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Cluster Based Leach Routing Protocol and Its Successor: A Review

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Abstract: **Wireless sensor network is the foundation block of today networking technology. Each and everything is going to be wireless supported day by day. Here sensors are playing a vital and important role to make every task automated. These networks suffer from energy constraints due to battery operated sensors. There is always a need for energy saving green wireless sensor networks. This paper presents an overview on basic energy saving hierarchical routing protocol. In this protocol clusters are created to divide sensing areas and hence tasks are distributed among cluster heads. The overall work is to form a green wireless network which reduces energy consumption and hence increases network lifetime in WSN through clustering. A brief review is provided on various cluster selection processes and criteria. The journey begins from initial proposed cluster protocol LEACH to mobile, multihop, fuzzy based and various advanced successor of it. This paper also describes comparative analysis of various LEACH characteristics and design parameters.**

Index Terms: **Wireless sensor network, Hierarchical routing protocol, Cluster, Fuzzy, LEACH.**

I. Introduction

Wireless sensor network is an emerging field in electronics and computer engineering. As the name suggest, it is the collection of nodes which are connected through wireless channel to form a network. These nodes are having special characteristics that it can sense the physical and environmental parameter in a network, hence known as sensor nodes. This sensed parameter (like temperature, humidity, pressure etc) is transmitted through wireless medium to fulfill network application [1]. The sensed information is processed and communicated to base station (BS). These can be used in different field like military application, agriculture even though this concept is used in smart city project. A basic WSN structure is consisting of sensing unit, power supply unit, processing unit and communication unit as shown in fig.1.

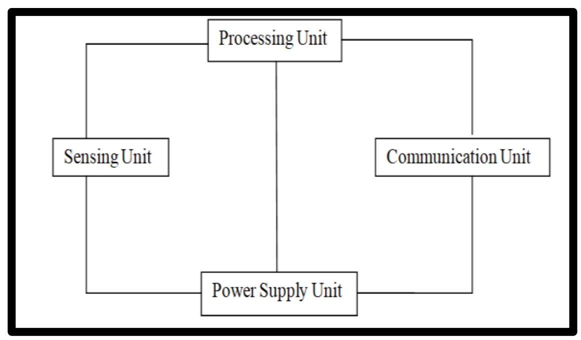

Fig.1 Basic structure of WSN

Sensing Unit: It consists of various sensor nodes, which are responsible for sensing physical and environment parameter. The collected sensed data is converted to analog to digital form. This data is further processed by processing unit. Sensor nodes can be designed with geo location unit and energy harvesting unit. The geo location unit provides information about location of a node, which is used for effective performance of network. The second unit provides some means of renewable energy source to charge the battery, which will increase network life time.

Processing Unit: It consists of microprocessor, which can process the sensed information and control the operation of other unit. The functioning of this unit is depends upon the capacity or amount of sensed data.

Communication Unit: It consists of transmitter and receiver involved in data transmission between source nodes to base station. This is highly energy occupied unit. Its function is mainly depends on the distance between source to base station and number of intermediate nodes. This operates in four mode

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transmission, reception, idle and sleep. Some amount of energy can be saved by putting the unit in sleep mode, when not in used.

1) Power Supply Unit:

It consists of batteries which are irreplaceable. Due to this they are having limited capacity to operate .Its function is to supply power to other units.

The sensor nodes are operated in field for longer period without human intervention. Due to battery supply, these nodes having limited energy for function. The saving of energy is on very high demand in WSN. Many researchers proposed different kind of routing protocols to save energy in WSN. There are various parameters which are used to design an effective routing protocol in WSN; some of them are discussed below [2]:

2) Energy Consumption:

The sensor node is assigned various tasks like computation, data collection, transmission and reception. The overall network functioning is based on sensor operation. All WSN sensor nodes are operated with battery, which are limited source of energy. The routing protocol should be design by considering this key parameter.

II. Deployment of nodes:

The allocation of sensor nodes within network is program or event driven, which is without human intervention. This can play an important role in designing of WSN.

III. Data Processing:

The sensed data is processed for many reasons in WSN like aggregation of data, collection and combining of data, relaying of data, event generation and dropping of data packets. This depends on application of WSN for their effective design.

IV. Fault tolerance:

Due to wireless nature of WSN, uncertainty is always present in network. If a sensor node failed in WSN, another should take its responsibility to continue the operation of WSN without affecting the performance. Designer should also consider various trends of mobility topologies and dynamics.

V. Security:

WSN is designed to operate in various crucial environments; like military application, disaster monitoring system. There is some fear of attack and threats in operation of WSN. So one should consider this parameter also for effective designing of WSN.

This paper is divided into seven sections. Section I covers introduction to wireless sensor network and the designing parameter of wireless sensor network. In section II, the concept of Hierarchical routing and its classification is discussed in detail. In section III, LEACH and its operation and model characteristics is discussed. Section IV gives detail about various successor of LEACH. At last in section V conclusion is provided.

VI. HIERARCHICAL ROUTING PROTOCOL

The most important and critical factor in designing of WSN, is energy consumption. The battery operated nodes has limited energy to work and sense information, to fulfil the working of network in the field. It is very difficult to change the battery in field. So before successful implementation of WSN, life time of battery must be considered. Various study shows, that the energy consumption is reduced in WSN by using hierarchical routing protocol [3]. In hierarchical routing, some nodes are selected as cluster head or leader which is responsible to transmit the information to BS. Others are normal nodes which are used to sense information where they are deployed.

This can be further classified into two types:

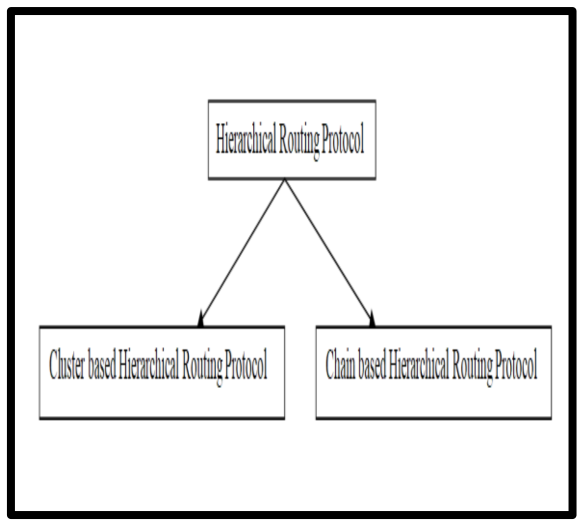

Fig.2 Classification of Hierarchical Routing Protocol

a) Cluster based Hierarchical Routing Protocol:

In this, network is divided into clusters and cluster head (CH) is selected, which work as intermediate node between sensors and BS. The sensed information is transmitted to CH first than it is transferred to BS. Examples are LEACH, TEEN etc.

b) Chain based Hierarchical Routing Protocol:

In this network, sensors are connected in a chain like structure. One cluster lead is selected among all sensors which transmits the sensed information to BS. The sensor node which has highest energy is elected as Cluster leader. Examples: PEGASIS etc.

Hierarchical routing protocol is a layered architecture; in which minimum congestion occur at sink due to less number of transmissions between nodes and BS. The key parameter of hierarchical routing is that, it is energy efficient routing protocol. Due to its cluster architecture it increases the life span of network as well as provides scalability [4]. The paper is mainly focused on cluster based hierarchical routing protocol especially on LEACH.

Performance Parameter for LEACH: Following are the measuring indices for performance evaluation of LEACH.

(i) Network Lifetime:

This is the time interval between network operation start until the death of the last node.

(ii) Stability Period:

This is the time interval between network operation start until the death of the first node.

(iii) Number of Alive Nodes per round:

This will measure the number of live nodes in each round.

(iv) Number of cluster heads per round:

This will measure the number of cluster heads formed in every round.

(v) Number of packets sends to base station:

This will measure the total number of packets which are sent to base station [5].

VII. LOW ENERGY ADAPTIVE CLUSTER HIERARCHY (LEACH)

It is the most widely used cluster based hierarchical routing protocol. W. Heinzelman et.al. First, Proposed the LEACH as an energy efficient routing protocol. The network is built by many clusters, in every cluster there is one cluster head (CH). Cluster head is responsible to transmit the information to BS directly. The main objective of energy efficiency is achieve by rotation of CH selection and localized cordination. Data aggregation is done at CH. A simple structure of cluster is represented in fig.3:

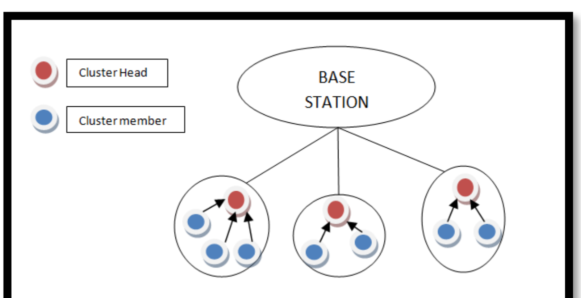

Fig. 3: cluster Structure

The Operational Principle Of Leach:

The operation of LEACH is carried out through rounds. In each round, there are two phases. First phase is known as set up phase and another is known as steady state phase. In this setup phase cluster is organized in a wireless sensor. This phase is further divided into two sub phase: CH selection and Cluster creation. CH is elected from all sensor nodes, firstly every sensor select a random number (k) in between 0 and 1. If this selected number is less than T (n), that sensor nodes become CH. The selection of k is random, so the CH is also not fixed. The equation to calculate T (n) is given below:

$$T(n) = \{\ P/(1 - P\ \times (r\ mod\ 1/P)\ ), \quad if\ n\ \epsilon\ G\ 0 \quad , \quad otherwise \qquad eq.(1)$$

Where p is desired percentage of cluster head nodes, r is the current round number and G is the set of nodes that have not been CH in the last $1/p$ rounds. The flow chart of LEACH process is given in below fig.4

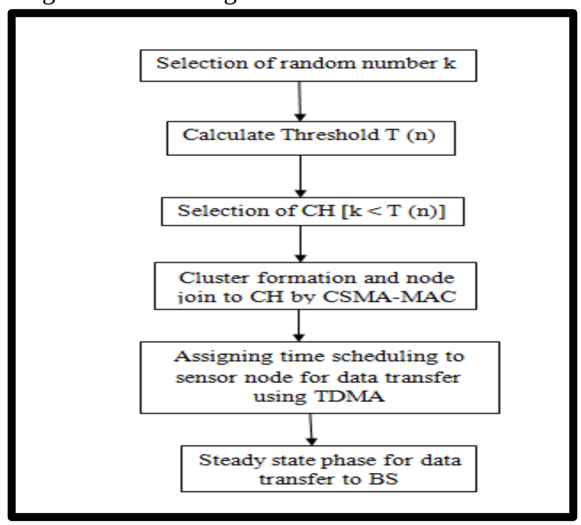

Fig.4 Flow Chart of LEACH Process

Each CH advertised itself and clusters are formed. Rest sensor nodes are connected to CH, which depends on distance between CH and node and through signal strength they received by CH. The joining of sensor node and CH is by CSMA-MAC protocol. After this, each CH assign schedule to its sensor node, when it can send data through TDMA. Steady state phase is responsible for data transmission to BS. Firstly sensor nodes sense the data in a cluster, which is transferred to CH and turn off their receiver. After all data collection by sensor node CH performs data aggregation and processing. Then finally data is send to BS. First phase required less time than second phase. This is based on static cluster algorithm. Author in [6], implemented LEACH through simple Radio Energy Dissipation Model. This model is consisting of electronics devices, transmitter, receiver and power amplifier. F. Comeau analyzes the energy parameter of LEACH in detail. The model used to simulate LEACH is given in fig.5

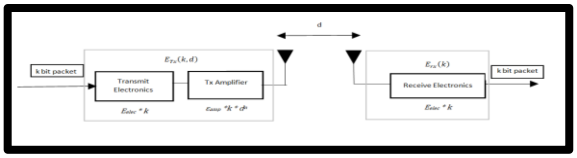

Fig. 5 Radio Energy Dissipation Model

- Limitation of LEACH:
- For small networks, LEACH is ideal because it means that all nodes can connect with each other and can connect to sink, which is not necessarily valid for large networks.
- At the beginning of each round, LEACH randomly selects the cluster heads without considering the remaining energy of these nodes. As a result, the CH nodes chosen would have the least energy level and therefore die very soon.
- Each cluster head that uses LEACH communicates with the BS directly, regardless of whether or not the distance is close. For long distance transmission, the communication between the cluster heads and the BS needs a lot of resources since the network is wide. But it'll shorten WSN's lifespan.
- LEACH offers time slots for each node in the network to send data to CHs, even though those nodes do not have data to transmit. In LEACH, on the other hand, if the number of cluster heads is limited, the scale of the clusters increases, leading to excessive delays caused by the number of nodes in the same cluster.
- Cluster heads should be focused in one location, so isolated nodes (without the head of the cluster) can be located.
- In LEACH, there is no way to guarantee that the chosen CHs are distributed uniformly across the network. In only one section of the network, all cluster heads can then be clustered. In addition, cluster sizes can be very complex, even without any members, certain clusters probably found.

VIII. SUCCESSOR OF LEACH

Many authors provide modification in basic LEACH routing protocol to improve energy, load balancing, fault tolerance and security. The work gives different objective and criteria to elect CH in cluster.

1) C-LEACH:

W. Heinzelman et al [7] developed a centralized LEACH protocol in 2002. It is based on centralized algorithm over the distribution algorithm. The CH is elected with the use of location information of nodes by BS. A central controller BS works effectively, as it holds the global information of a cluster which is used to manage the cluster and data transmission. The below flow chart explains the process of C-LEACH. It supports fixed number of CH and Cluster decided by BS. Author in [8] and [7] give the comparative details of LEACH and C_LEACH.

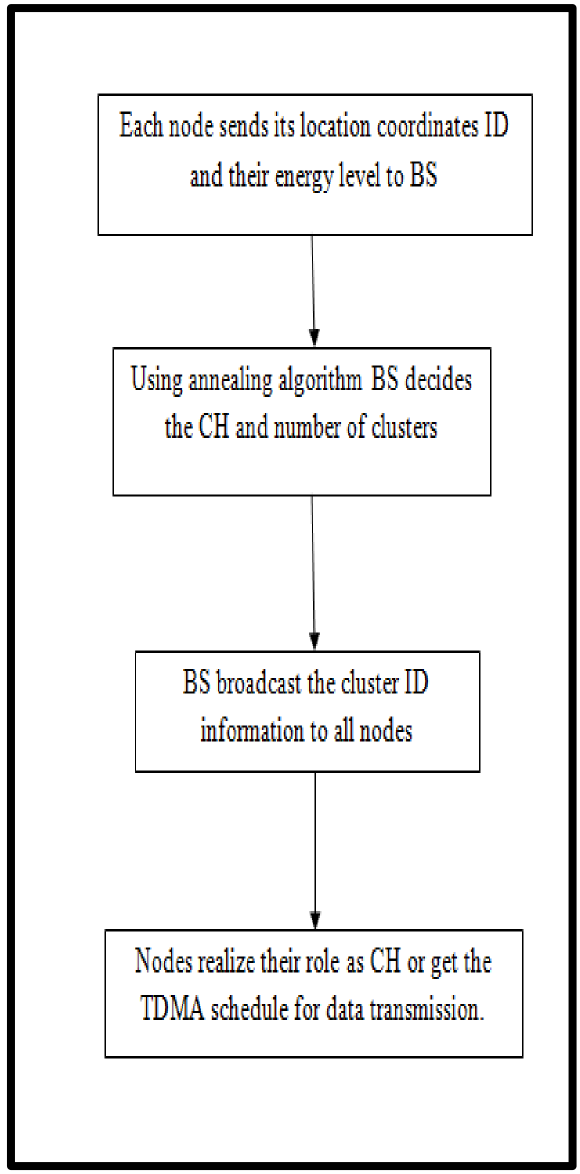

Fig.6 Flow Chart of C-LEACH Process

2) LEACH-B:

A. Depedri et al [9] proposed a new version of LEACH which is based on decentralized algorithm. Author invented new strategy to form clusters and to elect CH. The adaptive approach is utilized to elect optimum number of CH, which consider minimum amount of transmission energy as well as energy dissipated in broadcasting. Cluster formation includes total path and energy dissipation distance to elect the CH from node to BS.

3) GA-LEACH:

J. Liu et al [10] proposed an optimum solution based on genetic algorithm to elect cluster head. Here preparation phase is occurred before initialization of setup phase. In this phase information related to node status, localization and node ID are sent to BS. This phase is applied once before the set up phase to know the threshold and probability of CH selection. Author described pseudo code algorithm for the procedure. The simulation is done on uniformly distributed homogenous network. P.Sivakumar et. al. [11] compared the performance of GA-LEACH with LEACH and LEACH-C. Author considered different probability value from 0.05 to 5 for CH election. M.Radhika et al [12] explained and analyzed LEACH-GA for video transmission and calculated quality parameter for video as jitter and PSNR.

4) Mobile LEACH:

A.Nayebi et al considered the mobility of nodes in wireless sensor network. Author represented analytical view of mobile sensor network over static network which is further represented through geometric view. The paper introduced mobility of nodes with buffer zone concept. Simulation result indicates better performance in terms of packet loss ratio. [13]

5) Q-LEACH:

As name implied the area is divided into four quadrature which leads enhance the stability period, throughput and network life time of homogenous network. The proposed protocol has four cluster quadratures and CH is elected by BS. The BS considers location of sensor nodes and RSSI to elect CH. [14]

6) LS-LEACH:

M. Alshowkan et al [15] proposed security measurement with energy efficiency for LEACH. The proposed scheme provides great reduction to over hearing and idle listening in saving of energy. In addition to this authentication scheme is introduced with public and private key at new node entering, CH election phase. The overall performance is improved in terms of system throughput, network life time and the total energy consumption.

7) MOD LEACH:

D. Mahmood et al. [16] proposed the modified LEACH which utilizes two power levels for data transmission and cluster replacement scheme. Author defined soft (s) and hard (h) threshold for selection of CH. This paper represented intra and inter cluster communication along with CH to BS communication. The comparative study of LEACH and MOD LEACH with soft and hard threshold is performed to show the increased life time. N. Pandya et al [17] proposed an advance version of MOD LEACH which added differential mathematical equation for election of CH with sleep scheduling of nodes. Further *i*MODLEACH is proposed by S.Ahmed, [18] which considered probability of choosing a CH (p), along with soft and hard threshold. Author performs comparative study for various values of p, s and h.

8) LEACH-SM: B.Bakr et. al.

[19] proposed an optimized energy efficient sparse selection and sparse management scheme. Author provided simulation to calculate the length of the nap interval for CH and the percentage of the nodes of the cluster that become spare. Spares provide improvement over redundant transmission and hot spot problem in WSN. The proper management of spares by awake and nap time creates expansion of life time in WSN as compared to LEACH.

9) O-LEACH:

The CH is elected by amount of energy remains after each round it should be higher than 10 percent of residual energy than each sensor. Author simulated the proposed protocol for two locations of BS: at canter of square field and at the top of region. The simulation is done on 100 through MATLAB. The effectiveness of proposed protocol is compared with LEACH and LEACH-C. [20]

10) DE-LEACH:

S. Kumar [5] proposed a new extension which is single hop homogeneous network. The proposed protocol elects the CH by considering initial and residual energy of sensor node as well as distance of sensor node from BS. This is compared with LEACH for network life and energy efficiency.

11) E-LEACH:

H. Patel et al [21] investigated security and privacy in wireless sensor network in efficient energy way. Author proposed homomorphic encryption schemes for end-to-end privacy. Owing to a special algebraic attribute, homomorphic encryption provides data aggregation without decryption. Hence it needed less amount of energy and gives security.

12) A-LEACH:

J. ZHAO et al. [22] proposed adaptive version of LEACH. This routing protocol includes residual energy as well as shortest distance between CH to BS for the data transmission. Author suggested shortest path algorithm to find nearest CH to transfer information to BS. The comparative analysis of proposed protocol with LEACH AND LEACH-C are provided.

13) LEACH WITH MOBILE SINK:

S. Mottaghi et al [23] described impact of mobile sink over traditional LEACH. Simulation gives better results in terms of energy. Author also applied rendezvous points (RP) with CH to increase the performance.

14) LEATCH:

Low Energy Adaptive Tier Clustering Hierarchy: W. Akkari [24] proposed LEATCH protocol which is based on balancing clustering technique. It is an improvement over LEACH protocol as it is a two tier hierarchical structure. Author uses gateway node between a CH and base station to enhance the performance. The proposed protocol gives better results in terms of throughput, delay, power consumption, system life time, covered area and scalability than LEACH. The operation working of LEATCH includes super cluster formation and mini cluster formation. The BS elected the SCH by probability function pi (given in eq.2) and then MCH election (given in eq.3) and formation is done by SCH. The working is shown in fig. Author used OMNeT++ discrete event simulation platform to prove the applicability. It has fixed number of SCH and MCH.

$$Pi = \frac{Ei(t)}{Einitial} . K . \frac{1}{d} \quad \text{eq.(2)}$$

$$Qi = \frac{Ei(t)}{Einitial} . q . density \quad \text{eq.(3)}$$

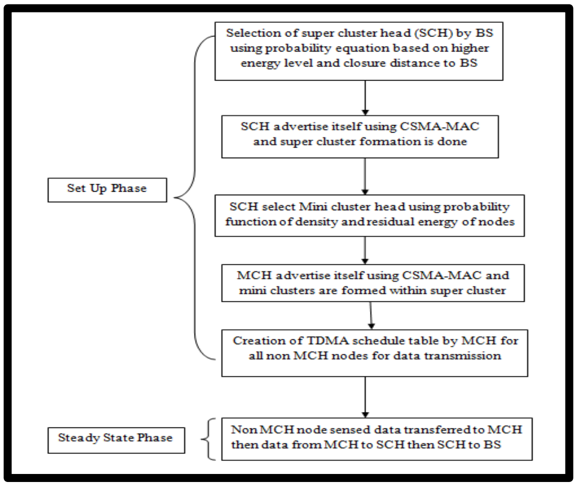

Fig.7 Flow Chart of LEATCH Process

15) DBCH-LEACH:

This is also a variant of LEACH, which includes distance and residual energy for election of cluster head. The proposed algorithm considers distance of node to base station and cluster head and base station for calculation of threshold. The node which is near to BS is elected as cluster head. The result for propose protocol shows better result in terms of balancing load and thus enhancing energy than LEACH. Author uses MATLAB for simulation. [25]

16) EE-LEACH

G. Arumugam et al. [26] proposed data gathering technique to implement energy efficient LEACH. Author used Gaussian distribution for deployment of nodes in network than optimal cluster is selected using residual energy of nodes. The data aggregation and data ensemble are done at CH. The proposed work shows better result in compare to traditional LEACH and energy-balanced routing protocol (EBRP).

17) TL-LEACH

V. Loscri et al proposed a two-level hierarchy for LEACH known as TL-LEACH which uses random rotation of local cluster base stations (primary cluster-heads and secondary cluster-heads). The use of two-levels of clusters for transmitting data to the base stations leverages the advantages of small transmit distances for more nodes requiring only a few nodes to transmit far distances to the base station. The benefits of TL-LEACH in comparison to LEACH are in terms of throughput, energy dissipation and lifetime. On comparing the results for the total number of data signals received at the base station over time TL-LEACH achieves lower latency than original LEACH. [27]

18) LEACH-DT

S. Kang et al [28] proposed LEACH elected CH based on threshold distance between CH and BS. Author provides multihop communication with multipath fading distance model. The proposed scheme optimally balances the energy consumption among the sensors. V. Gupta et al [29] modified DT_LEACH by adding one more metrics in election of CH as residual energy of node. Author show the improvement with comparative study.

19) LEACH-MAC:

P. Batra et al proposed routing scheme consider optimum number of CH to form a cluster instead of randomness. The scheme implemented on MAC layer. The improved scheme is compared for different BS location with LEACH and LEACH-SWDN. [30]

20) EM-LEACH: (enhanced multi-hop):

S.Soidari et al implemented a new CH election method and round time based computational model with respect to residual energy. This new multi hop routing protocol operates on levelling phase and a generic multi-hop routing process. It reduces the energy consumption and balance load to improve network life time. [31]

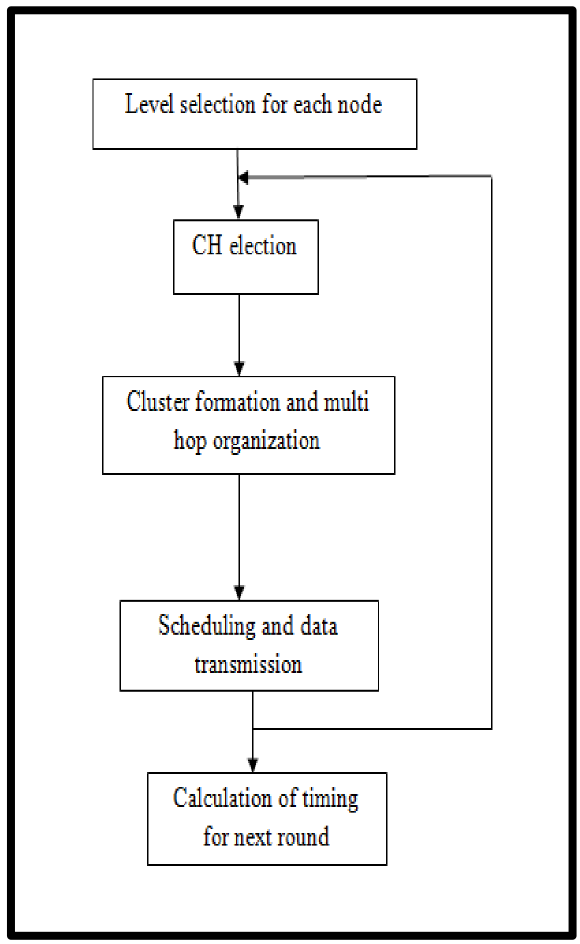

Fig.8 Flow Chart of EM-LEACH Process

21) ESO_LEACH

Author developed an enhanced swarm optimization method for cluster head election based on meta-heuristic approach. In the optimization, fitness function is defined for CH, BS and advanced nodes to increase the life time of network. Python is used for simulation and comparative analysis. [32] . Author [33] proposed optimal solution for selection of cluster head using BAT algorithm. This algorithm used weighted harmonic centroid strategy for local search. The proposed optimal LEACH is compared with six variations of centroid strategies.

23) LEACH-EP: L.

Wu et al proposed energy balancing in LEACH using network model, energy consumption model and assessment model. The main concept is to keep the arrangement of clusters in K rounds unchanged. Author achieved increment in network life time of LEACH by prediction of energy and delaying the dead time of node. [34]

24) ETL-LEACH

K. Manzoor et al proposed an extension to TL-LEACH called as ETL-LEACH. The drawbacks in TL_LEACH are it is not suitable for long-distance communications as much energy consumption occurs, also energy considerations is very much important in CH selection. These drawbacks were resolved in ETL-LEACH.

25) W-LEACH

H. Abdulsalam et. al. proposed a weighted solution to increase network performance which is suited for uniform as well as non uniform network. All the sensor nodes are assigned a weight on the basis of density of sensor and remaining energy of sensor. This will use to elect suitable CH and number of nodes in a cluster. It uses centralized weighted data aggregation technique through which sleeping and alive decisions are made. The performance is compared with LEACH using C simulator. [36] This is further extended by A. Hnini,[37] in which sleep and active state decision is self taken by sensor node. This reduces the burden of BS and making it a decentralized data aggregation technique. One more extension is given by the author in 2020 using game theory. Here author implemented sleeping of nodes by considering density and neighbour distance of node as players of game. Finally author concluded the proposed scheme is better than previous in terms of energy dissipation. [38]

The proposed routing used the CH switching role technique to ensure that the communication between the end nodes and the base station is smooth and robust which also helps in the overall increase in the lifetime of the cluster based wireless sensor network. ETL-LEACH not only enhances the two level cluster head algorithm but it also supports the large-scale network application scenarios. [35]

26) LEACH-POS:

Moorthi et al proposed an optimizing solution for power reduction in cluster head election in LEACH protocol. This optimized technique generates an improvement in lifetime of system, stability of nodes and data transmission. Author explained PSO (Particle Swarm Optimization) method for CH election through personal, global and hybrid PSO approach. The simulation result provides improvement over LEACH. [39]

Finally we compare LEACH and its successor on the basis of various parameters. The table of comparison is given below:

1. ANALYSIS OF ENERGY EFFICIENCY IN LEACH

1. If distance between BS-SN is small (S) and average residual energy of SN is low (L) then energy of network is good (G).
2. If distance between BS-SN is small (S) and average residual energy of SN is medium (M) then energy of network is good (G).
3. If distance between BS-SN is small (S) and average residual energy of SN is high (H) then energy of network is excellent (E).
4. If distance between BS-SN is medium (M) and average residual energy of SN is low (L) then energy of network is poor (P).
5. If distance between BS-SN is medium (M) and average residual energy of SN is medium (M) then energy of network is good (G).
6. If distance between BS-SN is medium (M) and average residual energy of SN is high (H) then energy of network is good (G).
7. If distance between BS-SN is large (L) and average residual energy of SN is low (L) then energy of network is poor (P).
8. If distance between BS-SN is large (L) and average residual energy of SN is medium (M) then energy of network is poor (P).
9. If distance between BS-SN is large (L) and average residual energy of SN is high (H) then energy of network is good (G).

According to fuzzy analysis we deduce that energy of network is excellent when distance between base station and sensor nodes are small and average residual energy of the sensor nodes are high,

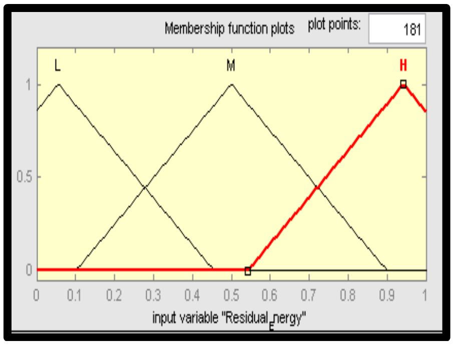

Fig. 9 Fuzzy Membership function for input variable "Residual Energy"

Table 1: Comparative analysis of LEACH and its successor

S.NO.	LEACH and its Successors	Hierarchical Level	Clustering method (distributed/centralized)	No. Of hops (single/dual/multihop)	Scalabilty (p/m/e)	Simulation environment (MATLAB/NS2/OMNET++	Data aggregation (Y/N)	Election of CH based on parameter
1	LEACH	TWO	D	O	P	MATLAB	Y	Probability
2	LEATCH	TWO	D	DUAL	E	OMNET++	Y	EI,ER, D
3	DBCH-LEACH	TWO	D	DUAL	M	MATLAB	Y	Distance From BS
4	C-LEACH	TWO	C	DUAL	M	NS2	Y	Residual Energy
5	LEACH-B	TWO	D	O	M	C++	N	Total path energy dissipation with fading channel consideration
6	EM-LEACH	MULTIPLE	D	multihop	E	OMNET++	Y	Levelling and generic multi-hop routing
7	LEACH-SM	TWO	D	O	P	MATLAB	Y	Sparse management scheme
8	O-LEACH	TWO	D	O	P	MATLAB	Y	Residual Energy
9	Q-	TWO	D	O	M	MATL	Y	four

	LEACH					AB		quadrants and RSSI
10	W-LEACH	TWO	D	DUAL	M	NS	Y	Node density and distance
11	DE-LEACH	TWO	D	DUAL	M	Not Specified	Y	distance and residual energy
12	GA-LEACH	TWO	D	DUAL	M	MATLAB	Y	Optimal Probability by genetic algo.
13	LEACH-POS	TWO	D	DUAL	E	Not Specified	Y	PSO
14	ESO_LEACH	TWO	D	DUAL	E	Python	N	Distance Optimization
15	Optimal LEACH	TWO	D	DUAL	E	Not Specified	Y	Two Stage CH By Position Using Bat Algorithm And Centroid Strategies
16	Mobile LEACH	TWO	D	DUAL	E	Xmulator	Y	Position And Velocity
17	EE-LEACH	TWO	D	DUAL	E	Not Specified	Y	Residual Energy
18	E-LEACH	TWO	D	DUAL	p	TOSSIM	Y	Probability homo morphic encryption schemes
19	TL-LEACH	THREE	D	M	M	NS2	Y	Density and Distance
20	ETL-	THRE	D	M	E	Netwo	Y	Residu

	LEACH	E				rk Simulator		al Energy
21	LS-LEACH	TWO	D	DUAL	M	NS2	Y	Residual Energy
22	A-LEACH	TWO	D	O	M	NS2	Y	Residual Energy and Distance
23	MOD LEACH	TWO	D	O	M	MATLAB	Y	residual energy and sleeping cycle upto 11
24	LEACH-EP	TWO	D	O	P	OMNeT++	Y	residual energy
25	LEACH-DT	TWO	D	DUAL	P	MATLAB	Y	residual energy and distance
26	LEACH-MAC	TWO	D	O	E	NS2	Y	application dependent

Table 2: Comparative analysis of LEACH and its successor

S.NO.	LEACH and its Successors	Mobility type (static or mobile)	Transmission delay (l/m/h)	Distribution of nodes (fixed/random)	Control message overheads (l/m/h)	Rotation of CH (y/n)	Uniform distribution of energy (y/n)
1	LEACH	S	M	R	M	Y/R	Y
2	LEATCH:	S	L	F	M	Y/F	Y
3	DBCH-LEACH	S	L	R	L	Y/R	Y
4	C-LEACH	S	L	R	M	Y/R	Y
5	LEACH-B	S	M	R	M	Y/	Y
6	EM-LEACH	S	M	R	H	Y	Y
7	LEACH-SM	S	L	R	L	Y	Y
8	O-LEACH	S	L	R	M	Y	Y
9	Q-LEACH	S	L	R	L	Y	Y
10	W-LEACH	S	L	R	L	Y	Y

11	DE-LEACH:	S	L	R	L	Y	Y
12	GA-LEACH	S	L	R	L	Y	Y
13	LEACH-POS	S	L	optimal	L	Y	Y
14	ESO_LEACH	S	L	Optimal with advanced node	M	less random due to advanced node	Amplified Energy
15	Optimal LEACH	S	L	R	M	Y	Y
16	Mobile LEACH	M	M	R	L	Y	Y
17	EE-LEACH	S	L	Gaussian Distribution	L	Y	Y
18	E-LEACH	S	M	R	M	Y	Y
19	TL-LEACH	S	L	R	M	Y/R	Y
20	ETL-LEACH	S	L	R	L	Y	Y
21	LS-LEACH	S	L	F	L	Y	Y
22	A-LEACH	S	L	F	L	Y with leader node	Y
23	MODLEACH	S	L	F	L	Y	Y
24	LEACH-EP	S	L	R	M	Y	Y
25	LEACH-DT	S	L	R	M	Y	N
26	LEACH-MAC	S	M	R	L	Y	C

Table 3: Comparative analysis of LEACH and its successor

S.NO.	LEACH and its Successors	Energy efficiency (p/e)	Algorithm complexity (low/ high)	Method of clustering(classical/fuzzy/metaheuristic)	Nodes types (Homogenous(H)/ heterogeneous (h))	Application(time driven/event driven)	Cluster communication (Intra/inter) in hop	Cluster size (controller/ uncontrolled/optimized)
1	LEACH	P	L	CLASSICAL	H	T	I=1 and i=1	U

2	LEATCH	E	H	CLASSICAL	H	E	I=1 and i=1	C
3	DBCH-LEACH	M	M	CLASSICAL	H	T	I=1 and i=1	U
4	C-LEACH	M	M	CLASSICAL	H	T	I=1 and i=1	C
5	LEACH-B	M	M	CLASSICAL	H	T	I=1 and i=1	O
6	EM-LEACH	M	H	CLASSICAL	H	T	Varies due to multiphop	C
7	LEACH-SM	O	M	CLASSICAL	H	T	I=1 and i=1	optimal
8	O-LEACH	O	L	CLASSICAL	H	T	I=1 and i=1	optimal
9	Q-LEACH	O	L	CLASSICAL	H	T	I=1 and i=1	optimal
10	W-LEACH	E	L	Game Theory	H	T	I=1 and i=1	U
11	DE-LEACH:	E	M	CLASSICAL	H	T	I=1 and i=1	C
12	GA-LEACH	M	M	Genetic-Algorithm	H	T	I=1 and i=1	optimal
13	LEACH-POS	E	M	PSO	H	T	I=1 and i=1	optimal
14	ESO_LEACH	E	M	Metaheuristic	H	T	I=1 and i=1	optimal
15	Optimal LEACH	E	M	BAT + Centroid	H	T	I=1 and i=1	optimal
16	Mobile LEACH	E	M	Geometric-Probabilistic Model	H	E	I=1 and i=1	optimal
17	EE-LEACH	E	M	Optimal Clusteri	h	T	I=1 and i=1	optimal

				ng				
18	E-LEACH	M	M	Encryption	H	T	I=1 and i=1	U
19	TL-LEACH	E	M	CLASSICAL	H	T	I=1 and i=multihop	U
20	ETL-LEACH	E	M	CLASSICAL	H	T	I=1 and i=multihop	U
21	LS-LEACH	M	M	Lightweight Secure Authentication algorithm	H	E	I=1 and i=1	C
22	A-LEACH	E	M	ADAPTIVE	H	E	I=1 and i=1	C
23	MODLEACH	E	M	CLASSICAL	H	T	I=1 and i=1	U
24	LEACH-EP	E	M	CLASSICAL	H	E	I=1 and i=1	U
25	LEACH-DT	E	M	CLASSICAL	h	T	I=1 and i=1	U
26	LEACH-MAC	E	M	CLASSICAL	H	T	I=1 and i=1	U

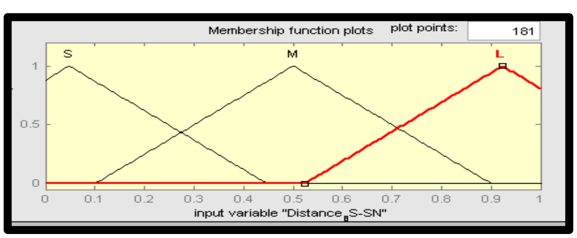

Fig. 10 Fuzzy Membership function for input variable "Distance"

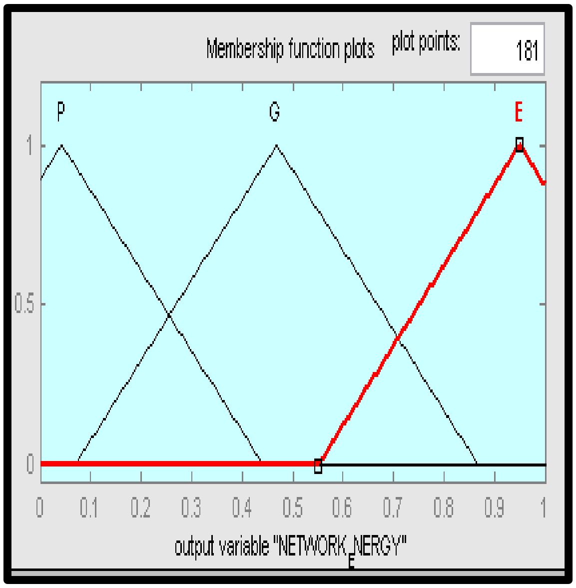

Fig. 11 Fuzzy Membership function for output variable "Network Energy"

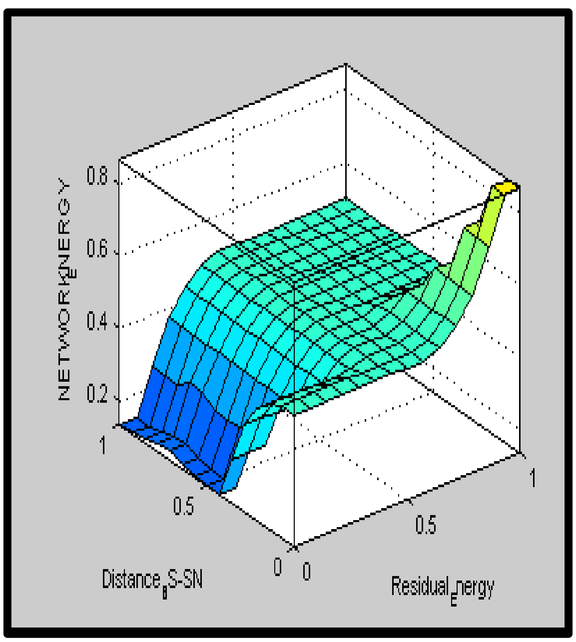

Fig.12 3-D representation of input and output variable

IX. CONCLUSION AND FUTURE SCOPE

This article provides a compressive study of LEACH protocol and its successor. This also includes various perspectives in designing of LEACH. Number of author proposed structure and architecture to represent their modification in basic hierarchical protocol LEACH. There work is represented through flow diagram and comparative tables. LEACH is a very renowned routing protocol as it is a bench mark to provide energy efficiency in WSN. Wireless sensor is basic building block in various emerging area of adhoc network. This builds lower level of internet of things (IoT). In today's modern technology world IoT is used everywhere. With the help of sensors automation form simple home and building is reached to smart city concept. It is not limited here its application are everywhere in monitoring agriculture, military work, hospitals, surveillance etc. All these automation is done through WSN-assisted IoT. Currently many researchers are working on software defined network and green wireless network. This clustering based protocol is also used to improve various factors like load balancing, QoS and power management. This can create green wireless sensor network. The researcher stated their work to make green computing and green communication in WSN. This opens area in depth for green networks. Some research work also adopts WSN in field of SDN by applying cache memory to sensor structure to speed up the work. The challenging area comes out as to make control plane at BS and data plan at sensors network to make SDN-WSN. The innovation and recent invention in the field of electronics engineering, WSN can be used to create intelligent smart portable devices, automated home and control system, human and machine driven automated system. Recently various applications are made to mask detect in covid19 condition based on sensors. As the population is increasing rapidly and demand of high speed automated sensor control system are increasing. Machine learning can also applied in WSN for optimization of cluster parameters.

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