘‘PEGASIS: Power-efficient gathering in sensor information systems,’’ in Proc. IEEE Aerosp. Conf., vol. 3. pp. 3-1125–3-1130.

Liu J. L., and Ravishankar C. V., (2011) “LEACH-GA: Genetic algorithm-based energy-efficient adaptive clustering protocol for wireless sensor networks,” International Journal of Machine Learning and Computing, vol. 1, no. 1, pp. 79-85.

Loscri V., Morabito G., and Marano S., (2005) "A two-levels hierarchy for low-energy adaptive clustering hierarchy (TL-LEACH)." DOI:10.1109/VETECF.2005.1558418Corpus ID: 36606936

Mahmoud T., Farid N. A. and David S. R., (2008) “Neighbourhood Backoff Algorithm for Optimizing Bandwidth in Single Hop Wireless Ad-Hoc Networks” LIFL/IRCiCA Laboratory - INRIA POPS Project. University of Sciences and Technologies of Lille, France.

Meenakshi S. and Anil K., Shaw (2012) “Transmission Time and Throughput analysis of EEE LEACH, LEACH and Direct Transmission Protocol: A Simulation Based Approach” Advanced Computing: An International Journal (ACIJ), 3, No.5.

Meenakshi S., Kalpana S. (2012) “An Energy Efficient Extended LEACH (EEE LEACH)” International Conference on Communication Systems and Network Technologies, Rajkot, India. IEEE DOI 10.1109/ CSNT.2012.88.

Miao, Guowang, Amin Azari, and Taewon Hwang. (2016). “E 2 -MAC : Energy Efficient Medium Access for Massive M2M Communications.” 64(11):4720–35.

Myung W. L. and Ganguk H., (2018) “Adaptive Contention Window Control Scheme in Wireless Ad Hoc Networks” IEEE DOI 10.1109/LCOMM.2018.2813361.

Naveen K., Sandeep , Pawan B., Prity M., (2012) “U-LEACH: A Novel Routing Protocol for Heterogeneous Wireless Sensor Networks ”, International Conference on Communication, Information & Computing Technology (ICCICT), Mumbai, India , Oct. 19-20.

Neha B., Uma K. (2017) “Performance Enhancement and Analysis of MODLEACH Routing Protocol in WSNs” Advances in Wireless and Mobile Communications. ISSN 0973-6972 10, Number 5, 949-959.

Nigam, G. K., Dabas, C.: (2018) ‘ESO-LEACH: PSO based energy efficient clustering in LEACH’, Journal of King Saud University - Computer and Information Sciences, ISSN 1319-1578, doi.org/10.1016/j.jksuci.2018.08.002.

Niyato, D., Hossain, E., & Fallahi, A. (2007). Sleep and wakeup strategies in solar-powered wireless sensor/mesh networks: Performance analysis and optimization. IEEE Transactions on Mobile Computing, 6(2), 221–236.

Odey, A. J., & Daoliang, L. (2012). Low power transceiver design parameters for wireless sensor networks. Communications, Network and System Sciences, Wireless Sensor Networks, 4, 243–249.

Ozcelik, Ihsan, M., Korpeoglu I., and Agrawala A. (2017). “Energy Efficient IP-Connectivity with IEEE 802 . 11 for Home M2M Networks.” Advance Access Publication 60(March 2017):883–97.

Pedro de la Fuente Aragón, (2010) “The improvements of power management for clustered type large Scope wireless sensor networks,” Warsaw University of Technology.

Patil, Kiran, and Prof S. L. Lahudkar. (2016). “A Survey of MAC Layer Issues and Application Layer Protocols for Machine-to-Machine Communications.”

Pawar S, and Kasliwal P., (2019) "Design and evaluation of en-LEACH routing protocol for wireless sensor network." International Conference On Cyber-Enabled Distributed Computing and Knowledge Discovery pp. 489-492.

Quynh T. N., Phung K. H., and Quoc H. V., (2012) "Improvement of energy consumption and load balance for LEACH in Wireless Sensors Networks. International Conference on ICT Convergence () " pp. 583-588.

Radha S., Josemin B. G., Priya S., (2020) “Contention window adjustment in MAC Protocol for WSN Applications” 6th International Conference on Advance Computing and Communication Systems. (ICACCS), 978-1-7281-5197-7/20 IEEE.

Renewable and sustainable Energy Reviews, Vol 55, March 2016, Pp 1041- 1054

Renzheng G., Xiaoying L., and Qiang H. (2018) “An Adaptive Contention Window Scheme for 802.11ah WLANs” College of Information Engineering Yangzhou University, Yangzhou 225127, China. WCSN. ITM Web of Conferences 17, 01016 https://doi.org/10.1051/itmconf/20181701016

Rohit P. and Deepti S. (2018) “EEHCCP: An Energy-Efficient Hybrid Clustering Communication Protocol for Wireless Sensor Network” Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (ICST). LNICST 223, pp. 199–207. https://doi.org/10.1007/978-3-319-74439-1_18.

Sasikala S. D., Sangameswaran. N, Aravindh. P (2015) “Improving the Energy Efficiency of Leach Protocol Using VCH in Wireless Sensor Network” International Journal of Engineering Development and Research. Volume 3, Issue 2 | ISSN: 2321-9939.

Seyedi A. & Sikdar B. (2008). Modeling and analysis of energy harvesting nodes in wireless sensor networks. In 46th Annual allerton conference on communication, control, and computing, pp. 67–71, IEEE.

Shah, Ghalib A., and Muhammad Shoaib. (2019). "Energy Efficient Uplink MAC Protocol for M2M Devices." IEEE Access 7:35952–62. doi: 10.1109/ACCESS.2019.2903647.

Shahwani, Hamayoun. (2016). "An Energy Efficient Clustering Technique in M2M Based on Affinity Propagation." (October). doi: 10.1109/ICET.2016.7813207.

Sharma M., (2012) "Transmission Time and Throughput analysis of EEE LEACH, LEACH and Direct Transmission Protocol: A Simulation Based Approach," Advance Computer An International Journal, 97–104.

Siavoshi, S., Kavian, Y. S., Sharif, H.: (2016) 'Load-balanced energy efficient clustering protocol for wireless sensor networks', IET Wireless Sensor Systems. 6, (3), pp. 67–73.

Sucasas V. Radwan A. Marques H., Rodriguez J., Vahid S., and Tafazolli R., (2016) ''A survey on clustering techniques for cooperative wireless networks,'' Ad Hoc Netw., vol. 47, pp. 53–81.

Sylwia R., Chris B., (2020) "Neighbour and Energy-Aware Contention Avoidance MAC Protocol for Wireless Ad Hoc Networks" University of Antwerp - IBBT, PATS Research Group, Middelheimlaan 1, B-2020 Antwerpen. 1-4244-0495-9/06/ IEEE.

Thiemo V., Hartmut R., Jochen S., Adam D., and Juan A., (2004) "Solar-aware Clustering in Wireless Sensor Networks", In Proceedings of the Ninth IEEE Symposium on Computers and Communications.

Tong M., and Tang M, (2010) "LEACH-B: An improved LEACH protocol for wireless sensor network." 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM) pp. 1-4.

Trupti M. B., Umesh C. S., Sushanta K. M., (2018) "Energy-efficient modified LEACH protocol for IoT application" The Institution of Engineering and Technology. ISSN 2043-6386 doi: 10.1049/iet-wss.0099 www.ietdl.org.

Twayej, Wasan. (2017). "An Energy Efficient M2M Routing Protocol for IoT Based on 6LoWPAN with a Smart Sleep Mode." (July):1317–22.

Usha M., Sankarram N., (2016) "Analysis and operations of variants of LEACH protocol" International Journal of Innovative Research in Computer and Communication Engineering Vol. 2, Special Issue 1.

Veyseh M., Wei B., and Mir N, (2017) ‘‘An energy-efficient decentralized clustering protocol for wireless sensor networks,’’ in Proc. 5th WSEAS Int. Conf. Telecommun. Informat., pp. 293–298.

Vishal G. and Doja M., (2018) “H-LEACH: Modified and Efficient LEACH Protocol for Hybrid Clustering Scenario in Wireless Sensor Networks” © Springer Nature Singapore Pte Ltd., Advances in Intelligent Systems and Computing 638, https://doi.org/10.1007/978-981-10-6005-2_42.

Wairagu G. Richard, (2009) “Extending LEACH routing algorithm for Wireless Sensor Network,” Data Communications Engineering, Makerere University.

Wang J., Yang X., Zheng Y. et al. (2012), “An Energy-Efficient Multi-hop Hierarchical Routing Protocol for Wireless Sensor Networks,” International Journal of Future Generation Communication & Networking, vol. 5, no. 4.

Wei,Hsiang-ho Lin Mei-ju Shih Hung-yu. (2015). “DeepSleep : IEEE 802 . 11 Enhancement for Energy-Harvesting Machine-to-Machine Communications.” 357–70. doi: 10.1007/s11276-014-0786-y.

Wu H., Cheng S., Peng Y., Long K., and Ma J., (2002) “IEEE 802.11 Distributed Coordination Function (DCF): Analysis and Enhancement, Proc. IEEE ICC, New York, NY, 2002/04-05

Xiangning F, and Yulin S., (2019) "Improvement on LEACH protocol of wireless sensor network." International Conference on Advance Computing and Communication Systems. (ICACCS)pp. 260-264.

Xu J., Jin N., Lou X., Peng T., Zhou Q, and Chen Y., (2012) “Improvement of leach protocol for WSN,” in Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on, pp. 2174–2177.

Y. Peng, Y. Li, and L. Shu, (2014)‘‘Practical Distributed coding for large-scale M2M networks,’’ in Machine-to-Machine Communications: Architectures, Technology, Standards, and Applications. Boca Raton, FL, USA: CRC Press, p. 87

Yang, Zhaohui, Yijin Pan, Wei (2017) "Energy Efficient Resource Allocation For Machine To Machine Communications" Uniersity College London.

Xu, Rui Guan, Yinlu Wang, and Ming Chen. (2017). “Energy Efficient Resource Allocation for Machine-to-Machine Communications with NOMA and Energy Harvesting.” (April). doi: 10.1109/INFCOMW.2017.8116367.

Yektaparast A, Nabavi F. H., and Sarmast A., (2019) "An improvement on LEACH protocol (Cell-LEACH)." International Conference on Advance Computing and Communication Systems. (ICACCS) pp. 992-996.

Younis O. and Fahmy S., (2004) ‘‘HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks,’’ IEEE Trans. Mobile Comput., vol. 3, no. 4, pp. 366–379.

Zhang, Changsen, Pengpeng Chen, Jianji Ren, Xiaofei Wang, and Athanasios V Vasilakos. (2016). “A Backoff Algorithm Based on Self-Adaptive Contention Window Update Factor for IEEE 802 . 11 DCF.” Wireless Networks. doi: 10.1007/s11276-015-1184-9.

Zhang Y., Yu R., Nekovee M., Liu Y., Xie S., and Gjessing S., (2012) “Cognitive machine-to-machine communications: visions and potentials for the smart grid,” IEEE Network, vol. 26, no. 3, pp. 6-13, 2012.