Efficient Energy Utilization in Fog Computing based Wireless Sensor Networks

By
Arslan Rafi
00000118455

Supervisor

Dr. Mian Ilyas Ahmad

Department of Computational Engineering

A thesis submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Computational Science and Engineering (MS CS&E)

In

Research Centre for Modeling and Simulation
National University of Sciences and Technology (NUST)
Islamabad, Pakistan
(April 2018)

Approval

It is certified that the content and format of the thesis **"Efficient Energy Utilization in Fog Computing based Wireless Sensor Networks"** submitted by **Arslan Rafi** have been found satisfactory for the requirement of the degree.

Supervisor: **Dr. Mian Ilyas Ahmad**

Signature: ____________________

Date: ________________________

Committee Member 1: **Dr. Salma Sherbaz**

Signature: _________________

Date: _________________

Committee Member 2: **Dr. Sana Ajmal**

Signature: _________________

Date: _________________

Dedication

I would like to dedicate this effort especially to my parents, whose unconditional love and support enabled me to reach this far in my educational career, to my teachers who inspired me all the way and all those friends who always supported me.

Certificate of Originality

I hereby declare that this project neither as a whole nor as a part has been copied out from any source. It is further declared that I have developed this project and the accompanied report entirely on the basis of my personal efforts made under the sincere guidance of my supervisor. No portion of the work presented in this report has been submitted in the support of any other degree or qualification of this or any other University or Institute of learning, if found I shall stand responsible.

Date

Arslan Rafi

Acknowledgements

"Anyone that truly efforts You will never let you go, no matter how hard the situation is".

First of all I would like to thanks ***ALLAH TA'ALA****, Who has given me strength and guidance in the accomplishment of this thesis. I am thankful to project supervisor Dr. Mian Ilyas Ahmad whose motivation and immense grip on the topic make me able to accomplish this project in the allocated time . I would also express heartfelt thanks to my thesis committee members Dr. Salma Sherbaz and Dr. Sana Ajmal for their skillful assistance and guidance. I have special appreciations to Dr. Waqar Ahmad and Mr. Adeel-ur-Rehman for continuous motivation. Their encouragement and motivation were the main source of strength that stimulated me to complete this study. I am also thankful to staff members and colleagues of RCMS who helped me through the difficulties I faced during the thesis. Last but not the least, I am greatly thankful to my parents and family members, without their financial and spiritual support, I would not be able to complete my research work.*

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Abstract

Wireless sensor networks consist of thousands of sensing nodes that are deployed at remote locations for a continuous probing of the surrounding environment in order to collect useful data. In general, these nodes are equipped with a fixed battery each having limited working period. The fixed battery condition is dominating now-a-days, so energy efficiency is an important factor to be considered when the protocols are being designed. In this thesis, we introduce a model of fog computing and implement an enhanced version of Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol named as LEACH with Dijkstra's Algorithm (LEACH-DA), which optimizes the power consumption or energy utilization based on shortest path selection. Also, load-balancing is incorporated by picking an appropriate cluster head among its alternates by calculating their traffic situation with the base station. Moreover, the proposed work demonstrates longer lifespan of each node involved with respect to that of the original implementation of the underlying protocol. Our performance tests reveal that the proposed LEACH-DA protocol extends the lifetime of network by upto 78% as compared to the original LEACH protocol for a fixed number of cluster heads and fog node.

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List of Abbreviations

BS	**Base Station**
CH	**Cluster Head**
WSN	**Wireless Sensor Network**
MAC	**Medium Access Control**
TDMA	**Time Division Multiple Access**
IoTs	**Internet of Things**
FN	**Fog Node**
LEACH	**Low-Energy Adaptive Clustering Hierarchy**
LEACH-DA	**Low-Energy Adaptive Clustering Hierarchy by making use of Dijkstra's Algorithm**
K-LEACH	**K- medoids Low-Energy Adaptive Clustering Hierarchy**
A-LEACH	**Assisted LEACH**
DD	**Direct Diffusion**
SPIN	**Sensor Protocols For Information Via Negotiation**

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Chapter 1

Introduction

1.1 Overview

This chapter presents the concept of wireless sensor networks (WSNs), their structure and an important energy efficient protocol, low-energy adaptive clustering hierarchy (LEACH) protocol. Also a brief introduction of fog computing is discussed. In addition we describe the research problem, its importance, our contribution and structure of thesis as well.

1.2 Wireless Sensor Networks

Wireless sensor networks are made up of thousands of small and low power sensing nodes known as sensors. These nodes are the combination of limited processing unit for processing data, memory for saving information, transceiver for communication with other nodes and a power source to remain alive for proper functioning. Sensor nodes are installed to monitor physical conditions including light, temperature, pressure and other environmental conditions such as surveillance, fire monitoring and pollutants, health care and industrial automation [1].

A typical sensor node consists of several components as shown in Figure 1.1. The role of these components is highlighted briefly in the following

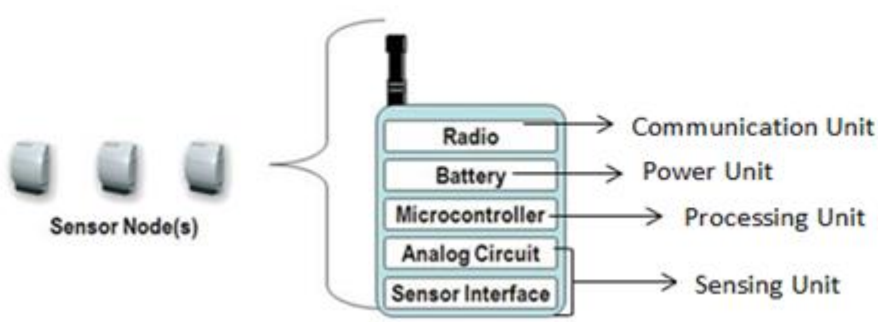

Fig 1.1 WSN Node Components

1. **Communication Unit**: Short range antenna is the key component of the node which performs communication among the nodes by using a wireless channel.
2. **Power Unit:** The power unit provides electrical energy to the node in order to perform its function of data collection and transmission.
3. **Processing Unit:** This unit is also known as the brain of the sensor node. It usually consists of a microcontroller with partial storage, to provide intelligent control in the network.
4. **Sensing Unit:** This unit involves analog to digital converter (ADC) and a sensing interface used for relating with other sensor nodes in the WSN. In this unit, sensors have the responsibility to observe the physical phenomenon and generate continuous signals based on the perceived information, then information in digital form is forwarded to processing unit by ADC.

Routing of data in WSNs requires some protocols that assure the restrictions on node size, energy and storage capability. As discussed before, sensor nodes are equipped with limited power [1] and therefore the rate of power or energy consumption in nodes describes the lifetime of WSN. Large numbers of protocols have been developed in WSNs which tend to preserve energy in order to prolong the network lifetime. But researchers focus on hierarchical routing protocols to control useful energy consumption.

In hierarchical routing, whole wireless sensor network is divided into different regions. Each region has cluster head and member nodes which collectively form clusters. Each cluster head has information about its own cluster and has no information about other clusters. Therefore, cluster head of each cluster is responsible for communicating with the base station instead of member nodes. In this way, more energy is preserved during communication by using hierarchical structure rather than using flat routing.

Figure 1.2 shows network of hierarchical routing protocol where member nodes in group sense information from the surroundings and send it to the base station through fog node, so that the data is collected, aggregated and then shared with the user through internet

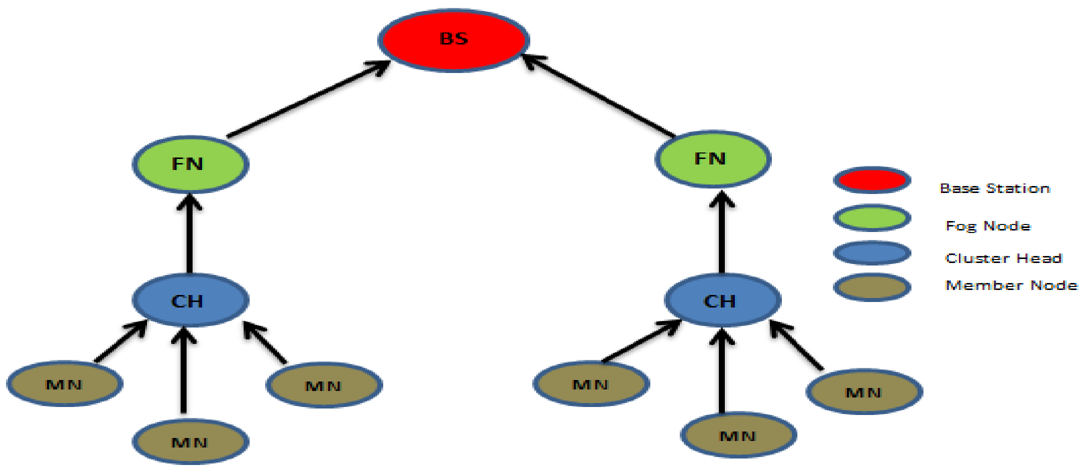

Fig 1.2 Hierarchical Sensor Network

1.3 Fog Computing

Fog computing is a new technology which provides services closer to the network. It is also known as Edge computing. It can perform different operations like computation, storage and providing network services between end users and cloud data centers.

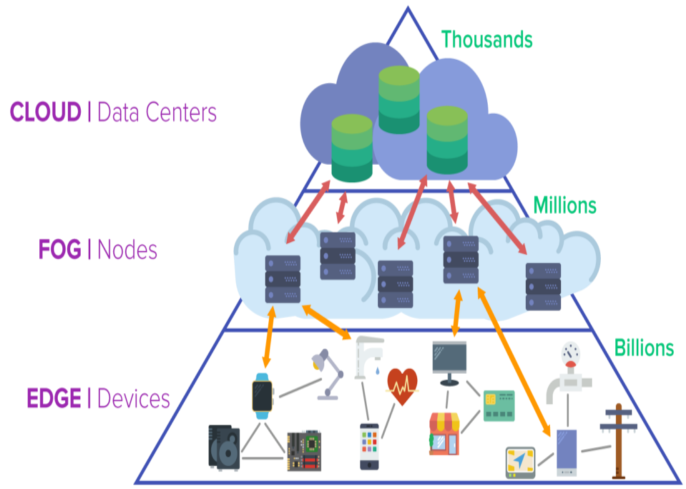

Fig 1.3 Fog computing Architecture

1.4 Low Energy Adaptive Clustering Hierarchy

LEACH is one of the time division multiple access (TDMA) based MAC protocol. LEACH is an important hierarchical routing protocol used in WSN to prolong the life time of the network. The protocol defines rules for creating small groups of adjacent nodes called clusters in which a single lead node is called cluster head that directly communicates with the sink. All other nodes in the cluster are known as member nodes. The members nodes can transmit their data to their associated clusters head and the cluster head aggregates and compresses the data before forwarding it to the base station. Therefore, cluster head consumes more energy as compared to its member nodes. So, cluster heads are randomly changed within the clusters in order to conserve energy of each node. A simple architecture of network with clusters shown in the Figure 1.4

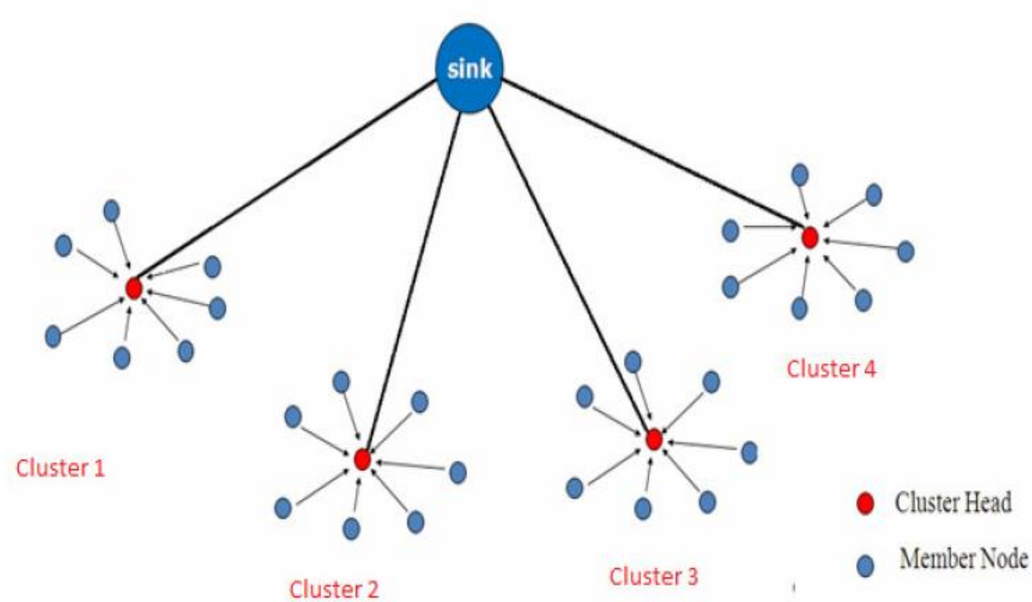

Fig 1.4 Architecture of WSN with clusters

1.5 Problem Statement

All the sensor nodes directly transmit information to the cluster head and cluster head forward it to the base station. These sensor nodes are located at some distance from its cluster head which communicates with the base station through internet. Clusters head consume some energy in communicating with the base station, which is reduced by introducing the concept of fog computing. However for the member nodes, we need to utilize an energy efficient approach especially for the nodes that are at large distances from cluster head. Thus we need to design a sensor network such that the associated sensor nodes consume less energy in communicating with the corresponding cluster head. To address this problem, we need to route the data in the cluster such that the distances between cluster head and sensor nodes are utilized.

1.6 Research Goal

The goal of this research is to analyze the existing LEACH protocol in a fog computing framework and update it in a way that improves the energy management of the sensor nodes. The objectives of the research are

1. To implement and simulate a fog computing network using MATLAB simulator.
2. To develop a new technique that enhance the network lifetime for WSN's.
3. To compare and evaluate the performance of the proposed settings with the existing LEACH framework.

1.7 Motivation

Many applications use different features of wireless sensor networks. Undertaking of the major impediments in the design and manufacture of such networks is needed in order to develop fabricate functional and coherent applications. Energy efficiency is one of the major demands for designing wireless sensor networks. Therefore, innovative techniques are required to increase energy efficiency to prolong the network lifetime.

1.8 Organization of the Research Thesis

In Chapter 2, background theory and related work is described. Chapter 3 explains the proposed methodology to increase WSNs lifetime. In Chapter 4, simulation results are provided that show the effectiveness of the proposed methodology as compared to LEACH. Finally Chapter 5 provides insights into future work based on experimental results.

Chapter 2

Background and Related Work

2.1 Overview

In this chapter, some important routing protocols used in wireless sensor networks (WSNs) are presented. A brief description of multiple access control layer routing protocols and network structure is discussed. Also we discuss work on the research problem that is approaches purely based on hierarchical protocols.

2.2 MAC Layer Protocol

Sensing, computation and communication are the three major power consuming tasks in WSNs. Communication is the one which consumes more power or energy [23].Therefore, we can say that higher energy consumption takes place during performing communication rather than computations and sensing in WSNs. Efficient implementation of MAC layer protocol provides more feasible solution to overcome the energy consumption problem. MAC provides consistent connections to take complete control over antenna activities as well as efficient bandwidth utilization in the network. Energy efficiency, device management and efficient resource sharing are significant factors which must be considered in designing MAC layer protocol [23]. The developed MAC layer protocol including carrier-sense multiple access with collision avoidance (CSMA), ALOHA, slotted-ALOHA, random-ALOHA, code division multiple access (CDMA), orthogonal frequency division multiple access (OFDMA) and time division multiple access (TDMA) are used to achieve these goals. Most of the recently designs MAC protocols for WSNs are TDMA (time division multiple access) protocol [24]. Next we describe TDMA protocol and then provide two examples that used TDMA in developing their medium access control.

2.3 Time Division Multiple Access (TDMA)

TDMA is considered as the best choice in wireless sensor networks (WSNs) [25] because of being more energy efficient. It generates time slots for sending and receiving data for each sensor node in the network. They are active during sending or receiving data and rest of the times are in sleep mode by shutting down the radio interface. Hence energy conservation takes place during the sleeping phase. A simple TDMA frame structure is shown in Figure 2.1. There are number of issues in the design of TDMA. Transmission interference is one of the most common problems that should be considered in designing TDMA. This problem arises when two neighbor nodes start transmitting data simultaneously or by two non-adjacent nodes sending data to the common receiver. Therefore, rescheduling phenomenon should play an important role in designing TDMA.

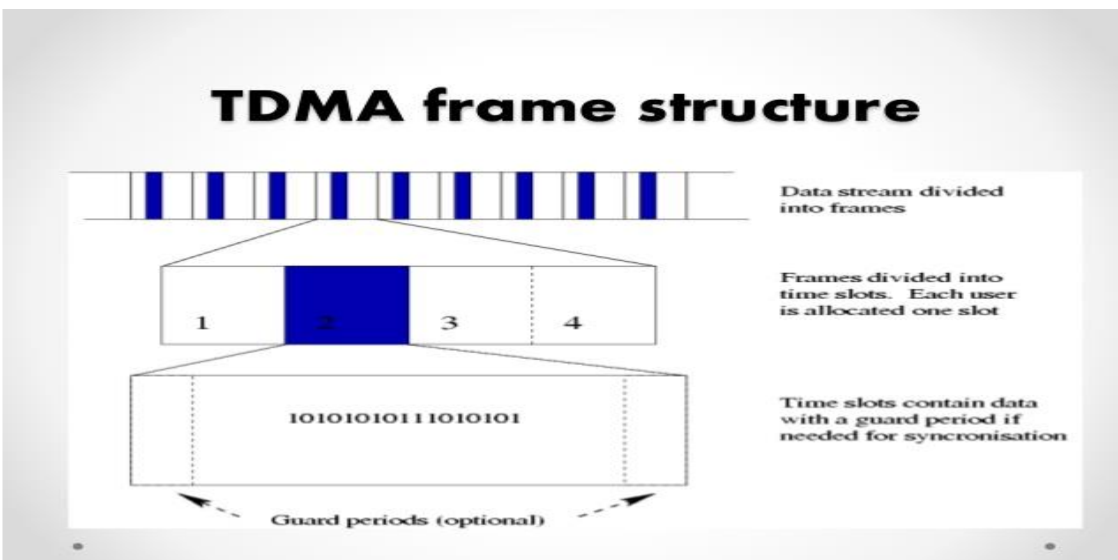

Fig 2.1 TDMA frame Structure

2.3.1 Sensor MAC (S-MAC)

S-MAC [24] protocol developed just for wireless sensor networks. In this protocol, time divides into long frames and each frame consists of active and passive part. During the passive part, sensor nodes shut down their radio interface in order to conserve energy and ensure communication with their neighbors during the active part. All the data remained in queue during sleeping (passive) phase and starts sending queued data when active phase starts. Energy consumption takes place only in the active phase. Therefore, this protocol gives rise the latency issue in wireless sensor network [26].

2.3.2 Lightweight MAC (LMAC)

LMAC [27] considers time-division multiple access methodology to provide a collision free network. LMAC utilizes a distributed algorithm as described in [28] for dividing time slots among sensor nodes distinct to TDMA that divides the time slots by a central manager. Sensor nodes organize time into different slots and each slot is divided into three sections such as communication request, traffic control and data section. When a node desires to transmit information, it looks for its time slot, broadcast a packet consisting of the target and length in the control section and then immediately sends the data. Nodes which are not an expected receiver shut their radio interface during data transmission. LMAC prolongs the network lifetime by 3.8 times as compare to S-MAC [27].

2.4 Network Routing Protocols in WSNs

WSNs have limitations in terms of bandwidth, battery life and energy consumption. Prolongation of network is the main goal in designing of WSNs. To achieve this, many aspects should be considered such as node deployment, energy consideration, scalability, fault tolerance and several challenges must be addressed. In wireless sensor networks, sensor nodes are deployed randomly or manually in network. In manual deployment, sensor nodes are manually located in the field with predetermined and known paths otherwise randomly scattered .Fixed battery condition is dominating in WSNs, so energy efficiency is an important factor should be considered when the protocols are being designed.

In multi-hop networks, as shown in Figure 2.2, each sensor behaves as sender and receiver. Therefore, it leads to significant power consumption among the sensors in the network. Lack of power, environmental interference and physical damage are some of the causes of nodes failure. In this situation MAC and other protocols should provide alternative means for sending data to sink.

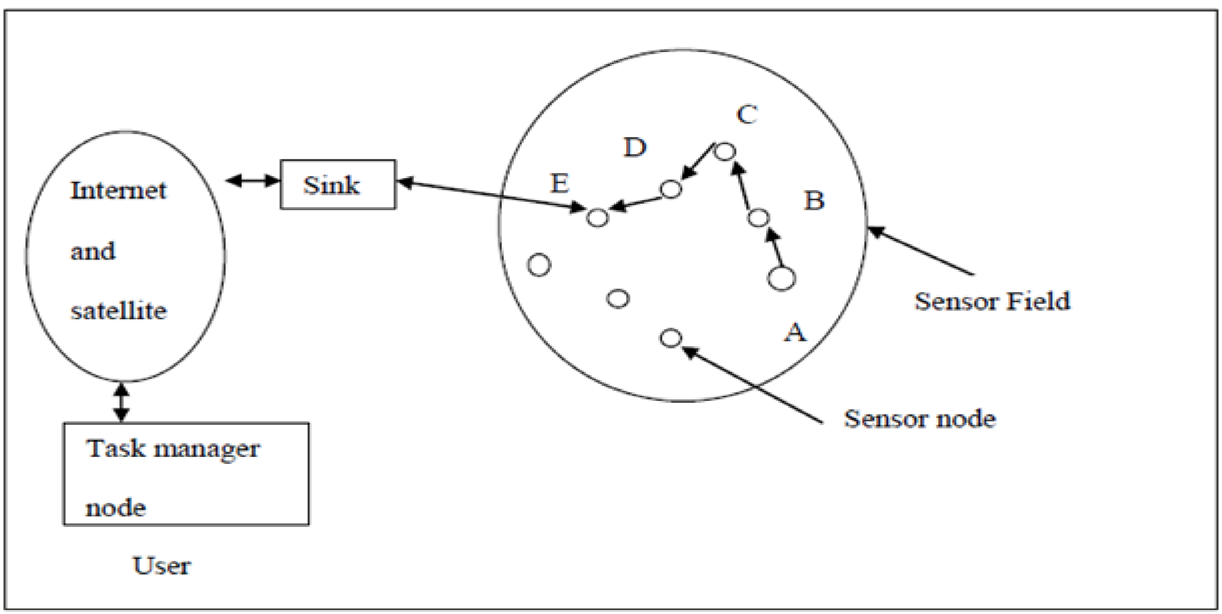

Fig 2.2 Sensor nodes scattered in the field

2.4.1 Network Structure

In wireless sensor networks, network structure and routing scheme is controlled by network routing protocols. Network structure consists of three types as flat routing [29] [30], hierarchical routing [31] [32] [33] and location based routing [34][35][36][37]. According to our research area, we discuss here only flat and hierarchical routing protocols.

2.4.1.1 Flat Routing

In this type of network structure, sensor nodes play the same role with same functionality in sending and receiving information. Due to large network, it is impossible to assign global identifiers to each sensor. Therefore, sink or base station send requests to the network and looks for data from sensor nodes in the network. This type of routing is called data centric routing [39]. Direct diffusion (DD) and sensor protocols for information via negotiation (SPIN) [38] are the examples of data centric routing protocols which is quite energy efficient.

2.4.1.2 Hierarchical Routing

In this type of method, sensors play a discrete role in sending and receiving information. Some of the sensor nodes are used for performing communication tasks, rest of the nodes can be used for sensing the target area in the network. Structure of hierarchical protocol considered as two layer design, one is responsible for selection of leader and other is used for routing purpose. In this type of routing protocol, cluster head plays the leading role for receiving information from other nodes in the network, aggregates this information and sends it to the sink. Formation of clusters and efficiently performing task to cluster heads leads to form an energy efficient network [39]. Creating clusters and selecting optimal cluster heads in order to preserve energy is the main goal of all the hierarchical routing protocols.

2.5 Fog Computing and WSN's

Under large wireless sensor networks, sensor nodes have to face massive volumes of data persistently. Processing of such data obviously requires huge amount of time. To cope with the situation, certain new trends have emerged, like Fog architectures [4]. Edge archetype is used to facilitate interconnection of sensor nodes with Internet to make them intelligent enough to give sharp response [5][6].Fog architecture includes number of nodes having capability to perform different computations are placed closer to the network and ingest data from the connecting sensor nodes in the network. These nodes are called Fog nodes (FN.) Employment of FNs helps in minimizing latency, avoiding from reproducing traffics between base station and the end-user. Thus, by having such setup in place, bandwidth utilization can be improved and control the energy consumption of the core network as well [7]. Fog computing architecture with respect to wireless sensor networks shown in the Figure 2.3 below.

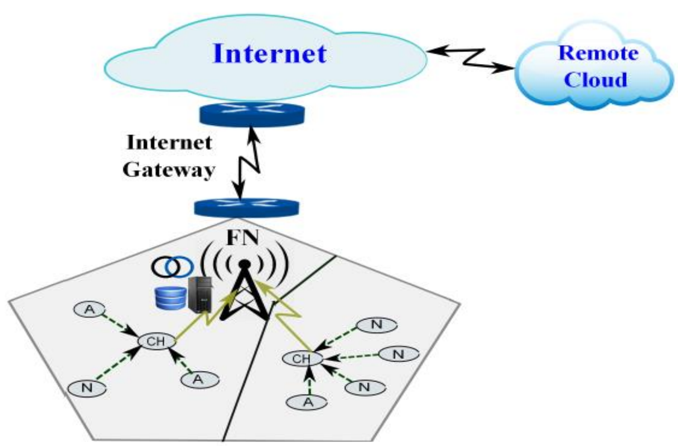

Fig 2.3 Fog computing architecture in WSNs

2.6 Dijkstra's Algorithm

In 1956, a computer scientist Edsger Dijkstra's introduce this algorithm. This is used for computing shortest paths among nodes in the graphs which may represent. Dijkstra exists in different variants, basically it is used for computing shortest path between source node and destination node.

Simple architecture of WSNs is shown in Figure 2.4 and describe that how Dijkstra's is implemented on this architecture in order to find the minimum path between starting node and ending node.

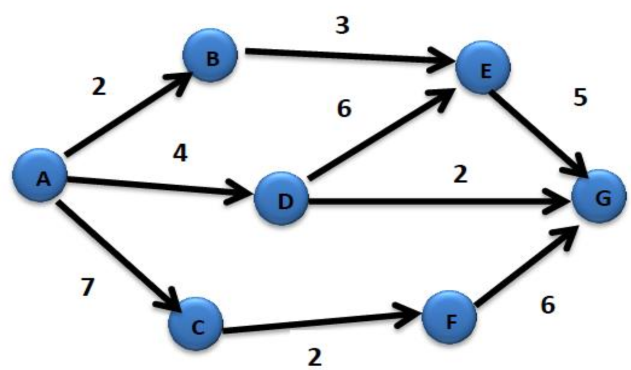

Fig 2.4 Architecture of WSNs

Suppose that we consider "A" as starting node and "G" as a destination node. From the above, we can see that multiple paths are available to reach the destination node "G" from the starting node "A". Starting from node A, we have three paths with the weights 2m, 4m and 7m which are directed towards the destination node G passing through node B, D and C respectively. We compute the distance of these three different paths and select the least weighted node from the starting node A. We select node B which has shortest distance as compared to node C and D respectively. So, we select the path AB with the weight of 2m and also carry with second shortest distance path as well which is an alternative path AD with weight of 4m and left the longest path which passes through node C. Now from node B, we have a single path which are directed towards destination node G passing through node E with weight of 4m. This new path becomes ABE having weight 6m respectively. On the other hand, from node D two paths are available to reach destination node G, one passes through node E with weight of 3m and other directly reaches to the destination node G respectively with the weight of 1m. So the weights of two new paths ADE and ADG from starting node A towards the destination node G becomes 7m and 5m respectively. According to Dijkstra's algorithm, we selected the path ADG which is the shortest path in the present scenario. The other path ABE is known as the incomplete path. Moreover, if we have two different paths having equal weights from source node to destination, we will select that path which composed of minimum number of nodes.

2.7 Calculation of Load on Cluster Heads

Communication is the one which consumes more power or energy [23]. Cluster head is responsible to communicate with base station and its member nodes present in the clusters. If the load on the cluster head is greater, it consumes more energy.

We calculate the load on each cluster head by using the following mathematical formula [41]

$$\textbf{\textit{Load}} = \frac{\boldsymbol{l}}{\boldsymbol{R}} \tag{2.1}$$

l = No. of packets transmitted from node

R= Total no. of packets submitted to node

2.8 Related Work (Literature Review)

W.B. Heinzelman [8] adaptive clustering algorithm named LEACH was proposed to combine clustering and routing in wireless sensor networks. LEACH protocol has capability to minimize the power /energy utilization to provide such clusters that prolong wireless sensor network lifetime.S

In order to explain LEACH protocol, we consider some important parameters as

TABLE 2.1: Important Parameters.

Parameter	Description
E_{elect}	Energy consumed per bit.
ε_{fs}	The energy consumed per bit and per area
ε_{mp}	The energy consumed per bit and per area
do	Threshold distance
EDA	The energy required for data aggregation.

Consider a simplified radio hardware energy dissipation model shown in Figure 2.5. It comprises of both free space and multi-path fading channel model completely relying on distance between transmitter and receiver.

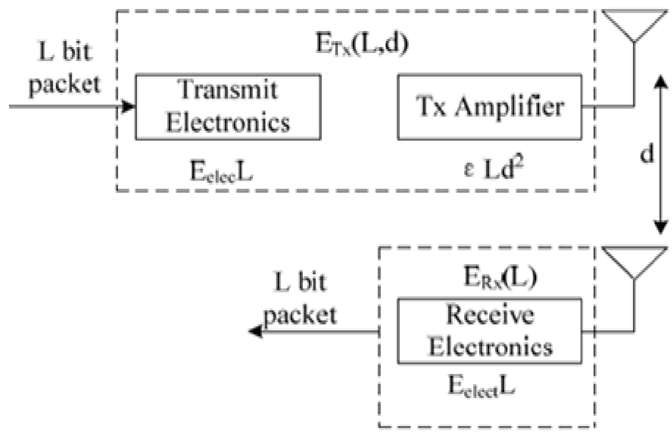

Fig 2.5 Radio Hardware Energy Dissipation Model

Transmission (E_{Tx}) and receiving costs (E_{Rx}) are calculated as [8]

$$E_{Tx}(l,d) = \begin{cases} l\,E_{elect} + l\,\varepsilon_{fs}\,d^2 \quad , d < d_o \\ l\,E_{elect} + l\,\varepsilon_{mp}\,d^4 \quad , d > d_o \end{cases} \qquad (2.2)$$

d= distance between transmitter and receiver

$$E_{Rx}(L) = E_{elect}\,L \qquad (2.3)$$

L = length of the message in bits

Hierarchical protocol LEACH includes transmission of information from sensor nodes to its cluster heads (CHs), cluster heads aggregate this information, compress and forward to sink [1]. Stochastic algorithm is used at each round to decide each node has ability to become cluster head or not. This protocols has two stages

i. Setup phase (election of cluster heads takes place)
ii. Steady phase (cluster head maintained and data transmission takes place)

Setup phase

In this phase, randomly distributed value between 0 and 1 is generated against each node in the whole network. If this randomly generated value of the node is smaller than the threshold, then respective node becomes cluster head. This threshold can be calculated [1] as

$$T(n = \begin{cases} \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)}, & if\ n \in G \\ 0, & otherwise \end{cases} \qquad (2.4)$$

Here,

p = desired percentage of cluster heads

r = current round

G =group of nodes that has not become CHs in last rounds

Steady Phase

Nodes in the network are grouped to its associated head node to form clusters and this associated head node is called cluster head (CH). Cluster head receives data from its member nodes of its cluster, aggregate and sends it to the sink (base station). The nodes within each cluster do not directly communicate with sink. The simplified structured of LEACH is shown in Figure 2.6

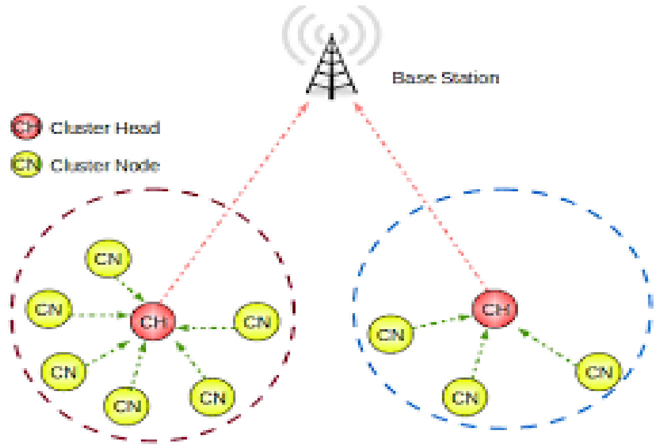

Fig 2.6 Structured of LEACH protocol

LEACH became suitable for WSN's but it does not care about the duplicate tasks and utility for nodes in the similar coverage area which results energy consumption. To overcome this problem, M. Y and Abdullah [9] proposed a new protocol based on LEACH named as task scheduling and distribution energy management mechanism of roles dormant cells (LEACH-SRDC). They developed scheduling process to send information from nodes to the respected users or re-broadcasting to the upper level of the network .Though, distribution of optimal cluster head is the major factor for communication. Therefore, because of using this approach selection of optimal cluster heads is done which can accomplish efficient task regarding to energy consumption. By the induction of this feature, this scheme is useful for accumulation to the existing LEACH. Experimental results proved that developed protocol LEACH-SRDC provides more energy preservation communication infrastructure as compared to existing LEACH protocol to prolong the network lifetime of wireless sensor networks.

In LEACH-SRDC, single cluster head is responsible for communicating with the sink. If cluster head dies, no more transmission takes place. To address this problem, N. Sindhwani and R. Vaid [13] introduced a new protocol named as LEACH-V based on primary and secondary cluster heads. In this protocol, each cluster has two cluster heads, primary and secondary cluster head. The primary cluster head (CH) is responsible for transmission of information which received from the sensor nodes to the base station. The secondary cluster head (vice-CH) becomes a cluster head when the primary-CH dies. Sensor nodes in each cluster only gather data from environment and send to the cluster head. This will provide a feasible expansion in lifetime of network.

LEACH-V is singled level technique, M. Sharma and A. K Shaw [12] introduced a multilevel clustering technique by decreasing the communication distance in order to increase the energy efficiency of the network named energy efficient extended LEACH (EEE-LEACH). In this technique, two layers are involved during cluster formation between the sensor nodes and the base station. Cluster heads are formed in the first layer where member nodes use fuse mechanism for transmission of their data to their associated cluster head (CHs) and these CHs aggregate all the data. Master cluster heads are formed in the second layer. When the master cluster heads are formed, CHs are going to find the most nearest master cluster head by calculating Euclidean distance among them and transmit all the data which are aggregated from their member nodes to the associated master cluster heads. Similarly, master cluster heads aggregate all the data from the nearest CHs and send to the sink. We should keep master cluster heads less in numbers than the CHs in order to minimize the distance between sensing nodes and the base station.

All the foregoing protocols, selected cluster heads randomly or based on calculating Euclidean distance which are not more feasible in term of energy preservation within the clusters. W. Luan and Zhu [11] suggested a new concept of cluster heads selection by calculating the weight of sensor nodes which is the combination of its degree and residual energy. This algorithm is purely based on degree and residual energy (weight) of the nodes. They named as node degree and energy-aware routing protocol (NDEA). This protocol greatly prolong the life time of the network.

In the antecedent protocol, distance parameter is neglected in order to select cluster head. K-medoids [17] LEACH is developed to cover preceding parameter (residual energy) as well as distance parameter together. In this protocol, K-medoids algorithm is used for partitioning of the sensor nodes in the whole network as cluster head, Euclidean distance is applied to make clusters by considering minimum distance between nodes and cluster heads. Most probably considers that node as cluster head which has maximum residual energy.

Communication is the key task in wireless sensor networks. K-medoids LEACH protocol plays single hop communication within the clusters, which consumed more energy because communication takes place from distant among sensor nodes and cluster heads. Therefore, M. Abad and M. Jamali [10] provided a variant of K-medoids where sensing devices communicate in multi-hop fashion. All nodes are not responsible to send data to its cluster head. Each sensor node has responsibility to send data to its closest neighbor as a result more energy is conserved. Hence, each node involves in aggregation and forwarding, which enhance cost and outlays of network.

All the protocols that have discussed, do not differentiate routing and data aggregation. But S. Kumar and A. Pal [14] proposed assisted LEACH (A-LEACH) which considers routing and data aggregation as two separating tasks. They focused on the routing rather than data aggregation. In this protocol, associated clusters have assisted nodes that perform routing task for the whole network. Therefore, this reduces the workload on cluster heads, resulting in an increased network lifetime.

Single sensor node present in the whole wireless sensor network has no information about base station or sink. If the cluster head of its cluster dies, it has no chance to send information to the sink or base station. In order to address this issue, M. Dakshayini [16] facilitate sensor nodes with global position system (GPS).).Therefore, they named “Energy-Aware Routing Algorithm”.

In this protocol, after random deployment of sensor nodes, individual node informs the location or position of the sink or base station in the network before introducing both the phases of LEACH protocol (set-up phase and steady phase). After collection of location information, coverage area of network assumes B is divided into different groups i-e, B1, B2, B3 and so on. These groups formed purely based on position of node and cluster heads election probability “p”. Moreover, base station is the creator of these groups. Individual group has cluster head which is elected randomly, in each round. Each cluster head broadcasts identity messages to its member nodes. All the cluster heads in the network receive and aggregate information from its members as in the steady phase of LEACH protocol instead of directly approaches to the base station. In this way cluster head leads to reduce energy consumption by decreasing communication distance. Therefore, results prove that modified version of LEACH is more energy efficient as compared to LEACH.

Energy aware routing algorithm introduced a new concept in WSN’s. But R. Mahakud [18] work provided more efficient protocol named as “PEGASIS” (power-efficient gathering in sensor information system). In this protocol, formation of chain takes place, based on closest sensor nodes inside the network. This provides an optimal route towards the sink node which results to preserved more energy. It reduces the overhead caused by dynamic cluster formation in LEACH. Thus, single leader is responsible for the transmission of data to the sink or base station.

The preceding protocol mostly deals with transmission of information by using those clusters which existed inside the range of base station or sink. Three level hierarchical protocols (TLHCP) [19] address this problem efficiently. In this protocol, predefined field is introduced around the sink or base station. This predefined field includes some sensor nodes and others are outside of this field. The outsider cluster heads from the respective fields looks the closest cluster head which exist inside the field of base station for transmitting data. These cluster heads aggregate data and send to sink. Cluster head inside the field area acts like a bridge between outsider cluster head and sink.

No doubt energy or power is one of the most important considerations for wireless sensor networks. Besides this, when we are dealing with the real-time applications along with energy, delay is also a key consideration. To address this, a new routing technique [21] which ensures "energy $\times$ delay" performance as well as cover other parameter includes energy efficiency and throughput of the network has proposed. This technique is known as shortest hop routing tree (SHORT). The main objective of this technique is to generate synchronized communication pairs and looks for the shortest route to transmit data.

Chapter 3

Proposed Methodology

3.1 Overview

In this section, we discuss our methodology for the problem of low energy consumption in WSN's. The approach is based on a modified form of the low-energy adaptive clustering hierarchy protocol that is making use of the Dijkstra's algorithm. The new protocol is named as LEACH-DA as it employs Dijkstra's algorithm internally in order to facilitate optimal path selection for the flow of data within each cluster of network. Making use of such an approach, LEACH-DA enables longer lifetime of the system by strengthening the stability of sensor networks while ensuring reduced energy consumption of the nodes.

3.2 Proposed model of LEACH-DA

Sensor nodes in the WSNs have capability of performing data acquisition, processing, computations and communication operations. Communication operation is one of these which lead to more power consumption in wireless sensor networks [40].

Our proposed model consists of two phases, set up phase and the steady phase. In the setup phase, election of cluster heads take place by using equation 2.4 whereas cluster head maintained and data transmission takes place in the steady phase. In this model, hybrid concept is used by finding the shortest path and computing the load of the cluster heads (CH's). Cluster heads within each cluster is maintained by considering minimum load on the cluster head. When cluster head is maintained, find out the shortest path from sensor nodes to the cluster head for data transmission by using a well -known algorithm named Dijkstra's Algorithm. Also the technique is applied in Fog computing environment. A simple wireless sensor network is shown in Figure 3.1

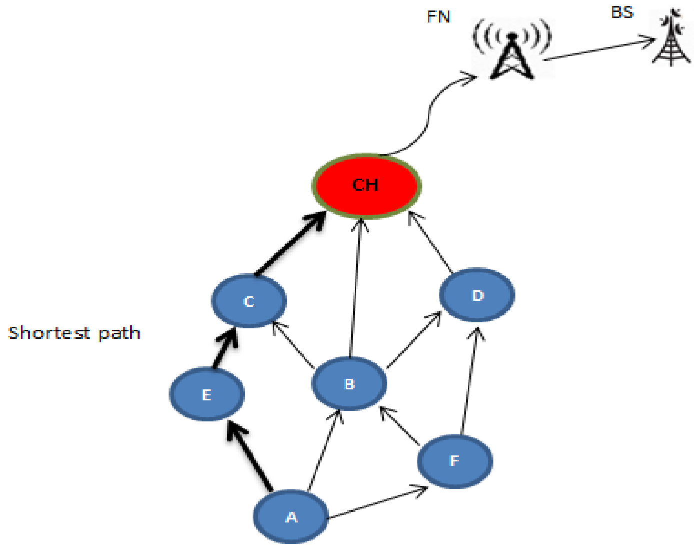

Fig 3.1 Proposed model of WSN

Our proposed model consists of following steps:

1. Create sensor network model.
2. Cluster formation takes place considering the position of sensor nodes in the network.
3. Selection of cluster head takes place by using equation 2.4.
4. Calculate the load of cluster heads present in each cluster of the whole sensor network by using an equation 2.1.
5. Find out the shortest possible distance between the cluster head and its member sensor nodes by using dijkstras algorithm.
6. If found that the load of cluster head is minimum or find the shortest path among the sensor nodes to the cluster head, then data is transmitted.
7. Go to step-4.
8. End of network lifetime.

3.2.1 Implementation of Dijkstra's Algorithm in LEACH

Shortest path algorithm Dijkstra's is used in the steady phase of existing protocol LEACH where clusters are formed, based on computing minimum distance by using Euclidean formula

$$d(p,q) = \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2 + \dots\dots\dots + (q_i-p_i)^2} \qquad (3.1)$$

d (p,q) is the distance from point p to q,

p and q are the cartesian coordinates in Euclidean space

3.2.2 Calculation of Energy Consumption

Energy consumption of each node depends on the position of the node where it exists in the network. Following formulas [1] used for calculating energy consumption

If (distance > do)

S(i).E = S(i).E-((ETX+EDA)*(4000)+Emp*4000*(node_dist(i)*node_dist(i)*node_dist(i) *node_dist(i))); (3.2)

else

S(i).E = **S(i).E- ((ETX+EDA)*(4000) + Efs*4000*(node_dist (i)* node_dist(i)));** (3.3)

So,

$$\mathbf{do} = \sqrt{\frac{Efs}{Emp}} \qquad (3.4)$$

TABLE 3.1: Equation Parameters

Parameter	Description
ETX	Transmit Energy
ERX	Receive Energy
S(i).E	Energy of the ith node
Emp	Energy of multipath loss
Efs	Energy of free space
EDA	Data aggregation energy
node_dist(i)	Distance of the ith node
do	Threshold distance

3.2.3 Importance of Fog Node

The main motive of fog computing is to provide different services at the edge such as computation, storage and networking. In our research work, fog node acts like an intermediate layer between the sensor nodes present in the wireless sensor network and the base station. Induction of the fog node, provide optimal path by reducing the distance among the nodes and the base station. Therefore, it has great contribution in energy preservation.

3.3 Motivation

The main motivation of this research work is to enhance energy efficiency under wireless sensor networks (WSNs) with the help of fog computing that act as an intermediate layer. In the proposed concept, we introduced fog nodes that are almost similar in functionality to the base station or we can say that fog nodes acts as sub-base station. Fog nodes serve as bridging points to cover all the targeted areas, acting as local data processing centers. Moreover, we modified the existing LEACH protocol based on finding shortest paths algorithm named Dijkstra's algorithm used for selection of optimal path for the flow of data. The flowchart of our proposed concept of clustering algorithm is shown in Figure 3.2

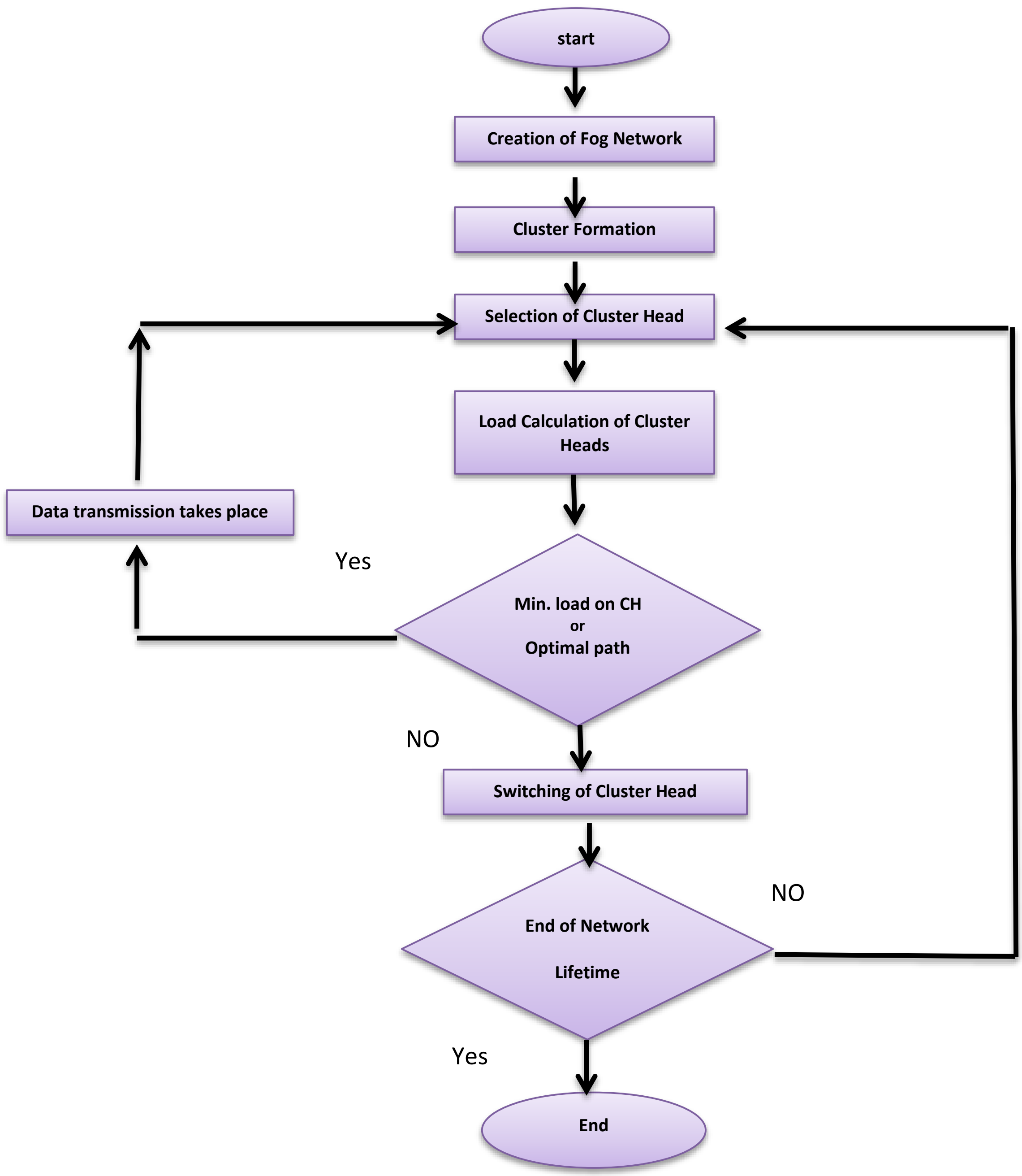

Fig 3.2 Flowchart of proposed concept.

From the above, first we create a fog based network by dropping several nodes regardless of their position. Secondly, cluster formation take place, we select some nodes as a source and others act as cluster heads (CHs) for transmission of data. Third, selection of cluster heads (CHs) take place based on LEACH [8] that are responsible for direct communication with the fog nodes surrounding to respective area. Fourth, to find the optimal path of sensor nodes using Dijkstra's algorithm or finds the cluster head with minimum load, transmit the data to the fog nodes (local base station) otherwise switching of cluster head (CH) takes place.

Algorithm of LEACH-DA

Input:

Parameter	Description	Value
ETX	Transmit Energy	50×10^{-9}joul
ERX	Receive Energy	50×10^{-9}joul
EDA	Data Aggregation Energy	5×10^{-9}joul
Efs	Energy of free space	$10e^{-12}$joul
Eo	Initial energy	0.5joul
N	Total number of nodes	100,200,500
do	Threshold distance	91.2m
Po	Probability of clusters	0.1

Set-up Phase

```
1.      r = rand(0,1);//generate random number between 0 and 1
2.        If (Initial. Energy> 0 && r mod (1/p) ≠ 0) then
3.   Calculate T (N)
4.        If (r < T (N)) then
5.    CH {n} == True;                    // then select n be a CH
6.      else
7.   CH {n} == False;                    // otherwise, s not be a CH
8.   end if
9.   end if
10.   If (CH{s} == True) then
11. Broadcast Message (Advertisement);   // broadcast message to neighbor sensor nodes
12. Join (Id (i));   // receive the broadcast message to all the member nodes with strongest signal and    join their
id and send back to CH
13. Cluster Form(c)
14. end if
```

Steady-State Phase (Modified/ Augmented)

```
1.   If (CH {n} == True) then
2.   Calculate (load of cluster heads);
3.   If (load of cluster heads is minimum or find shortest path using Dijkstra's Algorithm) then
4.       Start data Transmission until condition become true
```

5. else
6. Switching the Cluster Heads
7. If (end of network life time == True) then
8. end/ stop the network
9. else
10. Start next round
11. end if

Output:

Residual Energy = En=0

Chapter 4

Results and Discussion

4.1 Implementation Environment

We have estimated the performance of the proposed protocol by using MATLAB for the simulation under Microsoft Windows 7 x64 on Intel Core i5 by considering different number of sensor nodes including fog nodes that are distributed in the area of 300*500 meter^{2}. It is ensured that sink or base station is located at (150,495) and fog node is located at (150, 250) of the network. We have set 0.5 Joules as the initial energy for each node in the network while the minimum probability for becoming a cluster head to be 0.1. The parameters that are used to calculate the energy of nodes

1. Distance between the MNs and CHs.
2. Distance between the CHs and BS

Simulation parameters are summarized in Table 4.1

TABLE 4.1: Main Simulated Parameters.

Parameters	**Values**
Base Station(sink)	At(150,495)
Fog Node	At(150,250)
Electric Energy(Elect)	70nJoul
Sensor Nodes Distribution	Uniform
Data Aggregation Energy ,EDA	5nJoul
Initial Energy,E0	0.5J
No. of rounds, r	2500

4.2 Results and Discussion

4.2.1 Network of nodes=N=100

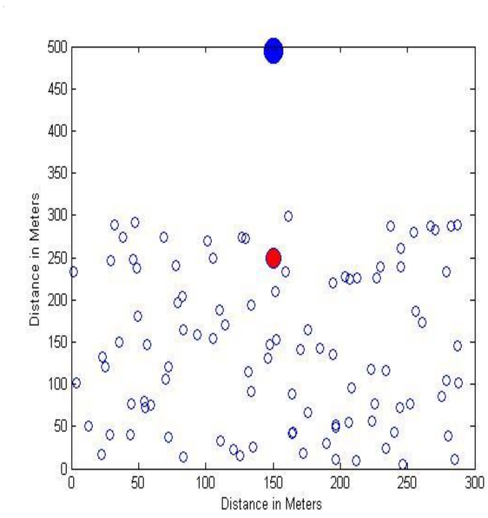

Fig 4.1 Structure of Network (N=100)

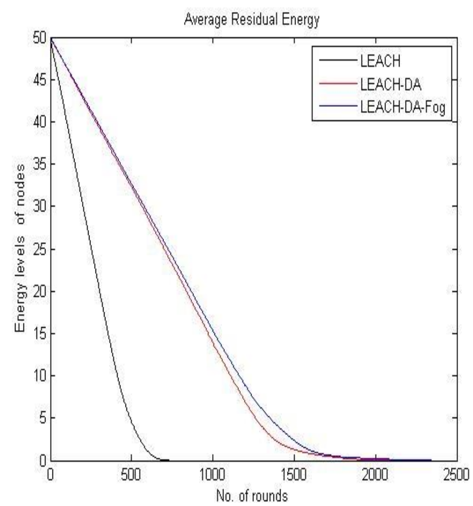

Fig 4.2 Energy levels of nodes Vs No. of rounds

We first consider a simple network of 100 sensor nodes that are randomly distributed in an area of 300×500 m^2. The base station of the network is located at (150,495) and fog node is located at (150,250) as shown in fig 4.1. In figure 4.2, graph is plotted by considering energy levels of nodes after 2500 rounds by considering different variants of LEACH. We can observe that, residual energy of each node is reduced as number of rounds increased. As a result, we estimated that LEACH-DA-Fog consumed less energy during transmission as compared to LEACH-DA and LEACH protocol respectively.

4.2.2 Network of nodes=N=200

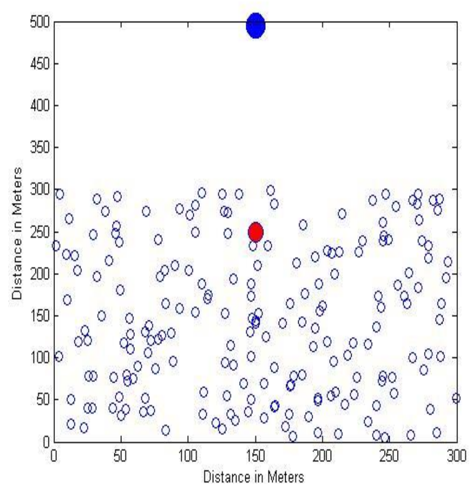

Fig 4.3 Structure of Network (N=200)

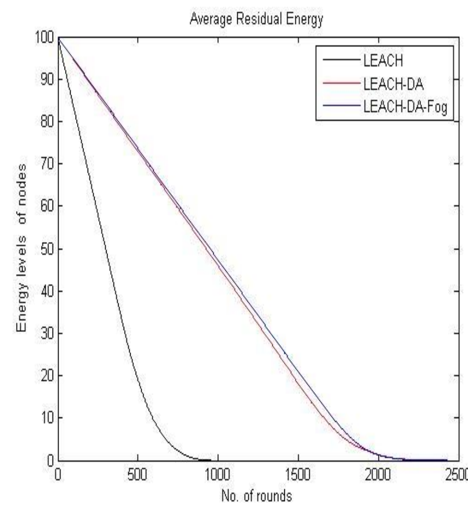

Fig 4.4 Energy levels of nodes Vs No. of rounds

In figure 4.3, network of 200 sensor nodes that are distributed randomly with the base station that is located at (150,495) and fog node at (150,250) are shown. In figure 4.4, graph is plotted by considering energy levels of nodes after 2500 rounds. We can observe that, residual energy of each node is reduced as number of rounds increased. As a result, we estimated that LEACH-DA-Fog network almost died after 2468 rounds which is greater than the network died considering LEACH-DA and LEACH protocol.

4.2.3 Network of nodes=N=500

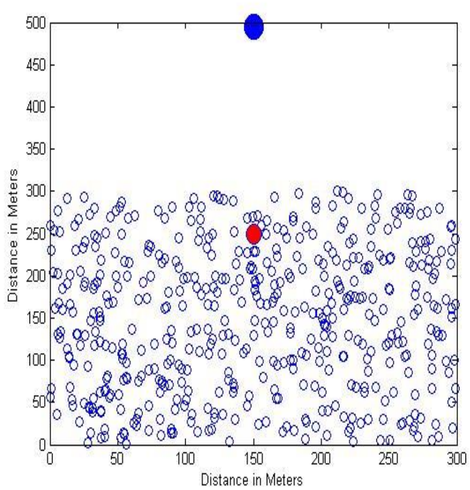

Fig 4.5 Structure of Network (N=500)

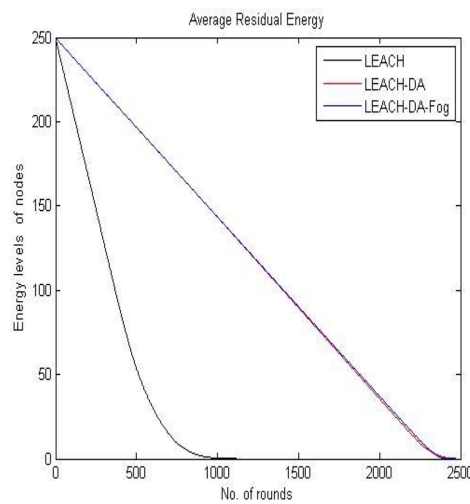

Fig 4.6 Energy levels of nodes Vs No. of rounds

In figure 4.5, network of 500 sensor nodes that are distributed randomly with the base station, located at (150,495) and fog node at (150,250) are shown. In figure 4.6, graph is plotted by considering energy levels of nodes after 2500 rounds. We can observe that, residual energy of each node is reduced as number of rounds increased. As a result, LEACH-DA-Fog consumed less energy during transmission as compared to LEACH-DA and LEACH protocol respectively. So, the network lifetime of LEACH-DA-Fog is greater than LEACH-DA and LEACH protocol respectively.

Chapter 5

Conclusion & Future work

In this chapter we discuss the conclusions and future work derived from our research work

5.1 Conclusions

1. Power consumption or energy utilization is one of the foremost challenges in developing an efficient protocol.
2. LEACH protocol is prominent for providing better clustering solution under wireless sensor networks among its predecessors/competitors.
3. We proposed a new algorithm named LEACH-DA (LEACH making use of Dijkstra's) and observed that it works well in the fog computing environment.
4. Our test results claim that the proposed clustering approach is more viable in terms of energy efficiency of the nodes as it increases the network lifetime by more than 75% compared to its original LEACH protocol.

5.2 Summary

Different versions of the LEACH protocol with its properties are summarized in the following table

Protocol	Hop count	CH-Selection	Advantages	Disadvantages
LEACH	Single-hop	Random	Distributiveness property within the clusters	Maximum energy consumes during aggregating and transmitting data
LEACH-A	Multi-hop	Remaining energy of the nodes	Reduction in nodes failure	Consumes more energy to communicate directly with base station
LEACH-K	Single-hop	Euclidean distance and maximum residual energy	Uniform clustering and load balancing takes place	Computational delay takes place
LEACH-TL	Multi-hop	Based on distance	levels of hierarchy is introduced to communicate with base station	enhance overhead for selecting SCHs.
LEACH-C	Single-hop	Based on location and energy of nodes	Base station is responsible for the selection of cluster heads	Base station must have accurate global information
LEACH-M	Multi-hop	Residual energy of the node	More energy is preserved	Scheduling becomes a difficult task
LEACH-V	Single-hop	Based on distance and energy parameters	No need to elect the cluster head each time	If vice-CH dies, energy consumption becomes very fast
LEACH-DA	Multi-hop	Random	Steady energy consumption takes place	Physical implementation is expensive

Table 5.1 Comparisons between LEACH protocols

5.3 Future Works

The topic of prolonging networks lifetime of WSNs is remain open to further research. Advance solutions can provide more efficiency in the existing protocols by considering constraints like power, computation, communication battery and storage. It would encompass the existing LEACH and its confident version.

When all the data are communicated by using shortest path, congestion may arise which introduces latency issue in the whole network. So, this protocol must be modified for real time applications.

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