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Review of recent Energy Efficient Clustering algorithms in Wireless Sensor Networks to maximize Network Life Time

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***Abstract*—Wireless Sensor Networks (WSN) showing their significance in our daily life over a large range of applications including industrial, healthcare and environment. In general, WSNs development and deployment exhibit plenty of challenges before the researchers. However, Network Lifetime maximization became the most attractive challenge as sensor nodes have a limited amount of energy resources like batteries. A lifetime of the network directly depends on energy consumption and hence energy efficient techniques became popular to address the challenge. Moreover, multi-hop WSNs motivated contemporary researchers to enlighten Energy Efficient Clustering algorithms for maximization of Network Life Time. A wide variety of proposals can be evidenced by the literature. However, our work culminates recent proposals of Energy Efficient Clustering algorithms. Finally, we tabulated the theoretical comparison of various approaches to expose the potential importance of optimization of energy consumption with the most popular approach and implementation tools used.**

Keywords-Wireless Sensor Networks; Energy Efficient Clustering; Network Life Time; WSN applications; Recent EEC algorithms

GLOSSARY

WSN	Wireless Sensor Network
SRN	Sensor node
MOO	Multi-Objective Optimization
EEC	Energy Efficient Clustering
CH	Cluster head
NL	Network Lifetime
HO	Homogeneous
HE	Heterogeneous
MO	Mobile
SH	Single-hop
MH	Multi-hop

I. A GLANCE OF WIRELESS SENSOR NETWORKS

Wireless Sensor Network (WSN) is a wireless network established by the spatially dispersed deployment of various nodes having sensing ability known as sensor nodes. In general, Wireless Sensor Network [1] is a subset of wireless networking applications, which focus on enabling connectivity without, the need, generally, of wires to connect to the sensors and actuators. It consists of hundreds or potentially even thousands of spatially distributed, low-cost, low-power, multifunctional, autonomous sensor nodes and communicate over short distances. The development of WSNs are motivated by military applications and now a day these networks are used in many industrial and consumer applications, such as industrial process monitoring and control, health monitoring. A wide range of WSN applications can be seen from the military surveillance to daily life, which is listed below based on the potential importance.

- Military Information Systems [2] maximizes security and gaining maximum benefits from attacking the opponent is the challenging task of these applications.
- Intelligent Transportation System [3] encompasses many functions such as traffic surveillance, parking assist, accident avoidance, driverless vehicle etc.
- Security Systems [4] like biomedical applications can be used for healthcare providers and regulatory agencies to determine an acceptable level of security and privacy
- Industrial monitoring to address solutions for automation of industry like laser cutting process [5]
- Environmental monitoring applications alert the changes over environment like earthquake disaster protection [6]
- Healthcare Monitoring [7] focus transmission of patients health information in hospitals

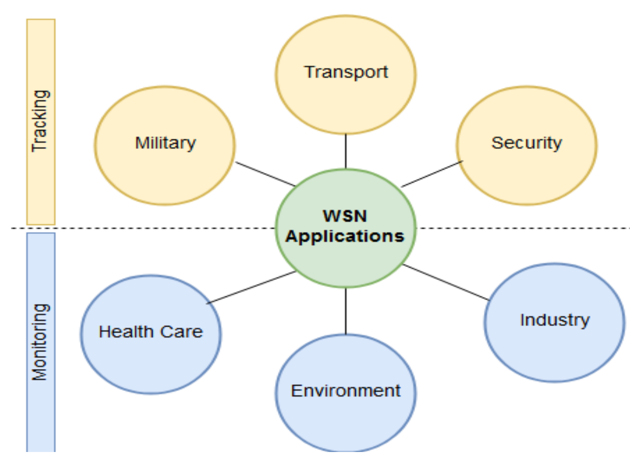

Figure 1. Wireless Sensor Network Applications

However, in his survey Zesong [8] broadly classified the WSN applications into two types: Tracking applications (Military and Transport) and Monitoring Applications (Industry, Environment and health) as shown in "Fig. 1".

A. Components of Wireless Sensor Networks

WSNs are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network. This network mainly consists of three types of nodes as a node:

- **Sensor Node**: It is the primary component of Sensor Networks which senses the information with special hardware devices known as sensors. These nodes also responsible to transmit sensed data over the network. There are several types of sensors including pressure, temperature, gravity, motion etc. Each sensor node equipped with Transmitter and Receiver circuits for sending as well as receiving data along with processing unit like microprocessor or controller. It also requires an Amplifier circuit, as the strength of the signal decreases on transmitting for long distances. Finally, the typical structure of sensor node can be seen from "Fig. 2".

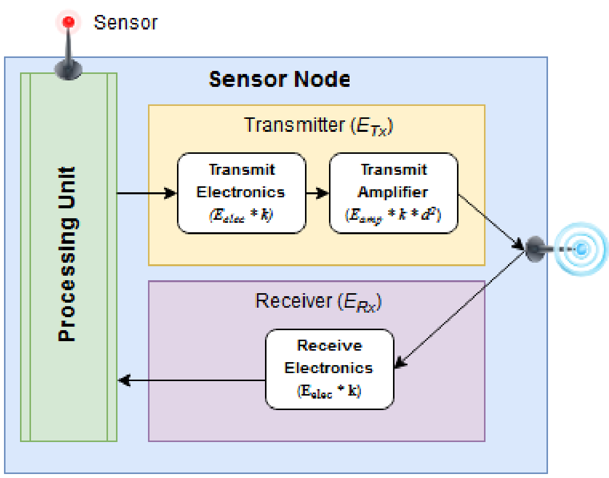

Figure 2. The typical structure of Sensor Node

- **Sink Node**: It is the destination node which is responsible to receive and aggregate data transmitted over the network. In general, any computer system may act as sink node or terminal.
- **Gateway Node**: It is an intermediate node which is responsible for bridging two networks or bridging sink nodes.

B. Types of Wireless Sensor Networks

Determination of types of WSNs is a very difficult task with a single factor, but types of WSNs can be categorized based on some important factors as follows:

- Based on **Topology** of network WSNs can be divided into two types: Structured WSNs which depicts preplanned structure with a number of nodes and topologies like start, tree and mesh. In these networks, nodes are deployed at fixed locations to sense the environment like air pollution monitoring. On the other hand, Unstructured WSNs do not follow any structure and nodes are randomly deployed at various location of the network. They also allow attaching new nodes and detaching existing nodes from the network and hence also known as Ad-hoc networks like Mobile ad-hoc networks.
- Based on **Sensor nodes** WSNs can be divided into two types: Homogeneous WSNs consists of a similar type of sensor nodes like Biometric systems which use same card readers or thumb readers for authentication of users. Alternatively, Heterogeneous WSNs consists of different type of sensor nodes like Smart buildings which use different sensors like temperature sensor, water level sensor etc. These applications require processing of heterogeneous data from different sensor nodes.
- Based on **Mobility** of sensor nodes WSNs can be divided into two types: Fixed WSNs whose sensor nodes are fixed and not movable like Traffic Monitoring System. Unlike Fixed WSNs, sensor nodes are movable in case of Mobile WSNs like Animal Tracking System.
- Based on deployment **Location** of sensor nodes WSNs can be divided into three types: First, Terrestrial WSNs in which sensor nodes are deployed around the earth for sensing environment like Forest fire detection. Second is Underground WSNs deploys sensor nodes under the earth layers like Landslide detection to prevent earthquakes. Similarly, Underwater WSNs deploys sensor nodes under the water bodies like Water level detection to prevent natural disasters.
- Based on the number of **Hops** for transmission WSNs can be divided into two types: one is Single hop WSNs are designed to transmit data from each sensor node to sink node directly without any intermediate node like water quality monitoring. Alternatively, Multi-hop WSNs are designed to transmit data through intermediate nodes for sending data from the sensor node to sink node. This will takes multiple hops by sending data to the nearby sensor node and so on to reach sink node.

Finally, a summary of types of Wireless Sensor Networks is listed in "Table I".

TABLE I. TYPES OF WIRELESS SENSOR NETWORKS

Factor	***Type***	***Example***
Topology	Structured	Air pollution monitoring
	Unstructured	Mobile ad-hoc networks
Sensor Nodes	Homogeneous (HOWSN)	Biometric systems
	Heterogeneous (HEWSN)	Smart Buildings
Mobility	Fixed (FIWSN)	Traffic Monitoring Systems
	Mobile (MOWSN)	Animal Tracking Systems
Location	Terrestrial	Forest fire detection
	Underground	Landslide detection

Factor	*Type*	*Example*
	Underwater	Water level detection
Hops	Single (SHWSN)	Water quality monitoring
	Multi (MHWSN)	Data centre monitoring

C. *Working principle*

Wireless Sensor Networks fundamentally relies on Peer-to-Peer network structure with wireless communication as shown in "Fig. 3". Data transmission over Wireless Sensor Network will be performed with following steps:

- **Initialization of Network**: Initially hundreds of dedicated sensor nodes are initialized by enabling respective circuits like transmitter, receiver, amplifier and processing units. Identification of routes will be performed by broadcasting messages over the network.
- **Sensing of Data**: After the establishment of the network, each sensor node of the network will start sensing the environment or physical information using sensors. This sensed information may be of any form including analogue, digital, image and some other.
- **Processing of Data**: Now the sensed information will be processed to convert it into the desired format for sending to sink node by the processing unit of the sensor node.
- **Sending data to Sink**: One sensed data is ready, each sensor node starts sending data to sink node using the transmitter. In some cases like multi-hop networks, sensor nodes also need to receive data using the receiver for re-transmission to sink node.
- **Aggregation of data at Sink**: Finally, Sink node is responsible to aggregate data transmitted by various sensor nodes in the network. In some cases, Sink node will also receive data from other networks through gateway nodes. This aggregated data will be used for the intended work of WSNs.

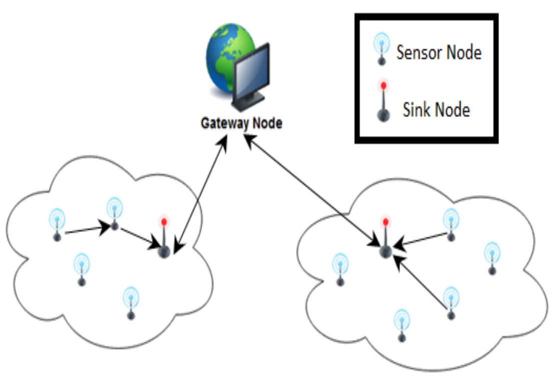

Figure 3. Working with Wireless Sensor Network

II. MAJOR CHALLENGES OF WIRELESS SENSOR NETWORK

Wireless Sensor Networks suffer from a large set of development and deployment challenges. Form the history, it is observed that each researcher is attracted to address the multiple challenges of WSNs and hence most of the proposals formulate Multi-Objective functions. In order to materialize this aspect, Zesong [8] in his survey published the Multi-Objective Optimization (MOO) metrics of WSNs along with a discussion of open problems of WSNs. According to him, MOO metrics includes Coverage, Network Connectivity, Network Lifetime, Energy Consumption, Energy Efficiency, Network Latency, Differentiated Detection Level, Number of Nodes, Fault Tolerance, Fair Rate Allocation, Detection Accuracy and Network Security. But, some of the metrics are interrelated to each other. For example, Network Lifetime purely depends on Energy Consumption and Energy efficiency of sensor nodes. More energy consumption decreases the lifetime of the network. Similarly, Coverage, Network Connectivity and Number of Nodes will exhibit challenges of Network Deployment. Table II of [8] and survey of lifetime maximization by Halil [9] proved that Network lifetime maximization became one of the major challenges of WSNs. Similarly, Ivana [10, 11] the exposed importance of security issues with possibilities of attacks in existing Wireless Sensor Network Protocols and Zeyu [12, 13] showcased fault diagnosis survey to elevate fault tolerance of WSNs. With all these, major challenges of WSNs can be considered as follows:

A. *Network Lifetime*

Network lifetime directly depends on energy consumption. From the theory of Radio Channel Model [14, 15], energy consumption for each sensor node can be computed from the following equations as: Transmitter energy (E_{Tx}), Receiver energy (E_{Rx}) and Amplifier energy as Free-space energy amplification factor (E_{fs}) for small distance and Multi-path fading amplification factor (E_{mp}) factors for longer distances with the following equations.

$$E_{Rx}(k) = k * E_{elec} \tag{1}$$

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \tag{2}$$

$$E_{Tx}(k,d) = \begin{cases} k * E_{elec} + k * E_{fs} * d^2 \ \ if\ d < d_0 \\ k * E_{elec} + k * E_{mp} * d^4 \ \ if\ d \geq d_0 \end{cases} \tag{3}$$

"Equation 1" gives, Receiver energy which depends purely on number bits received (*k*) and hence $E_{Rx}(k)$ can be computed as Circuit electronic energy (E_{elec}) multiplied with a number of bits (*k*). But, Transmitter energy depends on both a number of bits (*k*) and distance (*d*) of transmission. Amplification factors will be included based on the distance i.e. E_{fs} will be used for small distance and E_{mp} will be used for long distance which can be decided by a threshold distance d0 computed using "Equation 2". Finally, Transmitter energy can be obtained from "Equation 3". In general, Radio channel model uses some standard values of these electronic parameters as shown in Table II.

TABLE II. STANDARD VALUES OF OF ELECTRONIC PARAMETERS

Parameter	*Value*
Transmitter or Receiver Electronics (E_{elec})	50 nJ/bit
Free-space energy amplification factor (E_{fs})	100 pJ/bit/m^2

Parameter	Value
Multi-path fading amplification factor (E_{mp})	0.0013 pJ/bit/m^4
Data aggregation energy (E_{DA})	5 nJ/bit

B. Network Security

WSNs are more vulnerable to security attacks and could be broadly considered from two different levels of views: one is security mechanisms like layers [10] and another is basic mechanisms like routing [11]. Most of the security attack in WSNs is caused by the insertion of false information by the compromised node in the network. Some of the common attacks are listed in Table III. Majority of these attacks targets network layer and very few attacks focus other layers like transport, physical and application.

TABLE III. COMMON SECURITY ATTACKS

Attack	Layer	Consequences
Denial of Service	Multi-Layer	Eliminates network's capacity to perform its expected function
Sybil Attack	Network	Compromise of transmission routes
Hello flood	Network	Increasing energy degradation and collisions, creating false transmission routes
Information or Data Spoofing	Network	Attracting/repelling network traffic, creating routing loops
Blackhole	Network	Reducing traffic and increasing data loss
Data integrity	Transport	Falsifying routing data can disrupt the networks normal operation

C. Fault Tolerance

Fault Tolerance will be considered as least significant of the challenge of WSNs as they always increase the cost of additional hardware. It mainly addresses Reliability, Real-time performance and Safety of WSNs [12]. These mechanisms can be divided into three types: Redundancy based, Clustering based and Deployment based [13].

III. THE CONCEPT OF ENERGY EFFICIENT CLUSTERING

Above discussion reveals that greatest importance was engaged with maximization of Network Lifetime in WSNs. The need of energy efficient techniques was increased, as sensor nodes are equipped with limited energy resources like batteries. Similarly, multi-hop WSNs growing rapidly for efficient coverage of network along with optimization fault tolerance. These two points motivated researchers to unveil Energy Efficient Clustering algorithm. This EEC mainly divided into two phases as follows:

- **Set-up phase**: Initially network will be established by forming clusters among the sensor nodes of the entire nodes. First, each sensor node broadcast messages to other nodes of the network for the selection of cluster heads. After some time some of the nodes will be selected as CHs. Then, each CH advertises itself to form clusters by joining nearby sensor nodes. Every CH need to switch on both transmitter and receiver as it needs to re-transmit the received data to sink node.
- **Steady-state phase**: After generation of clusters, each sensor node starts sending data to respective CH. Then, CH re-transmits received energy to sink node and hence CH consumes a high amount of energy as shown in "Equation 4", where *t* indicates a number of nodes in a cluster and E_{DA} are Data Aggregation or Receiving energy. Steady-state phase is nothing but data transmission phase which uses Time Division Multiple Access (TDMA) schedule and hence it is the longest of the two phases.

$$E_{CH} = k * E_{elec} * (t-1) + k * E_{DA} * t + E_{Tx}(k,d) \quad (4)$$

Set-up phase is the vital phase even though it is smallest and has the greatest scope for a new proposal for improving algorithms. In 2000, Wendi [15] introduced first energy efficient clustering approach known as Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol for optimization energy consumption using a random selection of CH using a probabilistic threshold as shown in "Equation 5".

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (5)$$

Later number of proposals extended LEACH protocol for the same purpose can be observed from the survey of Sunil [16]. Table 2 and 3 of this paper lists pros and cons of each LEACH successor method for both single-hop and multi-hop WSNs respectively. All these algorithms use additional CH selection method along with LEACH protocol.

IV. RECENT ENERGY EFFICIENT CLUSTERING ALGORITHMS

Unlike LEACH, there of plenty of proposals are evidenced by the history. However, there are several reviews are a publisher on WSNs; none of it focused Network Lifetime maximization except Halil [9] who covered proposals up to 2014. This motivated us to present a review of recent algorithms after 2014 especially for comparison of Energy Efficient Clustering algorithms as follows.

- Dilip [17] proposed two protocols: Single-hop energy efficient clustering protocol (S-EECP) and Multi-hop energy efficient clustering protocol (M-EECP) for heterogeneous WSNs. CHs are elected by a weighted probability based on the ratio between residual energy of each node and the average energy of the network in S-EECP whereas, in M-EECP, the elected CHs communicate the data packets to the base station via multi-hop communication approach.
- Mehdi [18] presented distributed algorithm named scalable energy efficient clustering hierarchy (SEECH), which selects CHs and relays separately based on nodes eligibilities. High and low degree nodes are respectively, employed as CHs and relays. Firstly, some of the nodes are selected as tentative CHs using the distributive method. Then, a number of these nodes, as much as required, introduce themselves to the network known as CH candidates and the other nodes go to sleep. Afterwards, all candidates execute a simple algorithm so that final CHs could be selected.

- Fifi [19] presented a stable energy-efficient clustering (SEEC) protocol along with the extension to multi-level of SEEC. It is mainly intended for higher average throughput, longer stability period, which is crucial for many applications and takes full advantage of the presence of node heterogeneity. It depends on the structure of the network where the network is divided into small clusters, each cluster has a powerful node named advanced node (AN) and some normal nodes (NNs) deployed randomly in this cluster. More powerful supper nodes (SNs) are also assigned to cover distant sensing areas in case of the multi-level. In each cluster, NNs make the sensing operation, AN or SN then aggregate all data coming from its cluster and transmits them to the BS.

- Jenq [20] implemented a new regional energy aware clustering method using isolated nodes for WSNs, called Regional Energy Aware Clustering with Isolated Nodes (REAC-IN). CHs are selected based on weight determined according to the residual energy of each sensor and the regional average energy of all sensors in each cluster. Isolated nodes communicate with the sink by consuming an excess amount of energy. The regional average energy and the distance between the sensors and the sink are used to determine whether the isolated node sends its data to CH in the previous round or to the sink which will help to prolong network lifetime.

- Mohammed [21] proposed a mobile sink-based adaptive immune energy-efficient clustering protocol (MSIEEP) to alleviate the energy holes. It uses the adaptive immune algorithm (AIA) to guide the mobile sink-based on minimizing the total dissipated energy in communication and overhead control packets. Moreover, the optimum number of CHs will be find using AIA in order to improve the lifetime and stability period of the network.

- Hai [22] proposed a clustering protocol called Fan-Shaped Clustering (FSC) to partition a large-scale network into fan-shaped clusters. For each cluster, around central area is defined and only nodes in this area can be CH candidates. Each node in the central area with remaining energy predefined threshold sets a random backoff time; When the first node whose backoff time elapses, it broadcasts a Head message to announce that it wins the CH selection and other nodes receiving this message cancel their backoff time.

- Saman [23] introduced an innovative clustering protocol of load balancing which divides the whole network to the virtual circle with variable radiuses and utilizes an appropriate strategy in intra-cluster communications.

- Trong [24] proposed a new distributed clustering approach to determining the best CH for each cluster by considering both energy consumption and end-to-end delay requirements using energy-cost function and end-to-end delay function for use in an inter-cluster routing algorithm.

- Anindita [25] proposed an energy efficient clustering protocol based on K-means algorithm named EECPK-means for WSN where initial centroid selection procedure can be improved using midpoint algorithm. Prolong the network lifetime, it produces balanced clusters with an ultimately balanced load of CHs and considers residual energy as the parameter in addition to Euclidean distance used in basic K-means algorithm for appropriate CH selection. Multi-hop communication from CH nodes to BS takes place depending on their distances from BS.

- Ning [26] presented an energy efficiency protocol to prolong the network lifetime based on an improved particle swarm optimization (PSO) algorithm. Both energy efficiency and transmission distance into consideration. Moreover, relay nodes are used to balance the heavy consumption of cluster heads. The network results in better-distributed sensors and a well-balanced clustering system enhancing the network's lifetime.

- Xuan [27] introduced two-layer structure such that low layer nodes communicate with their CH, followed by the CHs communicating with the BS operating in either a one-hop or a multi-hop. It proposes a novel joint design of SNs clustering and data recovery. Furthermore, both the energy-efficiency and data forecasting accuracy are considered and investigated the tradeoff between them.

- Wenbo [28] proposed new clustering algorithm and event-driven cluster head rotation mechanism. An Energy-Efficient Heterogeneous Ring Clustering (E2HRC) routing protocol for WSNs is then proposed and corresponding routing algorithms and maintenance methods are established. The clustering information announcement message and clustering acknowledgement message were designed according to RFC and original RPL message structure.

- Khalid [29] implemented a novel energy-aware and layering-based clustering and routing algorithm (EA-CRA) for gathering data in WSNs. More specifically, it divides the field into a number of layers where the width of a layer not only decreases towards the BS but also is composed of a certain number of clusters.

- Wenliang [30] improved the LEACH algorithm by readjusting $T(n)$, considering the residual energy of the nodes and the factors of the long distance node. Then the data fusion rate allows the CHs to fuse data before sending the data and send the data to the BS. Finally, the free-space model and the multi-path fading model are adopted to avoid the excessive consumption of energy caused by the node d^4.

TABLE IV. RECENT ENERGY EFFICIENT CLUSTERING ALGORITHMS FOR NETWORK LIFETIME MAXIMIZATION

Year	***Month***	***Proposal by***	***Method***	***Citations***	***WSN Type***	***Approach***	***Constraints and or Thresholds***	***Implementation Tools***
2014 (3)	Mar	Dilip [17]	S-EECP, M-EECP	112	HE, SH/MH	LEACH	New probability thresholds *T(Sn)*, *T(Sa)* and *T(Ss)* to elect the CHs, where p_n, p_a and p_s are referred to as the weighted probability of normal, advanced and super node to prolong network lifetime and balance energy consumption among the CHs	NS-2
	Nov	Mehdi [18]	SEECH	66	HO, MH, Large Scale	Distributed clustering	Calculates p_{ci} for each node *i* which determines its chance for being a tentative CH, where E_{resi} denotes residual energy of node *i* and it is included to protect low energy nodes	MATLAB
	Dec	Fifi [19]	SEEC, MSEEC	32	HE, MH	Multi-level stability	Compute the total rounds of network lifetime (Rnds), which is the total of rounds from the network begins to all the nodes die for SN and NN as $(Rnds)_{SN}$ and $(Rnds)_{NN}$	MATLAB
2015 (3)	Feb	Jenq [20]	REAC-IN	96	HO, MH	LEACH	Define regional average energy $E_{ci}(r - 1)$ to find the probability that node n_i is selected as a CH in the round *r* which intern used to compute threshold $T(n_i)$ and CH is elected as LEACH	NS-2
	Aug	Mohammed [21]	MSIEEP	43	HO, MH, MO	Adaptive Immune	AIA is used to find the optimum number of cluster heads (CHs) to improve the lifetime and stability period of the network	MATLAB
	Dec	Hai [22]	FSC	36	HO, MH, Large Scale	Multi-layer	Compute the distance between two polar coordinates X and Y is calculated as $d_{X\text{-}Y}$ and node's transmission radius *r* which should be at least equal to $d_{X\text{-}Y}$ to guarantee that any node in two adjacent clusters can communicate to each other.	MATLAB
2016 (4)	Jun	Saman [23]	LBEEC	12	HO, MH	Multi-layer	each node calculates its cluster head R_{CH} radius and normalized $F_{CH-value}$ in order to be select as volunteer CH	MATLAB
	Aug	Trong [24]	DCEEC	16	HO, MH	Distributed clustering	Calculates TED_i for sensor *i* for the CH candidates using two controlling parameters: α used to adjust the dependence of the remaining energy of the CH candidates and β to adjust the distance between the CH candidates and the sink.	MATLAB
	Dec	Anindita [25]	EECPK-means	6	HO, MH	K-means	Set of k_{opt} number of clusters will be formed using *Centroid(X, Y)*, the residual energy of CH and $E_{threshold}$.	MATLAB
	Dec	Ning [26]	PSO	5	HO, MH	Topology Control	Optimizes fitness function $\mathcal{F}_{CH}$ which has two parts: $\mathcal{R}_{energy}$ is the ratio of CHs average residual energy to non-CHs average residual energy in the current round and $\mathcal{R}_{location}$ is the ratio of the average distance between the non-CH nodes and the BS to the average distance between the CHs and the BS.	MATLAB
2017 (6)	Jan	Xuan [27]	JDEEC-DR	3	HO, SH/MH	Multi-layer	Defines mean absolute error *MAE* to measure the forecasting accuracy using forecast value f_t for the t^{th} missing value, real value o_t of the t^{th} missing value and N is the total number of all the missing values	MUSCLES
	Feb	Wenbo [28]	E2HRC	5	HE, MH	Multi-layer	Established backbone network type routing mechanism based on optimal direction angle (DA), node residual energy (EN) and hop difference (HC).	Cooja
	Mar	Khalid [29]	EA-CRA	2	HO, MH	Multi-layer	Each tentative head calculates two weights: remaining energy of the tentative head and its location among all other nodes as $LeaderHead_{Weight}(n)$ and tentative head energy and its distance to the base station as $ClusterHead_{Weight}$	MATLAB
	May	Wenliang [30]	ICBEC	3	HO, MH	LEACH	The new threshold T(n) is computed using probability that the advanced node is elected to the CH as P_{adv} and probability that the common node is elected to the CH as P_{nrm}	MATLAB
	Jul	Padmalaya [31]	T2FL	6	HO, MH	Fuzzy Logic	Computes T2FLwhich is characterized by a superior membership function and an inferior membership function from Fuzzy Logic	MATLAB
	Sep	Jianpo [32]	FPCRA	5	HO, MH	Fuzzy Logic	Calculates the degree of centralization measure D_{doc}, multi-parameter iteration factor *f*, cluster radius function R_U and fuzzy power-optimization score *F(x)*	NS2

- Padmalaya [31] divided the whole sensor network into a number of levels and at each level, efficient CH is elected based on T2FL Model. Three fuzzy descriptors such as remaining battery power, distance to base station and concentration have been considered. Each CH sends the data to the next level till it reaches the BS.
- Jianpo [32] improved the energy utilization as well as data transmission efficiency and balance the load, therefore, a fuzzy power-optimized clustering routing algorithm is proposed. It optimizes the iteration radius and classifies the sensor nodes into different categories according to their node degree. Then select the CH by multi-parameter iteration adaptively among the same category and optimize the cluster structure with a comprehensive consideration of parameters such as the degree of centralization, the distance between node and base station and so on. Finally, fuzzy control is used to adjust the transmission power of cluster nodes dynamically to minimize the energy consumption.

Summary of these recent energy efficient algorithms listed in Table IV along with information of year of publication, number of citations, type of WSN for which it was proposed, the approach used, constraints and or thresholds used and implementation tools. This table reveals several facts as follows: Firstly, 2017 year recorded with more number of proposals (i.e. 6). Similarly, a huge number of citations was recorded for the methods S-EECP and M-EECP by Dilip [17]. However, the T2FL method by Padmalaya [31] stood first in the year 2017. Very few proposals like Dilip [17], Fifi [19] and Wenbo [28] addressed heterogeneous networks. Similarly, only two proposals Dilip [17] and Xuan [27] targeted for both single-hop and multi-hop networks. Altogether, we can conclude that Dilip [17] methods will the most popular method in several aspects. However, researchers using diverse approaches Multi-layer structure became attractive with 27% among them as shown in “Fig. 4”.

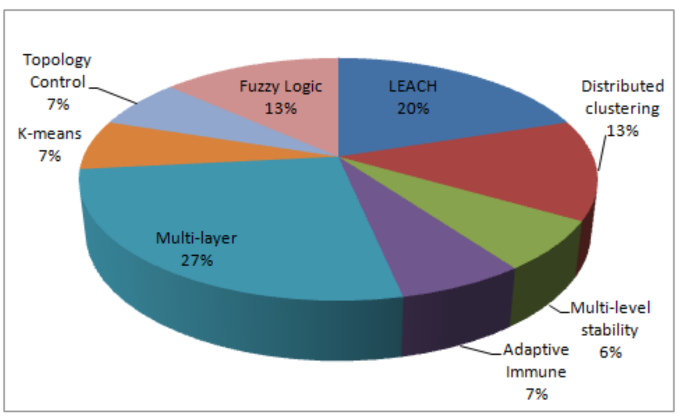

Figure 4. Comparision of WSN approaches used

Finally, MATLAB will become the most popular implementation tool with 79% for the simulation of WSNs as shown in “Fig. 5”.

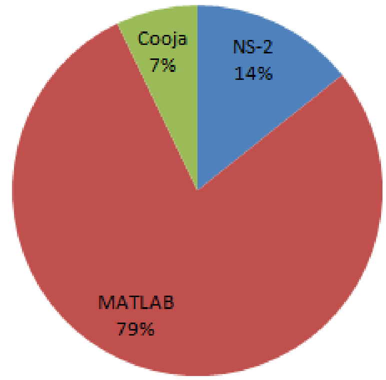

Figure 5. Comparision of Implementation tools

V. CONCLUSIONS

This review mainly focused on contemporary reach on Energy Efficient Clustering in Wireless Sensor Networks for maximization of Network lifetime. However, LEACH became the most admirable approach for optimization of energy consumption; several proposals can be seen from the history. Researchers are motivated by a variety of diverse proposals. Hence, we intended this paper for exploring recent proposals after 2014. Our analysis concludes some facts that: Dilip [17] method showed outstanding performance among these methods. Similarly, most researchers attracted to use Multi-layer structures for the design of WSNs and finally, MATLAB became the most popular implementation tool for the simulation of WSNs.

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