Efficient Clustering using Fuzzy Logic in the Wireless Sensor Networks

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June, 2019

<u>CERTIFICATE</u>

It is certified that the work contained in this thesis entitled "**Efficient Clustering using Fuzzy Logic in the Wireless Sensor Networks",** by **MUKEEM UR REHMAN (Roll No. 1170454006),** for the award of Master of Technology from **Babu Banarsi Das University** has been carried out under the supervision of **Mr. Ankit Dalela** and that this work has not been submitted elsewhere for a degree.

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ABSTRACT

In Wireless Sensor Networks (WSNs), power efficiency is one of the most essential factors influencing the networks' performance. Through a properly designed routing set of rules, WSNs' energy performance may be advanced evidently. Among diverse routing algorithms, hierarchical routing algorithms have blessings in improving nets' robustness and flexibility, and it's miles more appropriate for large scale of networks.

In this paper, a few standard hierarchical routing algorithms are delivered, and their blessings and defects are analyzed. Based on these analyses, a brand new hierarchical routing set of rules with excessive electricity efficiency named EESSC is proposed that is based at the advanced HAC clustering method. In EESSC, the sensor nodes' residual electricity could be taken into consideration in clustering operation, and a unique packet head is described to help replace nodes' strength statistics whilst transmitting message the various nodes. When the clusters had been formed, the nodes in cluster might be arrayed in a list and cluster head would be rotated automatically with the aid of the order of listing. And a re-cluster mechanism is designed to dynamic alter the result of clustering to make sensor nodes corporation greater affordable. At final, EESSC is compared to different normal hierarchical routing algorithms in a sequence of experiments, and the experiments' result which proves that EESSC has manifestly stepped forward the WSNs' power efficiency has been analyzed.

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CHAPTER 1

INTODUCTION:

1.1 WIRELESS SENSOR NETWORK:

A sensor node in a Wireless Sensor Networks (WSNs) is usually equipped with a transducer, a radio transceiver, small micro-controller and a energy supply (generally batteries)deployed in phenomenon supposed to display situations and parameters at diverse locations. Sensor nodes are capable of sensing many sorts of information from the environment inclusive of temperature, mild, humidity, pressure, wind direction and so on. They usually transmit the received records via RF (Radio Frequency) channel to the base station or Gateway. Recently, WSNs has been used and implemented for a extensive variety of software regions which includes – industrial process tracking &control and far flung manipulate, environmental monitoring, habit at monitoring, fitness care applications, home automation, item tracking, site visitors control and lots of other civilian and defense programs. However, WSN has its very own set of problems and constraints referring to layout obstacles and resource necessities in practices. Resource constraints encompass a restrained availability of valuable resource commonly –

a) Energy

b) Range of Communication

c) Bandwidth

d) Processing Power

e) Storage Capacity

The latest studies in WSNs intend to conquer those constraints by means of introducing new layout principles, developing new or enhancing current protocols, building new applications, and growing new algorithms. Researchers are currently engaged in growing schemes so that it will finally accomplish these necessities of WSN. One of the largest troubles in WSN's is electricity intake. This desires to be carefully examined and researched for its intake styles at every respective sensor node of the network to facilitate the improvements and constructing appropriate algorithm to reap finest power intake and maximize the network lifetime. Typically the sensor nodes are powered by using small batteries which can be able to storing only limited electricity to provide for a completely short period. Generally, the sensors nodes are deployed in far flung areas usually left unattended. In such situation externally feeding or replenishing electricity to the battery and changing batteries is hard or not viable frequently. Therefore, prolonging the network lifetime with given energy by means of the preliminary battery supply in conjunction with the community, is an important optimization intention in this issue. Hence the energy consumption by way of whole community in each thing may be minimized. The viable answer to lessen energy consumption can also lie in power conscious network that is designed in one of these manner that each layer of the device is strategically used. Energy in the sensor nodes fulfills a totally crucial venture of real-time at are cording from the sensors. Therefore this studies is directed onwards is at the lines of– 'how to layout an green and power-awareness protocols on the way to enlarge the lifetime of the in-tact networks in WSN'. Sensor nodes existence time is one of the most vital parameters in Wireless Sensor Network, together with the difficulty of figuring out appropriate cluster-heads and strength green routing protocol in wi-fi sensor networks. This has currently been the focal point of studies and development, where many researches are operating on those lifetime extension. This studies work and take a look at for that reason explained on this thesis, is stimulated through allowing rotation of cluster head function a few of the sensor nodes seeking to distribute the power intake optimally over all nodes within the network. Selection of cluster head for such rotation greatly complements the strength efficiency of the community. As a part of this thesis and studies work, many special routing protocols and algorithms are investigated to discover ways to lessen power consumption. In this thesis protocols are proposed for both homogeneous and heterogeneous WSNs, which shows different cluster head selection strategies and diverse cluster formation techniques. Comparison of their costs (in phrases of strength) of cluster head selection in exceptional rounds and different extensive results like cluster formation strategies, selection and distribution of cluster heads in addition to introduction of clusters shows a want of a mixed strategy for mentioning optimum and better effects [11]

1.1.1 Components of Sensor Node:

A wi-fi sensor networks encompass a large wide variety of sensors, those sensor nodes are either positioned carefully or randomly deployed over a geographical location and networked thru wireless links to form a WSN. These sensor nodes measure ambient circumstance in the surrounding environment that can be processed to reveal the characteristics of the phenomena going on at the location wherein the sensor nodes are deployed. Each sensor node in WSN is able to communicating with every other and the base station (BS) for the reason of statistics integration and dissemination.

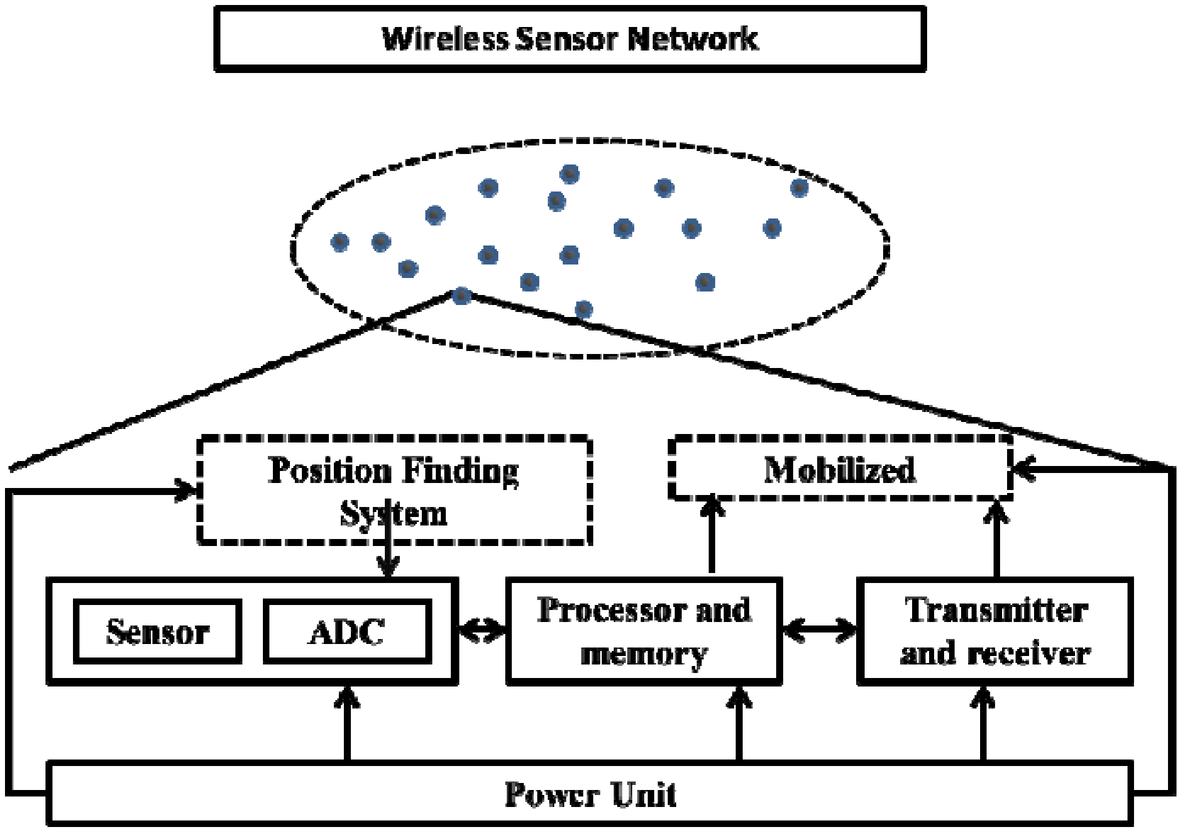


Fig. 1.1: WSN and Components of Sensor Node

WSN are used specially in army, civilian and for commercial packages. WSNs applications within the army subject include battlefield surveillance, intrusion detection, target discipline and imaging. However, WSN are now used in lots of civilian application regions which include environment and habitat monitoring, fitness packages, domestic automation and site visitors manipulate.WSN generally carries loads or heaps of sensor nodes which lets in for sensing over large geographical regions with more accuracy. Each node has 3 basic components as proven in Figure 1.1.

1. Sensing Unit
2. Processing Unit
3. Transmission Unit

The three basic additives are mentioned beneath

1.1.1.1. Sensing Unit

The sensing unit is usually made up of subunits, the sensors themselves and analog-to-virtual converters (AD- Cs). The indicators generated with the aid of the sensors, primarily based on the phenomenon to be sensed, are analog in nature and as a result want to be transformed to a digital to useful resource in addition processing(Tarannum&Suraiya,2010). The node senses the facts from the environment processes it and sends it to the base station. These signals are then fed to the processing unit.

1.1.1.2. Processing Unit

The node senses the information from the environment methods it and sends it to the base. The processing unit bureaucracy the core of the sensor node. This unit is in association with a small garage unit, manages the tactics that make the sensor node collaborate with the other nodes to carry the sensing duties. The processors employed within the sensor nodes encompass, the Atmel At Mega Microcontroller, MSP430, Intel Strong ARM, to name a few.

1.1.1.3. Transmission Unit

The transceiver unit connects wirelessly through the RF channel and is connected to an Omni-directional antenna that allows for communications in all instructions. The fundamental mission of a transceiver is to transform a chunk circulate arriving from the processing unit into electromagnetic radio waves. Some of generally used transceivers in sensor nodes are RFM TR family, Chipcoa CC10000 family, The Infineon TDA 525x circle of relatives and so forth. The node senses the facts from the environment tactics it and sends it to the base station. These nodes can both direction the information to the base station or to other sensor nodes such that the information ultimately reaches the bottom station. In maximum packages, sensor nodes are constraint in electricity supply and conversation bandwidth. These nodes are powered by using irreplaceable batteries and therefore network lifetime relies upon at the battery intake. Innovative strategies are advanced to correctly use the confined energy and bandwidth aid. These strategies work by using careful design and control in any respect layers of the networking protocol. For instance, at the network layer, it's miles noticeably desirable to discover techniques for electricity efficient route discovery and relaying of statistics from the sensor nodes to the Base Station (BS). So, the lifetime of the network is maximized.

1.2 CLUSTERING

Clusters are the organizational unit for WSNs. The dense nature of those networks calls for the need for them to be damaged down into clusters to simplify tasks such a communiqué. A sensor community can be made scalable via assembling the sensor nodes into businesses i.e. Clusters. Every cluster has a pacesetter, often known as the cluster head(Vive Katiyar et.Al, 2010).A CH may be elected by the sensors in a cluster or pre assigned by the network designer(Amir Akhavan Kharazian et.Al,2012). The cluster membership can be constant or variable. A variety of clustering algorithms have been specifically designed for WSNs for scalability and green communiqué. The concept of cluster based routing (Abbasi&Younis, 2007) is likewise applied to carry out electricity green routing in WSNs.

1.2.1 Cluster Formation

Sensor nodes generally use irreplaceable energy with the restricted potential, the node's ability of computing, speaking, and garage could be very restricted, which requires WSN protocols need to preserve energy as the main objective of maximizing the network lifetime. An strength-efficient verbal exchange protocol LEACH(Low Energy Adaptive Clustering Hierarchy), has been brought which employs a hierarchical clustering executed based on information received with the aid of the BS. The BS periodically adjustments each the cluster club and the cluster-head to conserve electricity. The CH collects and aggregates information from sensors in its personal cluster and passes on facts to the BS. By rotating the cluster-head randomly, energy consumption is anticipated to be uniformly distributed (AratiManjeshwar chooses too many cluster heads at from the BS with out considering nodes' residual electricity. As a end result, a few cluster heads drain their strength early therefore decreasing the lifespan of WSN. In every round of the cluster formation, network needs choose cluster head and transfer the aggregated facts.

1. Set-Up Phase, that's once more subdivided in to Advertisement, Cluster Set Schedule Creation levels.

2. Steady-State Phase, which provides information transmission using Time Division Multiple Access (TDMA).

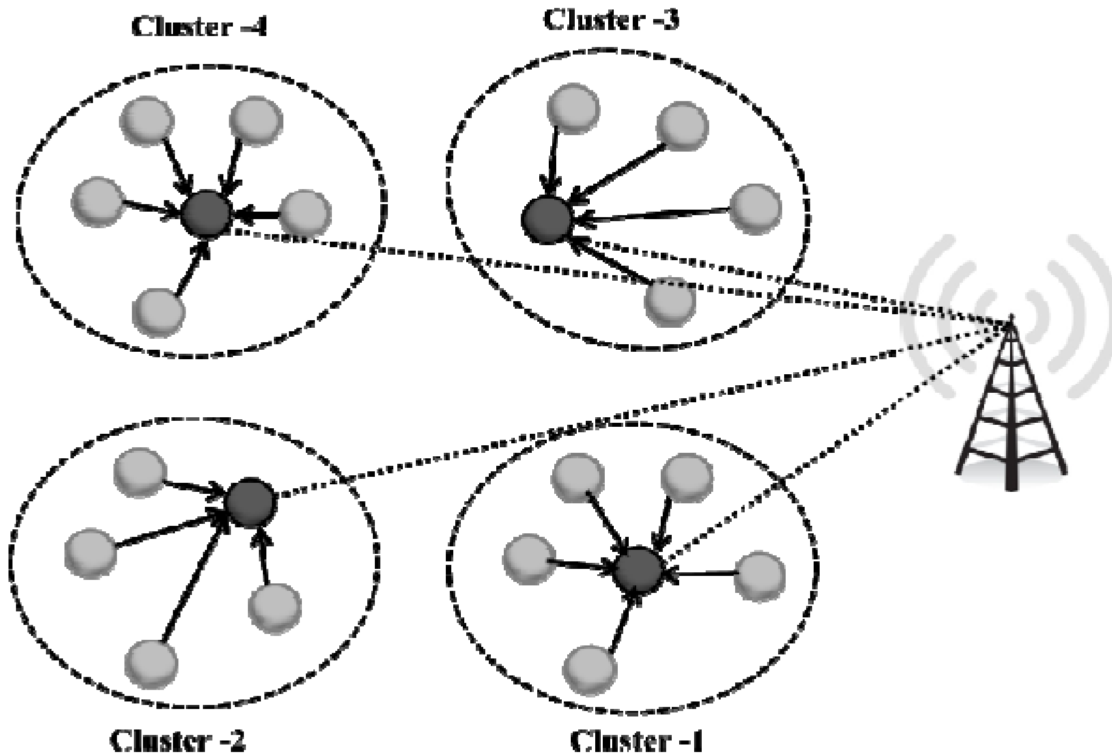


Fig.1.2. LEACH Clustering Communication Hierarchy for WSNs

The election of cluster head node in LEACH has a few deficiencies inclusive of, some very large clusters and really small clusters can also exist in the network on the identical time. Points listing the a number of the flaws of clustering algorithms

1. Unreasonable cluster head choice while the nodes have one of a kind energy.

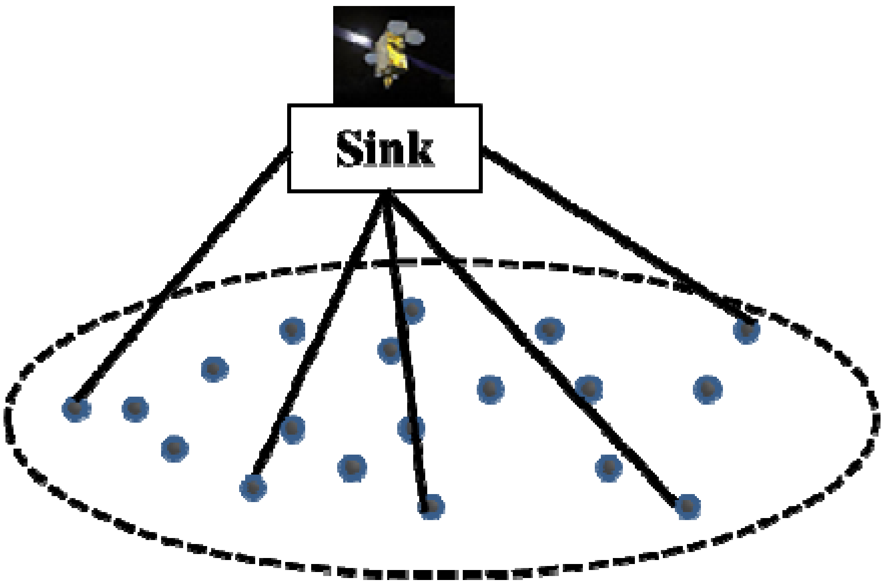
2. Cluster member nodes expend strength after cluster head become dead.

3. The algorithm does no longer take into account the location of nodes

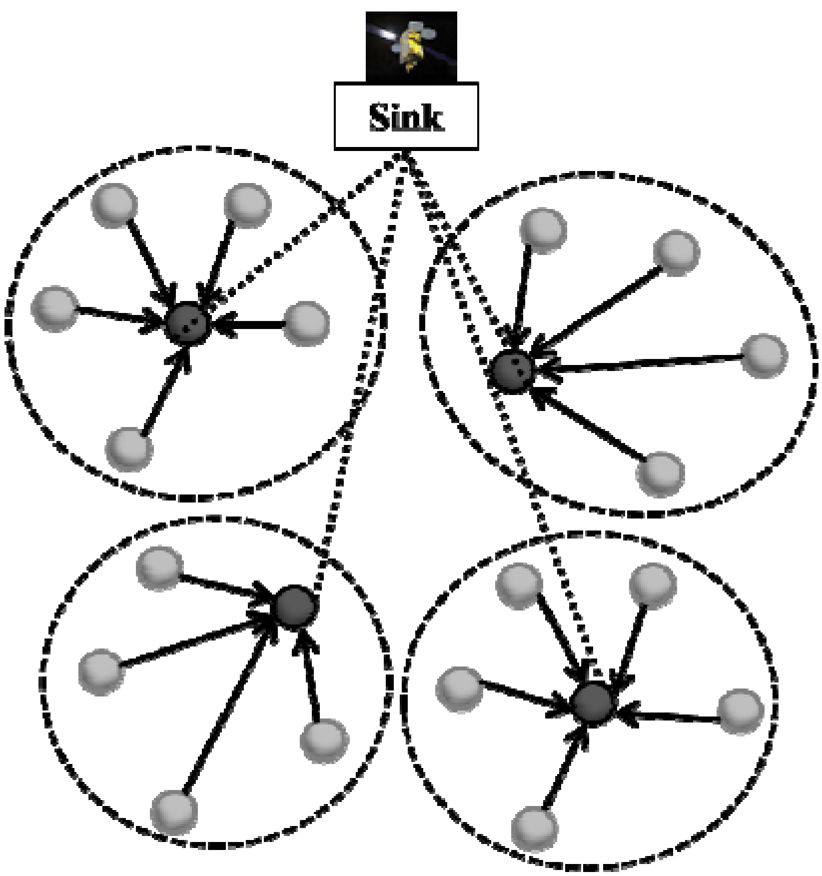
4. Ignores residual strength, geographic region and other information, which can also easily lead to cluster head node will hastily fail.

Motivated from this, such a lot of clustering proposals are said within the literature, Suggesting one of a kind strategies of cluster head selection and its function rotation.

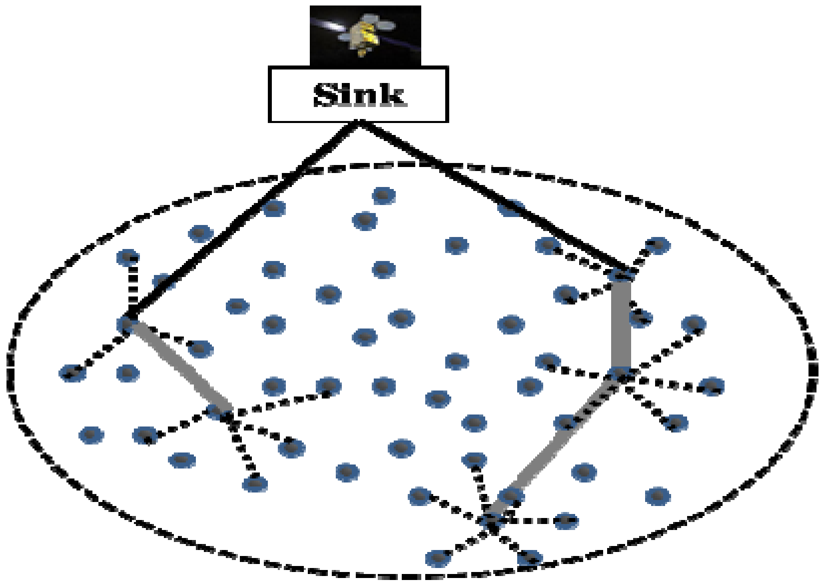
1.3 WIRELESS SENSOR NETWORK TOPOLOGIES



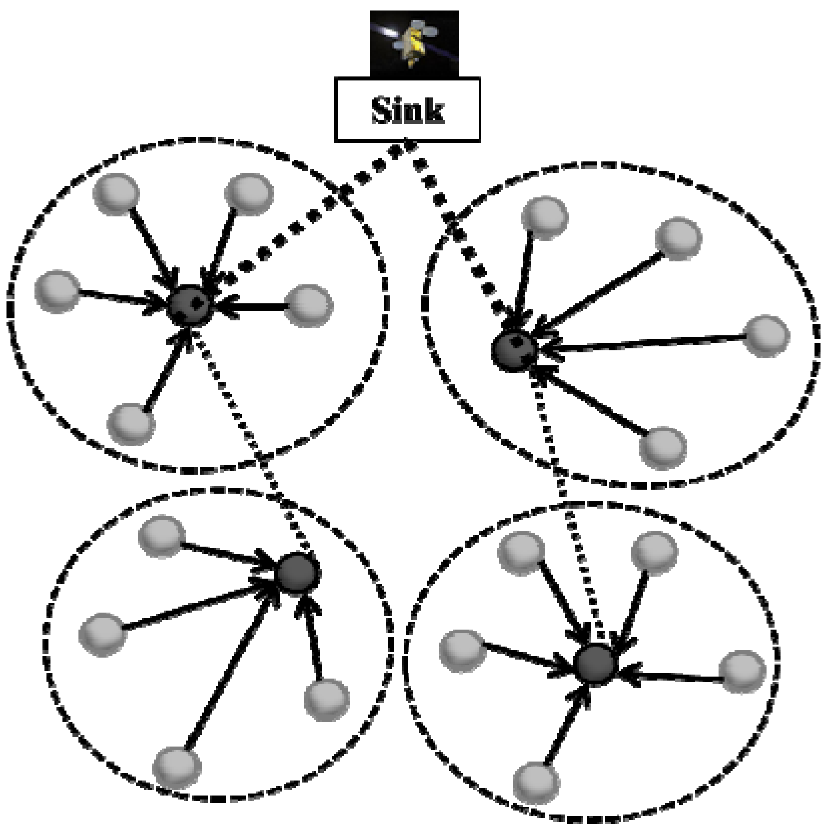
a) Single Hop Flat Model



b) Single Hop Clustering Model



c) Multi Hop Flat Model



d) Multi Hop Clustering Model

Fig.1.3. Classification of WSN Topology

WSN topologies are labeled into 4 styles of fashions as shown in Figure1. In the single-hop fashions (Figure 1.3(a) and Figure1.3(b)), all sensor nodes transmit their information to the sink node without delay. These architectures are infeasible in massive-scale regions because transmission cost becomes pricey in phrases of electricity intake and within the worst case, the sink node can be unreachable. In the multi-hop models, we will remember the flat model (Figure1.Three(c)) and the clustering model (Figure 1.3(d)). In the multi-hop flat version, due to the fact all nodes have to proportion the equal data inclusive of routing tables, overhead and strength consumption may be accelerated.

On the opposite hand, within the multi-hop clustering model, sensor nodes can hold low overhead and strength intake due to the fact unique cluster heads aggregate records and transmit them to the sink node. Additionally, wireless medium is shared and managed via person nodes inside the multi-hop flat version, which ends up in low performance in the resource utilization. In the multi-hop clustering model, resources can be allotted orthogonally to each cluster to reduce collisions among clusters and be reused cluster through cluster. As a result, the multi-hop clustering version is suitable for the sensor community deployed in far off large-scale regions.

1.4 CLASSIFICATION CLUSTERING STRATEGIES

While enhancing the constraints of LEACH, many clustering proposals for increasing network lifetime are said suggesting specific strategies of cluster head choice and its position rotation many of the sensor nodes, the use of special parameters (Ramesh & Somasundaram, 2011).Based on these parameters, those strategies of cluster head selection may additionally broadly be categorized as deterministic, adaptive and mixed metric (hybrid). In deterministic schemes unique attributes of the sensor node which include their identity quantity (Node ID), range of buddies they've (Node diploma) and in adaptive schemes the aid records like remnant strength, power dissipated at some stage in remaining round , preliminary energy of the nodes are used to decide their role at some point of exclusive facts collecting rounds. Based on who initiates the cluster head choice, the adaptive schemes can be categorized as base station assisted or self-organized (Probabilistic). Based at the parameters considered for identifying the role of a sensor node, the probabilistic schemes can also similarly be classified as constant parameter or aid adaptive.

Researchers normally assume that the nodes in wireless sensor networks are homogeneous, however in reality, homogeneous sensor networks rarely exist. Even homogeneous sensors have unique skills like distinctive tiers of initial energy, depletion price, and many others. In heterogeneous sensor Networks, generally, a huge quantity of cheaper nodes perform sensing, whilst a few nodes having comparatively more strength perform records filtering, fusion and transport. This results in the studies on heterogeneous networks wherein two or more varieties of nodes are taken into consideration. Heterogeneity in wireless sensor networks may be used to prolong the existence time and reliability of the network. Heterogeneous sensor networks are famous, especially in real deployments as described by means of Freitas et.Al(2009) and Corchado et.Al(2010).Most of the current electricity green protocols designed for heterogeneous networks are based totally on the clustering technique, which can be powerful in scalability and energy saving for WSNs.

1.5 ENERGY EFFICIENT ROUTE SELECTION POLICIES

Energy performance is a essential difficulty in WSNs. The current energy-efficient routing protocols frequently use residual strength, transmission electricity, or hyperlink distance as metrics to pick an most efficient route. In this segment, the point of interest is on strength performance in WSNs and the route selection policies with novel metrics a good way to boom course survivability of WSNs. The novel metrics result in solid network connectivity and much less additional route discovery operations. The gadgets used in a WSN are resource restrained, they have a low processing speed, a low garage capacity and a limited conversation bandwidth. Moreover, the network has to operate for lengthy intervals of time, however the nodes are battery powered, so the available electricity resources limit their usual operation. To limit electricity consumption, maximum of the tool additives, such as the radio, must be switched off maximum of the time. Another crucial function is that sensor nodes have huge processing talents within the ensemble, but now not individually. Nodes need to organize themselves, administering and coping with the network all collectively, and this is lots more difficult than controlling character gadgets(KavitaMusale&SheetalBorde,2013). Furthermore, changes in the bodily surroundings, wherein a network is deployed, make additionally nodes enjoy wide variations in connectivity and hence influencing the networking protocols. The principal design aim of WSNs is not most effective to transmit statistics from a source to a destination, but additionally to growth the life of the community. This can be done with the aid of employing power efficient routing protocols. Depending on the packages used, unique architectures and designs have been carried out in WSNs. The performance of a routing protocol relies upon at the structure and design of the network, and this is a very critical feature of WSNs. However, the operation of the protocol can have an effect on the power spent for the transmission of the information. The primary objective of contemporary studies in WSNs is to design strength-efficient nodes and protocols that would support numerous factors of community operations. In 2000 and 2002,the Pico Radio task at Berkeley and AMPs mission at MIT, respectively, targeted at the energy-confined radios and their effect at the extremely-low power sensing and networking. The preliminary efforts to develop energy-efficient sensors are in most cases pushed by way of educational establishments. However, the ultimate decade a number of industrial efforts have additionally appeared (a number of them primarily based on a number of the above educational efforts), consisting of agencies which includes Crossbow, Sensoria, Worldsens, Dust Networks and Ember Corporation. These corporations offer the opportunity to buy sensor gadgets prepared for deployment in an expansion of software scenarios together with diverse management tools for programming, protection, and sensor records visualization. In parallel to the development of the hardware of the sensors, and so that it will offer power-green solutions, the improvement of routing protocols to be able to require much less energy, resulting inside the extension of the community lifetime, is an ongoing studies vicinity. The simplest idea is to greedily transfer to lower mode on every occasion possible. The trouble is that the time and strength consumption required to attain better modes is not negligible. So, techniques and protocols that could consider strength efficiency and transmit packets through strength-efficient routing protocols and as a consequence prolonging the life of the community are required for the packets. This should result the death of the nodes along the shortest direction. Since in a WSN every node has to act as a relay so that you can forward the message, if a few nodes die faster, because of the shortage of energy, it's miles feasible that other nodes will not be capable of communicate any extra. Hence, the community will get disconnected, the power intake isn't always balanced and the lifetime of the whole network is severely affected. Therefore, a combination among the shortest direction and the extension of the community lifetime is the maximum suitable routing metrics for use in WSNs. Moreover, the lifetime of a node is successfully decided via its battery life. The most important drainage of battery is due to transmitting and receiving statistics among nodes and the processing elements.

1. Average Energy Dissipated: This metric is associated with the community lifetime and shows the average dissipation of energy per node over time in the network as it plays diverse functions including transmitting, receiving, sensing and aggregation of facts. Low Energy Consumption. A low power protocol has to consume less strength than conventional protocols. This manner that a protocol that takes into attention the remaining power degree of the nodes and selects routes that maximize the network's lifetime is considered as low energy protocol.

2. Total Number of Nodes Alive: This metric is likewise related to the network lifetime. It gives an idea of the place coverage of the network through the years.

3. Total Number of Data Signals Received at BS: This metric is equivalent to the electricity stored by means of the protocol by using now not transmitting continuously information packets (hiya messages), which aren't required.

4. Average Packet Delay: This metric is calculated because the average one-way latency this is determined among the transmission and reception of a records packet on the sink. This metric measures the temporal accuracy of a packet.

5. Packet Delivery Ratio: It is calculated as the ratio of the range of awesome packets acquired at sinks to the number at first sent from source sensors. This metric suggests the reliability of statistics delivery.

6. Time until the First Node Dies: This metric shows the length for which all of the sensor nodes on the network are alive. There are protocols in which the first node at the community runs out of power in advance than in other protocols, but manages to maintain the community operational plenty longer.

7. Energy Spent in keeping with Round: This metric is related to the total quantity of electricity spent in routing messages in a spherical. It is a short-time period degree designed to offer an concept of the power performance of any proposed approach in a selected spherical.

8. Idle Listening: A sensor node that is in idle listening mode, does not ship or obtain information, it is able to still devour a substantial amount of power. Therefore, this node should not stay in idle listening mode, but should be powered off.

9. Packet Size: The length of a packet determines the time that a transmission will remaining. Therefore, it's miles powerful in electricity consumption. The packet size has to be decreased by combining numerous packets into one massive p packet or by using compression.

10. Distance: The distance among the transmitter and receiver can affect the electricity this is required to ship and receive packets. The routing protocols can pick out the shortest paths between nodes and reduce electricity intake.

The choice of the strength efficient protocols in WSNs is a really vital difficulty and must be considered in all networks. There are numerous guidelines for strength-green direction choice. The most recognized is called “Call Packing”. This coverage routes new calls on closely loaded in preference to gently-loaded hyperlinks. The benefit of call packing is that it favors high bandwidth calls; however its major downside is that it calls up some links completely, and as a consequence reducing the connectivity of the network. The load balancing coverage, in comparison to name balancing, attempts to spread the burden frivolously many of the links. This coverage decides to direction new calls on gently loaded paths instead of on closely loaded ones. A third coverage, referred to as “the min-hop policy”, routes a name on the minimum-hop route that meets the power performance requirements. This kind of coverage has traditionally been useful in energy-green WSNs. The load-balancing coverage is a good appearing coverage in all topologies, and the decision packing policy is the worst in all topologies. In maximum instances, the distinction among the weight balancing and minimal-hop guidelines may be very small. The relative performance of call packing to load balancing is worse in carefully connected networks, rather than densely connected networks. Moreover, there are schemes for multi-hop routing. The first maximizes the minimum life of the nodes, at the same time as the second minimizes total energy intake. The simulation outcomes recollect the transmission electricity and the circuit strength spent in transmission, in addition to the receiver strength. The comparison famous that multi-hop routing is preferred via the primary scheme while the ratio of transmission power to circuit power is low and through the second scheme whilst this ratio is excessive. In order to balance the burden, the first scheme limits the variety of multi-hop routing. Outline Energy Efficiency metrics used on this thesis are the no of dead nodes, the common power of the network and nodes in numerous probabilities in selection of cluster head.

1.6 ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

Routing protocols in WSNs have a common objective of efficiently making use of the restrained resources of sensor nodes with a purpose to make bigger the life of the community. Different routing strategies (Karaka & Kamal, 2004),(Parul & Sheetal, 2012)can be adopted for exclusive applications based totally on their necessities. Applications may be time essential or requiring periodic updates, they may require accurate records or durable, less specific network, they may require non-stop glide of information or occasion pushed output. Routing methods may even be improved and adapted for unique utility. Generally, the routing protocols in WSNs may be classified into statistics-centric, hierarchical (Golam et. Al,2012), location primarily based routing depending on the network shape. In records-centric, all of the nodes are functionally equal and partner in routing a question acquired from the bottom station to the event. In hierarchical method, some nodes have brought responsibilities on the way to lessen the burden on other nodes inside the community. In location based totally, the expertise of positions of sensor nodes is exploited to course the query from the bottom station to the event.

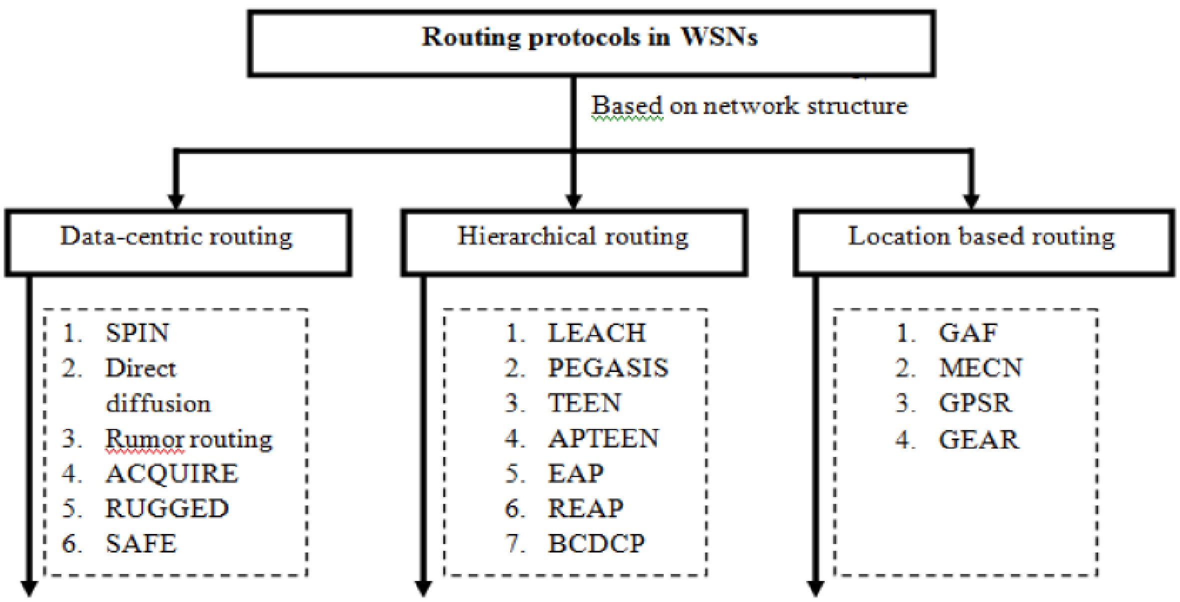


Fig.1.4. Classification Routing Protocols in Wireless Sensor Network

i) Data-Centric Routing Techniques: A huge quantity of sensor nodes are deployed over a region making it incomprehensible to assign a international identifier for every node. This has brought about the development of query based totally routing techniques known as information-centric routing protocol. In query primarily based, the base station sends a query to a sure location inside the community whose information it calls for. The question is dispatched to a random sensor node form the base station, and has to be forwarded to the intended place. The sensor nodes inside the place combination their sensed facts and route lower back to the base station alongside the opposite path found inside the preceding step.

ii) Hierarchical Routing Techniques: Hierarchical routing is the system of arranging routers in a hierarchical manner. A hierarchical protocol allows an administrator to make high-quality use of his speedy effective routers as backbone routers, and the decrease, decrease powered routers may be used for get right of entry to purposes. In this way, the access routers shape the first tier of the hierarchy, and the spine routers shape the second one tier. Hierarchical protocols take some time to preserve local visitors nearby, that is, they may no longer ahead traffic to the spine if it is not important to attain a destination.

iii) Location Based Routing Techniques: Routing algorithms primarily based on geographical location is an crucial studies issue inside the WSN. They use place facts to manual routing discovery and protection in addition to packet forwarding, accordingly enabling the satisfactory routing to be selected, lowering energy consumption and optimizing the entire community. Through 3 aspects involving the flooding limit scheme, the virtual region partition scheme and the pleasant routing desire scheme, the importance of location facts is visible in the routing algorithm.

CHAPTR 2

LITERATURE REVIEW

Expected boom in use and implementation of wireless sensor networks (WSNs) in distinctive environments and for unique applications creates new safety challenges. In WSNs, a malicious node might also initiate incorrect course statistics, exchange the contents of data packets, and even hijack one or extra proper network nodes. As the community reliability absolutely relies upon on character nodes' presence and collaborations with others, those malicious behaviors ought to halt WSNs. In **Hidehisa Nakayama,(2006) [1]** paper, the WSNs could be first labeled into three kinds in accordance to the manner that records are gathered. After a succinct summarization of every records gathering scheme, a comprehensive survey on safety problems could be provided. Finally, a few standard design guidelines in opposition to typical assaults together with our proposals in WSNs will be supplied. Unsolved issues and further studies will also be mentioned. Unlimited capability of WSNs has been attracting a top notch deal of attention. To ensure a sustainable development, a excessive level of safety needs to be accommodated. In this paper, we've got surveyed the predominant protection issues exhibited on the different layers of WSNs and mentioned three forms of countermeasures against diverse assaults. The first is the usage of comfy routing to save you assaults specifically from the outdoor. The 2d is to mitigate the impact of attacks via successfully circumventing the damaged place, wherein we've proposed the KAT mobility version for this reason. The third incorporates the approach used in advert hoc networks, in which we've got implemented PCA for a normally detection. Designing countermeasures enormously relies upon on the nature of WSNs inclusive of goal, scale, and stage of interest by the adversaries. The maximum vital issue in designing the countermeasures for WSNs is the value performance. Given the reality that the programs of sensor networks are flexible, it's far preferred to address the security in first-rate info and concerns so as to conceive an powerful incorporated answer. Although the appropriate solution won't exist, powerful countermeasures would still be a terrific deterrent. With advances in sensor technologies, more security features can be embedded in sensors and cellular sinks in the future. Many beneficial techniques developed within the constant/wireless networks or ad hoc networks may be adopted.

Wireless Sensor Network is a exceedingly allotted network of small and lightweight sensing nodes which can be deployed in a massive variety at multiple locations. These networks are beneficial in monitoring the device or environment. These sensor nodes plays sensing, processing after which speaking. Now an afternoon's these networks are implemented in various fields like navy, defense, woodland hearth, medical, disaster management and so on. In **Mayur Raj, (2014) [2]** paper it has been discussed approximately sensor community structure and main factors affecting the wireless sensor networks. Routing is a first-rate assignment faced via wi-fi sensor networks due to the dynamic nature of WSNs. Since power efficient routing protocols are of most important difficulty within the discipline of wi-fi sensor community. Therefore in addition sections of this paper it has supplied a quick evaluate of different energy efficient routing protocols proposed for wireless sensor networks. In this overview paper a brief creation approximately wireless sensor networks is given. It has also discussed approximately sensor community architecture. The major subject of this paper was to present a overview on fundamental elements affecting the WSNs. Energy is an crucial problem in wireless sensor networks because of its restrained lifetime capabilities so right here it has also supplied a survey on distinct strength green routing protocols within the discipline WSNs.

In Wireless Sensor Networks (WSNs), electricity performance is one of the maximum crucial elements to enhance the networks' overall performance, and well designed routing algorithm can obviously regulate the WSNs' electricity performance. In **Tao Du, (2014) [3]** paper, a few normal current routing algorithms are analyzed, and the benefits and defects of those algorithms are delivered. According to those analyses an power conscious ladder path diffuse routing algorithm named EALD is proposed. In EALD, the nodes' residual energy is taken into account whilst message packet selects transmitting route. And to ensure nodes' store acute electricity records, a unique packet head and a unique hyperlink which storing neighbor nodes are defined to update nodes' energy information when transmitting message. Through those designs, the course of transmitting can be dynamic adjusted to make the energy consumption among different nodes extra affordable. At last, EALD is in comparison with other usual routing algorithms in a series of experiments, and the experiments' result proves that EALD has manifestly progressed the WSNs' strength performance. To enhance the overall performance of WSN, editing the sensor nodes' energy performance is one of the maximum critical methods. "Hot Spot" and

“Energy Pole” are most important problems to be resolved to improve strength performance, and many routing algorithms are proposed to reap this goal. In this paper, after studying the especially existing algorithms, a brand new energy aware routing algorithm named EALD is proposed. There are 3 innovations approximately this algorithm as: first, a unique packet head is described to update nodes’ facts with transmitting message and special facts shape named LNN is saved in every nodes to memorize its neighbor nodes statistics; 2d, new ladder diffusion technique is designed to set off the nodes in WSNs; 1/3, an energy conscious routes deciding on method is designed to enhance the energy efficiency of WSNs. Finally the advance of EDLA in energy performance is proved through a sequence of experiments.

Energy harvesting generation has gained many attentions for its perpetual strength deliver for sensor nodes. However, the energy sources are still insufficient whilst the harvesting module is added on the node. To lengthen the network lifetime and meet the call for of inexperienced wi-fi network, a dynamical gradient aware hierarchical packet forwarding mechanism is designed. According to the relative role, the gradient conscious clusters are hooked up. Consequently, thinking about approximately the energy conversion performance and the relative distance, cluster heads are decided on reasonably. Further, with the aid of exploiting the to be had energy and the quantity of cluster members, packets can be forwarded to the sink in an power green manner. Results display that the network lifetime may be progressed extensively. The power harvesting generation has significantly boosted the development of WSN, through presenting theoretically limitless power components for longer network existence time. However the harvested electricity is confined to the tool cost and strongly depending on parameters consisting of the light intensity and sunshine length in lots of sensible applications, which encourage us in designing an electricity efficient packet forwarding mechanism. **Dapeng Wu,(2015) [4]** proposed GEEC design the intra and inter-cluster routing primarily based at the harvested electricity to enhance the performance of WSNs. The effectiveness of the proposed technique has been proved thru our simulations. In future works, we plan to very well study the EH price prediction generation for a greater unique node capability estimation. Due to the improvement of cellular sensor nodes in exercise, the in addition studies is planned at the scalability, applicability and performance of information forwarding and sleep scheduling algorithms, with the aid of which the EH technology may be introduced to WSNs with cell sensors and the electricity-efficiency and community lifetime may be similarly optimized.

Energy efficiency is an essential demand of Wireless Sensor Networks (WSNs). Through facts aggregation, energy efficiency may be improved through filtering wrong facts and merge redundant ones. If invalid transmitting is cut down, the nodes' power could be ate up and the usage of wireless channel will be extended. Designing records aggregation set of rules is one of the maximum green studies fields to enhance WSNs' performance. In this paper, a brand new statistics aggregation algorithm named ERDL (Efficient and Real time set of rules primarily based on Dynamic message List) is proposed by **Tao Dua, Shouning Qua, (2016) [5]**. ERDL works based on community layer of WSNs, and a dynamic listing can be created in filtering node to keep records messages ever relayed by this node. All messages in WSNs could be judged whether or not reduplicated or no longer in line with the contents in listing. In ERDL the filtering performance is progressed, and the actual time performance of transmitting is likewise ensured. At ultimate, a series experiments are simulated to prove the performance of ERDL. In this paper, based totally at the exact analysis of WSNs' characteristics and present researches, a brand new information aggregation algorithm named ERDL is proposed. ERDL is designed on cluster-primarily based shape, and routing method is originated from our previous researches. In ERDL, there are three improvements: first off, a list structure is designed to shop history messages to judge messages' redundancy in preference to durations postpone; secondly, the content of listing's item can be updated dynamically while transmitting; at last, the period of listing can be adjusted in step with the messages density and repetition of filtering nodes. Based on these innovations, ERDL has apparent benefit in actual-time transmitting and it can hold high green aggregation with little extra hardware burden, and it's far more fit for massive scale of WSNs that is the trend of networks improvement. In the end of this paper, a sequence of experiments are designed and simulated to prove the advantages of ERDL.

Minimizing electricity consumption to maximize community lifetime is one of the crucial worries in designing wi-fi sensor community routing protocols. Cluster-based totally protocols have shown promising strength-efficiency overall performance, in which sensor nodes take turns to act as cluster heads (CHs), which carry out higher-stage facts routing and relaying. In such case the electricity intake is extra evenly disbursed for all of the nodes. However, most cluster-based totally protocols improve power-performance at the fee of transmission delay. In this paper, **D. Yi, (2016) [6]** advise an progressed put off-conscious and power-efficient clustered protocol known as Hamilton Energy-Efficient Routing Protocol (HEER). HEER paperwork clusters within the community initialization segment and links members in each cluster on a Hamilton Path, constructed using a greedy algorithm, for statistics transmission reason. No cluster reformation is needed and the members on the direction will take turns to grow to be cluster head. The design lets in HEER to shop on community administration energy and also balance the load comparing to standard cluster-based protocols. The algorithms designed in HEER additionally way that it does now not suffer long postpone and does now not require every node to have international place statistics evaluating with conventional chain-based protocols together with PEGASIS and its versions. We implemented the HEER protocol in MATLAB simulation and as compared it with several cluster-based totally and chain-based protocols. We found that HEER is able to acquire an advanced network lifetime over the present day protocols whilst maintaining the average statistics transmission put off. In the simulation, HEER completed 66.Five% and forty.6% extra rounds than LEACH and LEACH-EE, which might be cluster-based protocols. When compared with chain-primarily based protocols (PEGASIS and Intra-grid-PEGSIS), HEER managed 21.2 instances and sixteen.7 times more rounds than PEGASIS and Intra-grid-PEGASIS respectively. In addition, HEER can removed 90% of transmission delay evaluating to LEACH and LEACH-EE and 99% comparing with PEGASIS and Intra-grid-PEGASIS. In this paper we proposed an electricity and put off-conscious routing protocol based on clustering and the concept of Hamilton path. We transmit and mixture facts payload via a Hamilton path fashioned with all cluster individuals which will lessen overall network electricity consumption via saving transmission variety. The design additionally achieves greater balanced electricity intake for CHs. When the CM range grows the cost of forming Hamilton route and information aggregation each boom. Therefore we added cluster length control in our protocol design. This assures that the usage of every packet is maximized while the average delay for statistics transmission to BS may be controlled. Furthermore, with the direction formed, HEER protocol paperwork its clusters handiest once at the preliminary round and the CMs at the path takes turns to turn out to be CH. Hence, HEER saves more community control overhead comparing with different hierarchical protocols that want to shape clusters again in each round. To compare our layout inside the HEER protocol, we simulated LEACH, LEACH-EE, PEGASIS, intra-grid-PEGASIS as well as HEER itself to compare the overall performance. The evaluation taken into consideration various common WSN deployment situations, which includes grid deployment and random even deployment. The effects imply that HEER protocol has most useful overall performance in all eventualities, in phrases of community lifetime whilst first useless node seems.

A cluster-primarily based version is most suitable in wireless sensor community due to its capacity to lessen electricity intake. However, coping with the nodes within the cluster in a dynamic surroundings is an open undertaking. Selecting the cluster heads (CHs) is a cumbersome method that significantly impacts the network overall performance. Although there are several research that advocate CH choice methods, most of them aren't suitable for a dynamic clustering surroundings. To keep away from this hassle, numerous strategies had been proposed primarily based on shrewd algorithms such as fuzzy logic, genetic algorithm (GA), and neural networks. However, those algorithms work higher inside a unmarried-hop clustering version framework, and the network lifetime constitutes a huge issue in case of multi-hop clustering environments. **Mohamed Elhoseny, (2017) [7]** introduced a brand new CH choice technique based totally on GA for each unmarried-hop and the multi-hop cluster fashions. The proposed method is designed to meet the requirements of dynamic environments by using electing the CH based totally on six principal functions, namely, (1) the final electricity, (2) the ate up electricity, (3) the range of close by buddies, (four) the energy aware distance, (5) the node vulnerability, and (6) the diploma of mobility. We shall see how the corresponding effects display that the proposed algorithm substantially extends the community lifetime. In a clustering WSN, each cluster usually consists of as a minimum one surrogate node, frequently called the CH. The CH may be dynamically chosen or pre assigned by using the community fashion designer. Communication among the cluster and the base station is facilitated via this CH. The trouble of selecting the CH in a multi-hop clustering model is more complicated than in a single-hop model. The multi-hop clustering version is a unique case of the clustering model in which a CH cannot transmit the records at once to the BS. There are six foremost sizable elements for choosing a CH node in a multi-hop cluster version in WSNs. These factors are: the gap from cluster middle, the vulnerability index, the degree of mobility, the diploma of mobility, the closing battery energy, the range of close by buddies, and the fed on power. All those elements are associated whilst selecting CH and ignoring one in all them will affect the community lifetime. The diploma of priority differs for every component. In the prevailing contribution, we have proposed a new CH choice technique based totally on GA, referred to as DCH-GA, for both single-hop and the multi-hop cluster fashions. The manner introduced right here is designed to in shape the necessities of the dynamic environments with the aid of electing the CH based totally on six most important capabilities. During exam, we repeated simulations and stated the common overall performance. Comparison research had been performed with a few strategies reported inside the literature. In the destiny paintings, we shall recognition on at ease information transfer among every node and the CH node deliberating the dynamic surroundings within the cluster.

Extending the life of wi-fi sensor networks (WSNs) while delivering the anticipated degree of provider remains a warm studies subject matter. Clustering has been recognized within the literature as one of the number one method to shop conversation power. In this paper, **Tariq Taleb, (2017) [8]** argue that hierarchical agglomerative clustering (HAC) gives a suitable foundation for designing notably electricity efficient conversation protocols for WSNs. To this give up, we look at a brand new mechanism for deciding on cluster heads (CHs) primarily based both on the bodily area of the sensors and their residual power. Furthermore, we examine specific styles of communications between the CHs and the bottom station depending on the viable transmission tiers and the capacity of the sensors to act as visitors relays. Simulation results display that our proposed clustering and communication schemes outperform nicely-is aware of existing techniques by means of comfy margins. In specific, networks lifetime is extended by means of greater than 60% as compared to LEACH and HEED, and by extra than 30% as compared to K-approach clustering. In this paper, the several clustering and communique schemes to improve power-performance of WSNs and subsequently boom their lifetime were proposed. In contrast to a few exiting schemes, our clustering technique primarily based on HAC determines the most suitable wide variety of clusters in regards to strength intake. Furthermore, we designed a unique cluster head selection mechanism based totally at the proximity from a digital power-conscious centroid. As this digital factor can circulate throughout the operation of the network, the CH function may be exceeded over to other nodes without transferring the cluster club. Single-hop and multi-hop communique among the CHs and the base station had been also studied on this paper. Numerical experiments have shown that multi-hop routing protocols on the overlay nodes lead to sizeable lifetime profits as compared to LEACH, HEED and K-approach. But even our single-hop has exhibited better overall performance than these protocols because of the clustering scheme and the CH choice and re-selection mechanisms. As destiny work we plan to layout a fully allotted version of our clustering and conversation schemes so as to enhance the scalability and the dependability of our approach.

Clustering is a promising and famous technique to prepare sensor nodes right into a hierarchical shape, lessen transmitting statistics to the base station through aggregation methods, and lengthen the network lifetime. However, a heavy site visitors load might also reason the unexpected dying of nodes because of energy resource depletion in some network areas, i.e., warm spots that result in community carrier disruption. This problem could be very vital, specifically for information-collecting situations wherein Cluster Heads (CHs) are accountable for gathering and forwarding sensed statistics to the base station. To keep away from warm spot hassle, the network workload should be uniformly disbursed among nodes. This is performed by means of rotating the CH position among all network nodes and tuning cluster length in keeping with CH situations. In this paper, a clustering algorithm is proposed by **Peyman Neamatollahi, (2018) [9]** that selects nodes with the highest ultimate electricity in each area as candidate CHs, among which the excellent nodes will be picked because the very last CHs. In addition, to mitigate the new spot problem, this clustering set of rules employs fuzzy common sense to alter the cluster radius of CH nodes; this is based totally on some nearby facts, consisting of distance to the bottom station and local density. Simulation effects display that, by means of mitigating the new spot problem, the proposed approach achieves an improvement in phrases of each network lifetime and strength conservation. Because power constraint is a big challenge when designing WSNs, many research have been executed to acquire strength-green algorithms. Nevertheless, maximum of the preceding clustering methods have now not taken into consideration load balancing inside the community. Current processes regularly pick very last CHs from amongst randomly decided on candidate CHs. This random choice can also bring about inappropriate CH election with admire to electricity conservation and CH distribution within the subject. The proposed algorithm in the cutting-edge paper is designed for WSNs with desk bound sensor nodes randomly dispensed in the subject. The foremost goal of the proposed set of rules is to lengthen the community lifetime by way of evenly distributing the workload and, for this reason, keeping off warm spot hassle by means of the construction of unequal clusters. To reap this, the proposed algorithm mostly makes a specialty of selecting right CHs from to be had sensor nodes and adjusting the cluster radius to mitigate the new spot trouble with the assist of fuzzy common sense based totally on the node's relative distance to the BS and neighborhood density. UCF selects the CHs from amongst the CH applicants by means of handiest considering the residual strength of sensor nodes without the usage of the random characteristic. To keep in mind the new spot issue, CHs farther from the BS with much less nearby density have a bigger cluster radius than those in the direction of the BS with extra local density. Therefore, small-size clusters can shop some strength for inter cluster communications. In the experiments, the UCF completed 30% development in community lifetime, extra than 56% reduction in clustering overhead, and 12% development in overall strength conservation when compared to different simulated protocols. Therefore, the outcomes of the simulation display that UCF is extra green than other famous allotted algorithms (DUCF, M-LEACH, and HEED) in terms of load balancing, network lifetime, and power efficiency. In addition, based totally at the simulation outcomes, UCF is a scalable protocol which its superiority does now not rely upon the BS place or the range of sensor nodes. The presentation of an unequal clustering algorithm for mobile sensor nodes is left as a destiny paintings.

Proficient clustering method has a essential function in organizing sensor nodes in wi-fi sensor networks (WSNs), utilizing their energy sources efficaciously and imparting durability to community. Hybrid strength-efficient distributed (HEED) protocol is one of the prominent clustering protocol in WSNs. However, it has few shortcomings, i.e., cluster heads (CHs) version in consecutive rounds, extra paintings load on CHs, choppy energy dissipation through sensor nodes, and formation of warm spots in community. By resolving those troubles, you could decorate HEED abilities to a greater volume. We have designed versions of Optimized HEED (OHEED) protocols named as HEED-1 Tier chaining (HEED1TC), HEED-2 Tier chaining (HEED2TC), ICHB-based OHEED-1 Tier chaining (ICOH1TC), ICHB based OHEED-2 Tier chaining (ICOH2TC), ICHB-FL based OHEED-1 Tier chaining (ICFLOH1TC), and ICHBFL-primarily based OHEED-2 Tier chaining (ICFLOH2TC) protocols. In HEED1TC and HEED2TC protocols, **Prateek Gupta, (2017) [10]** have got used chain-based intra-cluster and inter-cluster communication in HEED, respectively, for even load balancing among sensor nodes and to avoid more paintings load on CHs. Furthermore, for suitable cluster formation, minimizing CHs version in consecutive rounds and lowering complicated uncertainties, we've used bacterial foraging optimization algorithm (BFOA)-inspired proposed smart CH selection based on BFOA (ICHB) set of rules for CH selection in ICOH1TC and ICOH2TC protocols. Likewise, in ICFLOH1TC and ICFLOH2TC protocols, we have used novel fuzzy set of rules additionally for CH choice to remedy the new spots trouble, proper CH choice masking whole community, and maximizing the community lifetime to a wonderful extent. The simulation effects confirmed that proposed OHEED protocols are able to handle above-discussed issues and supplied some distance better results in comparison to HEED. In this paper, a hard and fast of OHEED protocols based totally on OHEED- 1 Tier chaining and OHEED-2 Tier chaining procedures named as HEED1TC, HEED2TC, ICOH1TC, ICOH2TC, ICFLOH1TC, and ICFLOH2TC protocols along with ICHB algorithm and novel fuzzy policies were proposed. These variations of OHEED protocols reap 38.Forty four, 18.59, sixty two.88, 50.00, 350.00, and 275.56% development in network lifetime respectively, in evaluation with HEED. OHEED protocols are capable of overcoming the constraints of HEED and provide proficient effects in terms of minimal required CHs, right load balance amongst sensor nodes, much less quantity of packets' broadcast, comfort of holes & warm spots problem with prolonged community lifetime. Simulation outcomes show that the overall performance ofICFLOH1TCandICFLOH2TC protocols are a ways better than different OHEED protocols in terms of network lifetime. Moreover, ICFLOH2TC sends very much less quantity of records packets to the BS (with entire community facts) in evaluation to ICFLOH1TC. Therefore, this protocol proves equipped, wherein less range of facts packets at BS is the prime requirement for facts evaluation and selection-making purpose. Both OHEED-1 Tier chaining and OHEED-2 Tier chaining protocols work effectively and may be applied in keeping with the community-unique conditions. This work would be useful for community protocol designers in the course of attaining higher most beneficial outcomes in designing clustering protocols with the ability of selecting bio-stimulated strategies or fuzzy machine policies or each to the nice in their community state of affairs suitability.

In Wireless Sensor Networks (WSNs), electricity performance is one of the most critical elements influencing the networks' overall performance. Through a properly designed routing set of rules, WSNs' energy efficiency may be progressed naturally. Among various routing algorithms, hierarchical routing algorithms have blessings in improving nets' robustness and versatility, and it's miles extra suitable for big scale of networks. In **Tao Du, (2013) [11]** paper, some ordinary hierarchical routing algorithms are introduced, and their benefits and defects are analyzed. Based on those analyses, a new hierarchical routing set of rules with high power efficiency named EESSC is proposed that is based on the stepped forward HAC clustering technique. In EESSC, the sensor nodes' residual power would be taken into account in clustering operation, and a special packet head is described to assist replace nodes' energy records while transmitting message many of the nodes. When the clusters have been formed, the nodes in cluster might be arrayed in a listing and cluster head could be turned around automatically with the aid of the order of listing. And a re-cluster mechanism is designed to dynamic regulate the result of clustering to make sensor nodes company extra affordable. At closing, EESSC is compared to different regular hierarchical routing algorithms in a series of experiments, and the experiments' end result which proves that EESSC has manifestly improved the WSNs' power performance has been analyzed. To improve the overall performance of WSN, elevating the sensor nodes' strength performance is one of the maximum crucial strategies. ‘‘Hot Spot’’ and ‘‘Energy Hole’’ are principal troubles to be resolved to enhance energy performance, and lots of hierarchical routing algorithms were designed to obtain this goal. In this paper, after reading the mainly current algorithms, a new strength aware hierarchical routing algorithm named EESSC is proposed. There are 4 innovations approximately this set of rules as: first of all, a new strength aware clustering technique primarily based on HAC is designed to make the cluster of sensor nodes extra affordable; secondly, a special type of list storing cluster member nodes is defined to rotate CH mechanically; thirdly, a unique packet head is designed to dynamically update the nodes' residual strength information whilst transmitting message; at closing, one kind of re-clustering mechanism is designed to optimize the clusters' distribution. Four standard hierarchical routing algorithms are simulated with EESSC with the aid of Matlab. Through the contrast, it is able to be concluded that EESSC has boost in energy efficiency of all algorithms, and resolves the troubles of ‘‘Hot Spot’’ and ‘‘Energy Hole’’

CHAPTR 3

PROBLEM FORMULATION AND SIMULATION METHODOLOGY

Wireless Sensor Networks (WSNs) is one of the most important information access platforms, and it is always deployed in extreme environment where people could not survive to obtain information [1]. WSNs can be applied in multiple fields such as military, agriculture, industry, and environmental protection, and it is one of the most focus topics in computer research fields [1,2]. There should be one or a few sink nodes and a number of sensor nodes in WSNs. Sink node's energy is supplied by cable and it should be unlimited; sensor node's energy is supplied by battery and it is limited. If some sensor nodes' energy is exhausted, information from the area monitored by these nodes will not be obtained. And dead nodes will not relay data from other nodes, thus, other sensor nodes will be increasingly burdened with transmission [2]. Given these issues, energy consumption in WSNs is an important research spot. So raising the sensor node's energy efficiency is an important factor to improve the performance of WSNs. There are many researches focusing on modifying the sensor node's energy efficiency, and designing an efficient routing algorithm is one of the most important approaches. There are three kinds of routing algorithms about energy efficiency in research: data centric routing algorithm, hierarchical routing algorithm and location-based routing algorithm. Data centric routing algorithms find and update the routing information at the same time of transmitting the message. Typical data centric routing algorithms include Directed Diffusion [3] and SPIN [4]; the latest researches propose the algorithms including LEO [5] and LDACO [6]. This kind of algorithm has some advantages as they have simple architecture, the WSNs is easy to be deployed and they have strongly self-organization ability; but these algorithms have a deadly defect that it uses a low efficient mode like ''flooding'' to transmit information, and this mode would produce a lot of additional burden to nodes, so this kind of routing algorithms are mostly used in small scale of WSNs. Location-based routing algorithms use the nodes' position information to select route. Typical location-based routing algorithms include GEAR [7], SPAN [8] and the latest researches propose HGMR [9] and GREES [10]; this kind of algorithm is always combined with other method in application; and these algorithms have the advantage as the route would be founded very quickly, and the routing information would be accurate; but it has a main defect that its efficiency is highly influenced by geographical environment of WSNs. Hierarchical routing algorithm is one of the most popular researches in WSNs and many typical algorithms are proposed which would be introduced in Section 2.2. In this type algorithm, sensor nodes would be divided to several parts according to some rules, and every part means a cluster. In every cluster, there would be a selected sensor node acting as Cluster Head (CH) and other nodes acting as members of cluster. CH is responsible for collecting the information from its members and forwarding the message to sink node. This kind of routing algorithm has the advantages as the energy consumption of sensor node is more balance, and the robust of WSNs is strong. But it has some faults as the architecture of this type of WSNs is relatively complex, and it is difficult to be designed, and the method of clustering and rotation of CH would highly influence the algorithm's efficiency [11].

3.1. THE CONCEPT OF ENERGY EFFICIENCY

Energy efficiency is a key factor of improving WSNs' performance and the concept of energy efficiency would be introduced in this part through the following two definitions. Definition 1. Networks lifetime: The networks lifetime means the period from WSNs activated to its failure for some sensor nodes dying for energy exhausting. Definition 2. Energy efficiency: It is the ratio of networks lifetime to its sensor node's energy. And if the sensor node's energy is stable, the longer networks lifetime means more energy efficiency. In WSNs, the node's energy would be consumed to sense, calculate and transmit the message. Among these operations, energy consumption in transmitting is much more than others [1], and there are many factors influencing energy consumption in transmitting such as node hardware parameters, the length of message and the distance from start node to end node. In this work, the energy consumption is calculated by the classical formula as the following equation [14].

$$B_{\tau x}(L,D)=\begin{cases}LE_{E1ec}+L\varepsilon_{fs}d^2, d<d_0\\ LE_{E1ec}+L\varepsilon_{\mathrm{m}\rho}d^4, d>d_0\end{cases}$$

In Eq. (1), L means the length of message; d means the distance of transmitting; EElec is a hardware parameter of energy consuming in operating transmission channel; efs and emp both are hardware parameters of energy consuming in operating amplifier; and d0 is a threshold of distance related to nodes hardware. According to Eq. (1), the distance is the key factor influencing energy consumption because in most WSNs all sensor nodes have the same hardware parameters and the information packet formation would be stable. So decreasing the distance of every hop would conserve the nodes' energy. But it cannot ensure to prolong the network lifetime just through conserving nodes' energy. For example, if some nodes are located at the optimal energy path, these nodes would always forward the information, and their energy would be exhausted much faster than others. So WSNs would be failed for these nodes' death, which is called ‘‘Hot Spot’’. And in multi-hop WSNs, the inner sensor nodes which near the sink node would forward a lot of message from the outer layer nodes, so these nodes' energy would be exhausted much faster than the outer ones. And this phenomenon is called ‘‘Energy Hole’’. Based on these analyses, the key factor of designing energy efficient routing algorithm is to resolve the problems of ‘‘Hot Spot’’ and ‘‘Energy Hole’’.

3.2. EXISTING HIERARCHICAL ROUTING ALGORITHMS:

In 2000, Heizelman proposed a famous hierarchical routing algorithm named LEACH [14], and the main thought of LEACH is that every sensor node can be elected as CH according to the probability calculated by whether it has been elected as CH. In the clustering phase, a number between 0 and 1 would be randomly selected by every sensor node. There is a unified threshold which is related to the percentage of CHs in WSNs. If the generated number is less than the threshold, the node would become the CH; otherwise, it would select a cluster to join in. When all CHs have been decided, they would broadcast some inviting message to other nodes, and these nodes would judge to join which CH's cluster according to the signal's strength of inviting message it received. After a several rounds of transmitting information, WSNs would redo the clustering. LEACH uses the periodic re-clustering and CH rotation to improve the energy efficiency of WSNs. Some experiments have proved that WSNs' lifetime can be prolonged through LEACH. But it is not yet perfectly in energy efficiency, because LEACH chooses CH only according to some probabilistic terms, but not taking the node's residual energy into account. And LEACH did not think about the problems of ‘‘Hot Spot’’ and ‘‘Energy Hole’’. Based on the thought of LEACH, there were many similar algorithms proposed such as LEACH-C [15], TEEN [16], HEED [17] and ERA [18]. LEACH-C adopts the thought that sink node is answer to choose CHs by collecting all sensor nodes' information. This method has advantage that the CHs would be well chosen and the global energy balance would be well controlled; but LEACH-C has a restriction that all nodes in WSNs must be able to communicate with sink node directly, and this restriction would lead that the nodes faraway from sink node consume much more energy than the ones near the sink node, and it will restrict the scale of WSNs. In HEED, the sensor nodes' residual energy is taken into account when CH is being chosen, and there would be two candidate CHs in every cluster. Every candidate CH would send inviting message to other nodes to campaign for CH, and other nodes in cluster would elect the final CH according to the signal's strength it received. HEED can dynamic adjust CHs' deployment based on the nodes' residual energy, but this algorithm would consume much energy at the choosing CH phase which would shorten the lifetime of WSNs. TEEN adopts two thresholds including a hard threshold and a soft threshold to reduce the number of sending message, and to conserve nodes' energy or to send information in time would be balanced in this algorithm. But the value of threshold is difficult to be set, and this algorithm would lead to the network congestion. ERA is another typical hierarchical algorithm. Its thought is also origined from LEACH, and the communication cost is taken into account when clustering. The communication cost consists of nodes' residual energy, the distance from the CH to sink node and the distance from member nodes to the CH. But this algorithm did not resolve the problem of dynamically updating the node' residual energy information, so it cannot accurate cluster the nodes.

The algorithms introduced above are proved to be able to resolve the ‘‘Hot Spot’’ problem, but the ‘‘Energy Hole’’ problem is not taken into account. Thus in [19–21] some hierarchical routing algorithms were proposed to resolve the problem of ‘‘Energy Hole’’. As has been introduced in Definition 2, the nature of ‘‘Energy Hole’’ is that the nodes near the sink node would consume more energy than outer ones, so the key of resolving ‘‘Energy Hole’’ is to conserve the inner nodes' energy. The key thought of these algorithms is that the nodes in WSNs are clustered with unequal radius. The nodes near the sink node will be arranged in a relative small cluster, and the nodes faraway the sink node will be arranged in a relative large cluster. According this method, there are more clusters which have less members near the sink node than the ones faraway the sink node. This method will help inner nodes conserving energy because the CH in small cluster would have little burden of collecting information of its members, and more clusters means more CHs to share the task of forwarding information from outer clusters, thus the energy of inner nodes would be conserved. These algorithms have been proved to be able to resolve ‘‘Energy Hole’’ in theory, but they are all very complicated to be designed, and the radius of cluster is not easy to be controlled.

All algorithms introduced previously adopt the dynamic clustering method, in which CH would be chosen before the cluster has been formed. After some rounds of transmitting, CH would be rotated through an optimal method. These algorithms are easy to cluster the sensor nodes, and can ensure the energy consumption balancing. But they need to periodic execute the re-clustering operation, and some new CHs need to be elected again every times. So much energy would be consumed in clustering phase and it will reduce the energy efficiency. To reduce energy consumption in this phase, some new hierarchical routing algorithms adopting static clustering method have been proposed. In this type algorithm, all nodes would be clustered firstly, and after some rounds of communication, the component of every cluster would not be changed any more, and just the CH would be rotated. In [22], a static clustering routing algorithm based on K-means is proposed, and in this algorithm, CH would be elected by computing the mass center of cluster. This method is easy to be deployed, but election CH need to deal with so large amounts of data that much energy would be consumed, so it has not obvious advantage in energy efficiency. In [23], a new static clustering routing algorithm named DHAC (Distributed HAC) was proposed based on the improved HAC. In DHAC, all sensor nodes would just be clustered one time in the activation phase, and the rotation order of CHs has also been arranged meanwhile. This algorithm has obvious advantage in conserving energy consumption in clustering than those introduced above, but it does not think about the node's residual energy when clustering, and the distribution of clusters is so inflexible that it cannot be dynamically adjusted according to the WSNs' condition. And all these static clustering routing algorithms cannot resolve ‘‘Energy Hole’’ problem because all nodes are treated similarly and the nodes in the center of clusters would be died much faster than others.

3.3. THE MODEL OF WSNs:

The model of WSNs would be defined, and based on the model the routing algorithm is able to make sure its responsibility. Because WSNs is an emerging research, the model of WSNs is designed for specific application, and there is not a unified standard to be used, the model of WSNs in this paper is defined based on the former researches as [4,7,10,14,15,19–21,23]. The detail of model is as follows:

1. The WSNs should be deployed in a widely area, and there are a number of sensor nodes randomly distributed all over the monitoring area. The vast monitoring area and a number of sensor nodes are fit for the development tendency of WSNs; randomly deployed nodes can be appropriate the practical applications.

2. There is only one sink node in WSNs, and the sink node is limitless in energy and is randomly located in or out sensor area. The sink node is powered by cable so it has limitless energy; the flexible location can measure algorithms' performance of facing different WSNs' architecture.

3. All sensor nodes have the same hardware parameters. Standardized nodes can reduce the production cost and be easy to be randomly deployed.

4. Every node would not move once deployed and it can know the exactly location of itself. It is the main difference of WSNs with ad hoc networks that nodes are stable in WSNs; and with the decrease of hardware cost, nodes can be easy to be equipped with GPS unit.

5. The transmitting channel in WSNs between two nodes is symmetry, which means that the energy consumed when sending message from node A to node B is equal to the one from node B to node A. It is fit for the specialty of wireless signal transmission, and most of researches adopt this type channel.

6. The node can automatically use the proper energy consumed in transmitting information according to the distance. The on-chip operating system has finished this function.

7. The conflict control and the channel selection would be dealt with MAC protocol, and routing protocol is not referred to. Because routing algorithm is working in network layer of WSNs, and most algorithms are designed transparent to MAC protocol so that they can use MAC protocol directly.

3.4 THE DESIGN OF ENERGY AWARE CLUSTERING METHOD BASED ON HAC

HAC is a typical clustering method based on partition, and its whole procedure can be divided as follows: at first, every node acts as a one-node cluster; then these small clusters begin to merge each other to the larger ones; and repeat to merge small clusters until all clusters' scale has satisfied the threshold. In this paper, an improved HAC clustering method which the nodes' residual energy is added into calculation distance is designed.

3.4.1. The introduction of classical HAC

The procedure of HAC includes five operations: calculation the distance of every pair of nodes, initial clustering, electing CH of all clusters, merging small clusters, and electing new CH. In this section these five operations would be explained by three steps: Step 1: Distance calculation. Distance means the difference of a pair of nodes and it is the basis of clustering. In WSNs, the spatial distance is the most important factor of energy consumption, and Euclidean formula is the most used method to calculate the spatial distance of any pair of nodes as the following equation:

$D_{ob} = \sqrt{(X_0 - X_b)^2 + (Y_0 - Y_b)^2}$ (2)

In Eq. (2), Xa and Ya respectively represent X axis Y axis of node a, and Xb and Yb respectively represent X axis Y axis of node b. The axis

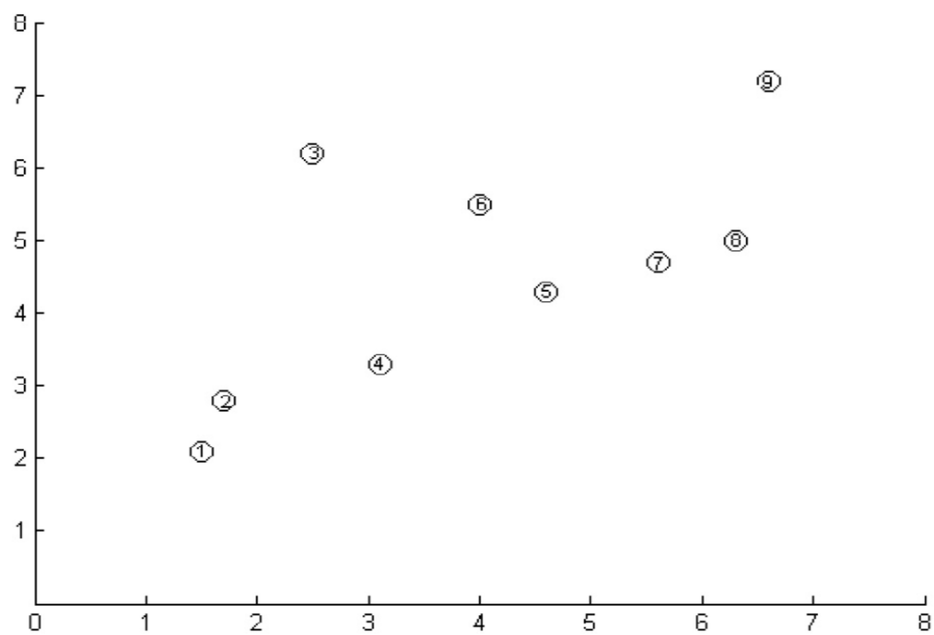


Fig.3.1. A typical model of WSNs' deployment station.

of nodes in Fig. 1 is shown in Table 1, and the result of every pair of nodes by Eq. (2) is as Table 2.

Step 2: Primary clustering. In this step, each node acts as CH, and sends its own information such as its location, clusters structure to its neighbor nodes. Then every CH would calculate distance from itself to other clusters, and would build a matrix to reserve the result. there are three mainly calculation formulas in application including maximum nodes distance as Eq. (3), minimum nodes distance as Eq. (4) and average nodes distance as Eq. (5). In these formulas, D(i, j) is the distance from node i in cluster A to node j in cluster B, and there are m nodes in cluster A and n nodes in cluster B. In these methods, Eq. (5) is the most popular ones, and it is also applied in EESSC to build distance matrix.

$D_{Slin1_{(}} = Mi \uparrow \iota(D(1,1), D(1,2), \ldots, D(i,j), \ldots, D(m, \uparrow \iota))$ (3)

$D_{C1inlc} = Mox(D(1,1), D(1,2), \ldots, D(i,j), \ldots, D(m, \uparrow \iota))$ (4)

$D_{PGMA} = \frac{l}{mn} \sum_{3i=12_{r,\ldots:}m, j=12i3,in} \ldots D(i,j)$ (5)

Step 3: Merge clusters. In this step, the smaller clusters would be merged into big ones judging by the calculation result of the formula introduced in step 2, and the new CH would be elected meanwhile. Because it has not a unified standard to elect CH in HAC, and according to the specialty of energy efficiency, a concept named SEPC (the Summary of Every Pair of nodes in Cluster, SEPC) would be adopted. The SEPC would be calculated by Eq. (6), and the node with minimum SEPC would be elected as CH, and in Eq. (6) n means the number of nodes in cluster. After merging clusters, it would be judged if the scale of all clusters has satisfied the threshold. If there still is small cluster, all CHs would broadcast their clusters' information, and the merging operation would be repeated. The distance of each cluster after one time merging is listed in Table 3, and the procedure of WSNs shown in Fig. 1 by HAC is shown as Figs. 2–5.

$C(i) = \sum_{j=lj \neq i}^{n} D(i,j)$ (6)

Table 1

Axis of nodes.

Node ID	1	2	3	4	5	6	7	8	9
x-Axis	1.5	1.7	2.5	3.1	4	4.6	5.6	6.3	6.6
y-Axis	2.1	2.8	6.2	3.3	5.5	4.3	4.7	5	7.2

Table 2

The distance of every pair of nodes.

	2	3	4	5	6	7	8	9
1	0.73	4.22	2.00	4.22	3.80	4.85	5.61	7.21
2		3.49	1.49	3.55	3.26	4.34	5.10	6.59
3			2.96	1.66	2.83	3.44	3.98	4.22
4				2.38	1.80	2.87	3.62	5.24
5					1.34	1.79	2.35	3.11
6						1.08	1.84	3.52
7							0.76	2.69
8								2.22

3.4.2. The procedure of energy aware HAC:

Based on the classical HAC, a new energy aware one is proposed in this section, and the method is mainly improved in which the node's residual energy is taken into account when clustering. And to ensure that the node's residual energy information can be updated in time, a special structure like list named LNC (List of Nodes in Cluster) is designed to save the nodes' information including their location, energy station and neighbor nodes, etc. The detail of LNC will be demonstrated in the next section. Through this method, the distribution of clusters could be dynamically adjusted according to WSNs' energy condition. The procedure of energy aware HAC also can be divided to three steps.

Step 1: Distance calculation. In this method, the nodes' distance would be calculated according to Eq. (7) which is improved from Eq. (2). In Eq. (7), Ea and Eb respectively mean the current energy of node a and node b, and E is the initial energy of sensor node. If all nodes have same current energy, the clustering result would be equal to the result of classical HAC. If the energy value of nodes is as Table 4, the new distance of every pair of nodes would be listed as in Table 5.

$$D'_{ob} = \frac{2B}{B_0 + B_b} \sqrt{(X_0 - X_b)^2 + (Y_0 - Y_b)^2} \quad (7)$$

Through Eq. (7), the distance between a pair of nodes is their Euclidean distance at least when nodes' residual energy equals to their initial value, and with the WSNs operating the distance would be larger and larger when their energy changes lower. Step 2: Primary clustering. In this step, there is only one improvement compared with the classical HAC that when every node acting as CH, a LNC of this cluster would be created. And the LNC would be saved and maintained by CH, and every node's order of in LNC is arranged by the reverse order of its SEPC. Step 3: Merge clusters. The mainly improvement with classical HAC in this step is that the nodes' residual energy would be added when calculation the distance between each pair of clusters, and a new calculation formula based on Eq. (5) is used as Eq. (8).

$$C'(i) = \sum_{j=1 j \neq i}^{m} D'(i,j) \quad (8)$$

Table 3

Distance matrix of second round clustering.

	3	4	5,6	7,8	9
1,2	3.86	1.74	3.71	4.98	6.90
3		2.96	2.24	3.71	4.22
4			2.09	3.24	5.24
5,6				1.76	3.31
7,8					2.46

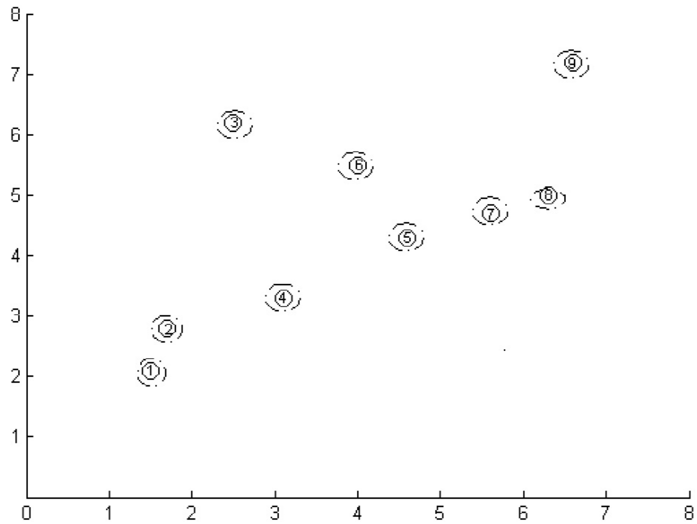


Fig.3. 2. The clusters' member distribution after first round of clustering.

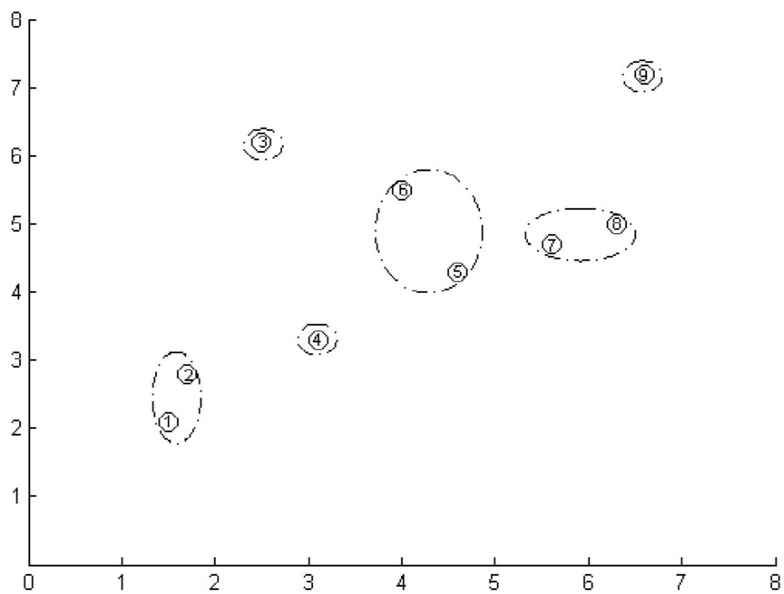


Fig.3.3. The clusters' member distribution after second round of clustering.

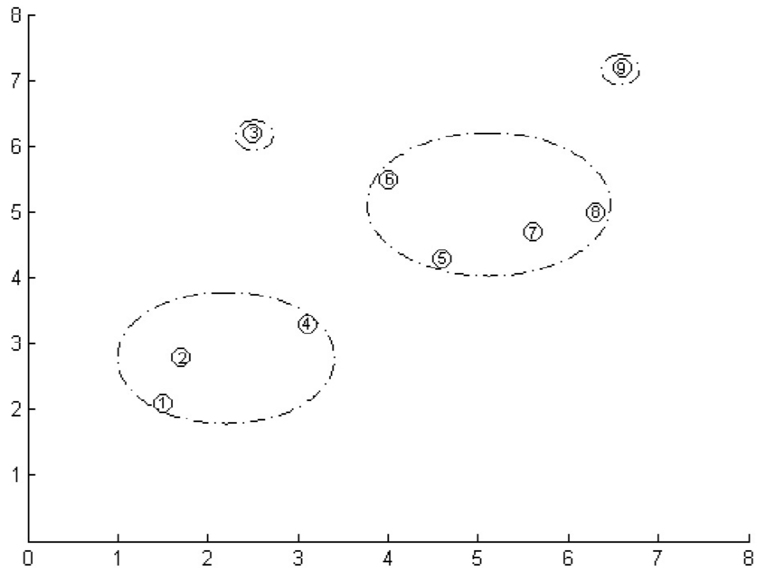


Fig.3.4. The clusters' member distribution after third round of clustering.

If the node's energy is not much different, the result of this method is almost same as HAC. But if there is much difference between nodes' energy as Table 5, the result of clustering would be shown as Fig. 6.

Comparing Fig. 5 with Fig. 6, it can be concluded that the improved HAC method can dynamic adjust the distribution of clusters

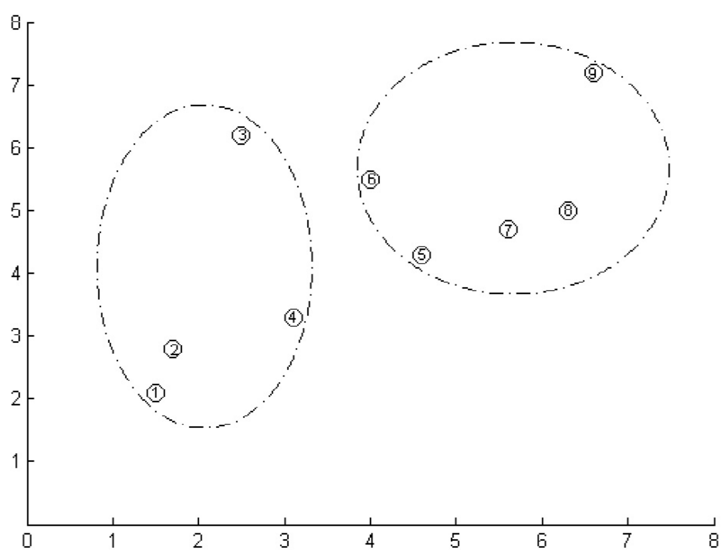


Fig.3.5. The clusters' member distribution after final clustering.

Table 4

Nodes residual energy station.

Node ID	1	2	3	4	5	6	7	8	9
Energy	0.6	1.7	0.8	0.7	0.6	2	0.6	1.5	0.5

Table 5

New distance value of every pair of nodes.

Node	2	3	4	5	6	7	8	9
1	0.63	6.03	3.08	7.03	3.80	8.09	5.34	13.11
2		2.79	1.24	3.08	1.76	3.77	3.19	5.99
3			3.95	2.36	2.02	4.92	3.47	6.49
4				3.66	1.34	4.41	3.29	8.73
5					1.03	2.98	2.24	5.65
6						0.83	1.05	2.82
7							0.73	4.90
8								2.22

according to the nodes' energy condition. And in Fig. 6, the nodes with more energy would like to be in the center of cluster, so that they have more probability to be elected as CH and can undertake more tasks of forwarding message; on the other hand, the nodes with less energy would be located at the outer layer of clusters, and they have less probability to be CH and just need to sense environment. And with the decrease of nodes' energy, if the threshold of merging is not changed, the sociality of clusters would become less, and the number of clusters would increase. So through energy aware HAC, the clusters' architecture is more reasonable, and the ‘‘Energy Hole’’ problem can be partly resolved.

3.5. The DESIGN OF EESSC

The clustering method can reasonably adjust the WSNs nodes deployment according to their residual energy. But in WSNs, all sensor nodes have same initial energy, and the unbalance of nodes' energy would come with WSNs operating. So the capability of dynamically adjusting the distribution of clusters when transmitting message is in demand, and the existing static routing algorithms have not this function. In this section, a semi-static hierarchical routing algorithm would be designed to take advantage of energy aware HAC to improve the energy efficiency of WSNs. The algorithm is consisted of four steps: the first one is to initial the WSNs and all nodes would be activated; secondly, all nodes would be clustered through the method of energy aware HAC, and the LNC of every cluster would be created; thirdly,

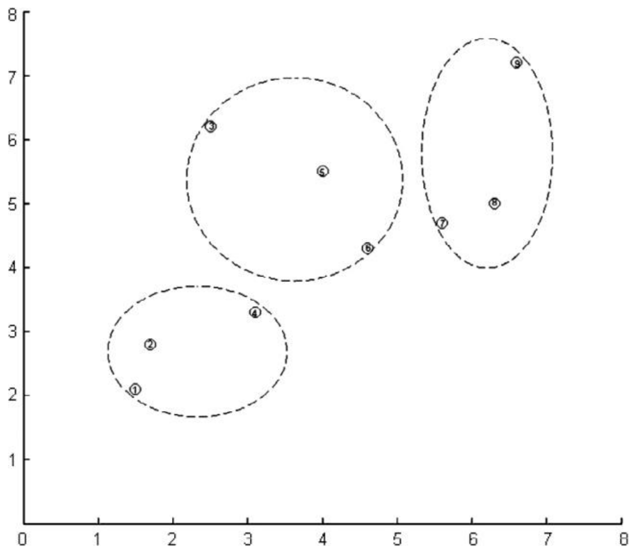


Fig.3.6. New result of clustering by energy aware HAC.

WSNs would begin to work normally and the all CHs in clusters would be rotated by the order of LNC, at the same time of rotation, LNC would be transformed to the next CH; At last, re-clustering would be operated if existing LNC whose all member nodes are not able to act as CH.

3.5.1. The data structure of EESSC

To achieve the target of energy aware clustering, the real-time condition of nodes' energy must be accurately obtained. To realize this function, a special data packet head as Table 6 would be used, and a special list named LNC which stores the cluster's nodes information as Table 7 would be maintained by every CH (an example of LNC is shown as Fig. 7). And other data definitions used in the algorithm would be introduced as following: IDi means a sensor node whose identity is i. DLOCi (Distance List to Other Clusters) means a list storing the distance from cluster whose CH is i to other clusters. PACT means a data packet which is used to activate the WSNs. In PACT, Id means the node which forwarding the packet, PACT.ene means the residual energy of node ID, and PACT.axe means the location of node ID. PCON means the confirmation packet for PACT and its formation is like PACT. PDA means a common data packet and its head including the last forwarding node's residual energy and axis. Clisti means a LNC of cluster whose CH's node is i. C-threshold means the threshold merging clusters. If the there are not any clusters' distance less than C-threshold, the merging operation would be ceased. In-threshold means the standard for a sensor node to be elected as CH. The detail would be introduced in Section 4.4. Out-threshold means the standard for a CH no longer to act as CH. The detail would also be introduced in Section 4.4.

3.5.2. Activate WSNs and initial clustering

After all nodes have been deployed, WSNs should start to work, and the procedure is that the sink node would send a special order packet PACT to all sensor nodes to activate them. In EESSC, the activating packet would be sent and forwarded by the means of directly diffusion, and every node would modify the setting of PACT with its own information when it forwards PACT to its neighbor nodes. Node which receives PACT would access the packet head and obtain the energy and location information of the node which forwarding this packet to it, then update the packet head with its own information and forward the packet to its neighbor nodes. At the same time, a series of operations would be executed by every node receiving PACT as: node would claim itself as CH; a LNC of this cluster would be created by CH; its DLOC would be updated; and a confirmation packet would be sent to the original node as a feedback. The structure of LNC has been introduced in Section 4.1 and DLOC is a list which stores the distance from the current cluster to its neighbor clusters (an example is shown as Fig. 8). The pseudo source code of this procedure as follow:

Procedure activation

1 PACT.ID=SN; PACT.axe=SN.axe; PACT.ene=infinity;

//Set the initial information of PACT

2 SN sends the PACT to the one-hop neighbor nodes;

3 The nodes receive the PACT;

4 Clisti.head=IDi;

//set itself as CH, and create LNC;

5 If PACT.ID not in DLOCi

//if the node i has not the distance information to last node

6 If PACT.ID!=SN

//and the packet is not directly sent from SN

7 ID joins the DLOCi and the value of the item is

computed as Eq. (6) and procedure as Fig. 8;

8 Send the PCON to the source;

9 End if

10 Updating PACT;

// the information of node i would be written in PACT;

11 Forward the PACT to the one-hop neighbor nodes;

12 Else if PACT.ene < the one in DLOCi

13 Updating DLOCi;

//ensure the information in DLOCi is acute;

. . .

14 Receive the PCON;

// receive the PCON to ensure that the DLOCi is

completely

15 If Pcon.ID not in DLOCi

16 ID join the DLOCi and the value of the item is computed as

Eq. (6);

17 End if

18 Goto procedure merge clusters;

19 End procedure

3.5.3. Merge clusters

After all nodes have been activated, the initial clusters have been generated, and every cluster has also calculated and stored an initial DLOC. And then the phase of merging clusters should be executed. In this phase, there are three main operations to be executed: firstly, every cluster should browse its DLOC to find the nearest cluster whose distance to it is less than C-threshold to be merged; then two clusters would be merged should execute a serried of operations as: combining their LNC and DLOC; electing the CH of new cluster. Combining clusters' LNC and

DLOC are the most important operations in this phase. When combining two clusters' LNC, all nodes' SEPC should be re-computed, and the order of nodes in new LNC must be arranged by the reverse order of SEPC. And when combining two clusters' DLOC, ones would be

Table 6
The structure of packet head.

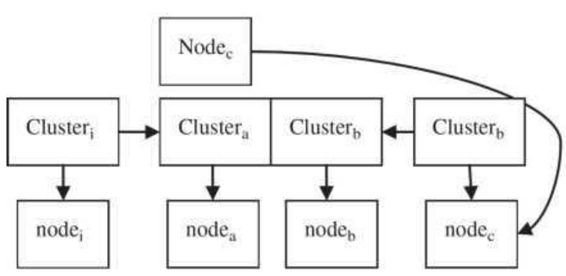
ID	ID of the node which sends this packet
Pkt-typ	Packet type (ACT/CON/DATA)
Ene	The energy of node ID
Axis	The axis of node ID

Table 7
The structure of LNC.

ID	ID of this cluster's CH
L-Next	The next node which LNC would be sent to
Ene	The node's residual energy
SEPC	The node's SEPC
Axis	The node's axis

CHi	$node_x$	$node_y$	$node_z$	…………… ………..	$node_m$

Fig. 7. An example of LNC whose CH is node i.



added to other ones' end, and merge the same item, then re-compute the values. The detail of combining LNC is shown in Fig. 9 and the detail of combining DLOC is shown in Fig. 10. The CH of new cluster is the first node of LNC. The pseudo source code of merging cluster as follow:

```
Procedure merge clusters
1 For every cluster
2 Browse the DLOCi;
3 If exist the Cdis<C-threshold
// assumed the cluster is j in DLOCi;
4 If i < j
5 Browse Clistj
6 for every node in Clistj
7 add the node to the end of Clisti;
8 end browse Clistj
9 compute the distance between every
node in Clisti;
10 re-arrange the Clisti;
//Combine the two LNC as Fig. 9
11 send the Clisti to the first node in
new list;
12 delete Clisti and Clistj;
13 browse DLOCi;
//combine DLOC of i and j, as Fig. 10
14 for every item in DLOCi;
15 add the item to the end of
DLOCj;
16 updating DLOCi;// for every item,
re-computing by Eq. (6)
17 delete DLOCj;
18 return to Browse the other clusters;
End procedure
```

3.5.4. CH rotation and re-clustering

When all CHs cannot find any other clusters' distance less than C-threshold in their DLOC, the clustering phase would be finished and WSNs would come into sensing and transmitting phase. In this phase, EESSC should realize the functions as maintaining steady and efficient route from source node to sink node, reasonable rotating CH automatically, and re-clustering if necessary. In the procedure of message transmitting, CH would collect sensed data packet from its member nodes, and at the same time, the energy information of its member nodes would be obtained from these packets' head. Then the LNC and DLOC stored in this CH would be updated by this information. And CH would calculate the energy consumption in the whole procedure and update the CH information itself. If the energy condition of current CH becomes so low that it cannot act as CH, it would browse LNC and find the nearest node to current CH whose energy condition is high enough to act as CH, then DLOC and LNC would be sent to this node. The new CH would send to every member node the notice that CH has rotated. The procedure of CH-rotation would be shown in Fig. 11.

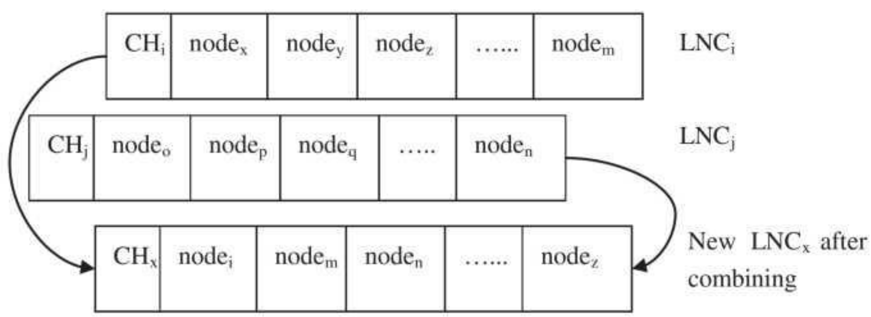


Fig. 9. The illustration of combining LNC.

In the procedure of CH rotation, if there is a node with energy that just a little more than the threshold to act as CH, and it has been elected as CH, its energy is too little to act as CH for a long time, and a new CH must be elected. This phenomenon is called thrilling, and it will reduce the networks performance. To avoid this problem, two different thresholds are applied to decide the CH rotation: the bigger one named in-threshold is used to judge if the member node can act as CH, and the smaller one named out-threshold is used to judge if the current CH can go on acting as CH. The in-threshold is designed as Eq. (9) and out-threshold is designed as Eq. (10).

In these equations, c means a constant acting as adjustment coefficient and E means the average residual energy of nodes in cluster.

$T_{in} = (1 + c) \times \overline{B}$ (9)

$T_{out} = (1 - c) \times \overline{B}$ (10)

When the current CH's energy is less than out-threshold, LNC would be browsed to find the node which has more energy than in-threshold. If existing one LNC has not a node to act as CH, the current CH would send a packet to SN to execute the procedure of re-clustering. In this algorithm, procedure activation would be executed as re-clustering. The pseudo source code of data transmitting as follows:

Procedure data transmitting and CH-rotation

1 The cluster head CHj receives the packet; //maybe from its member or from other CH

2 If PDA from its cluster member Node IDi

3 X= Clisti.Node[j].ene/PDA.ene; //Calculation the ratio of node current energy with the value stored in CH.

4 Clisti.Node[j].dsum= X_(Clisti.Node[j].dsum); //Use the ratio to update the node's information in LNC.

5 Browse the Clisti;

6 If node j in Clisti.Node[k].list

7 Clisti.Node[k].list.node[j].dm<-
X_(Clisti.Node[k].list.node[j].dm) //update other nodes' information in LNC.

8 Updating Clisti.Node[k].dsum;

9 End if at 6

10 Clisti.Node[j].ene<- PDA.ene; //Set new energy of the node in LNC

11 End if at 2

12 CHj forward to next hop or to BN;

13 Update the Clisti.head as former;

14 Browse Clisti // calculate average energy of all members

15 E=E+ Clisti.Node[k].ene;

16 end Browse and calculate Tin and Tout

17 If Clisti.head.ene < Tout //Judging the CH rotation if should be executed

```
Find the next node k in Clisti;
If Clisti.Node[k].ene> Tin
Clisti.head<-k; //automatically rotate CH
Update the Clisti to Clistk;
Send Clistk to new Cluster head k;
Delete Clisti;
Else keep finding the next node in Clisti;
If all nodes in Clisti has been browsed// no node can act as CH.
Send a re-cluster demand to SN;
Goto Procedure Activation;// to re-cluster the WSNs.
End Procedure
```

3.6 PROBLEM STATEMENT

In this presentation work we have focused on the problem which are faced during the equal the partition of the cluster nodes under specific cluster. In the conventional WSN protocols the clustering mechanism start with random selection of nodes and cluster are made just on the bases of neighbor node distance to cluster head. Hence the main problem in such type of clustering mechanism is that they only consider the nodes distance to cluster head.

And other parameter like residual nodes energy, average cluster energy, distance to sink are not figure out. Hence by during weight age to other parameter which impact the life time. The performance of WSN can be increased.

CHAPTER 4

RESULTS AND DISCUSSIONS

In existing researches, there are two standards to calculate the WSNs' lifetime: the first, if there is just one node dead, the WSNs should be seemed failure; the other, if there are over a ratio (mostly, 30%) sensor nodes dead, the WSNs should be seemed failure. The both two standards are applied in the proposed algorithm. And to overall and exactly estimate different algorithms, there are three kinds of simulation for all algorithms: the lifetime's variability with the number of sensor nodes increase; the lifetime's variability with the change of sink node's location; and the lifetime's variability with the increase of sensor nodes initial energy. The results of simulations are respectively shown in Figures. On the condition that sensor nodes have the stable initial energy (0.5 J), and the sink node is just located in the different spot of area, the simulation results are shown. The conclusion is draw from Figures that the lifetime of proposed fuzzy embedded clustering algorithm is better than the best one results of base paper. And from the curves of all algorithms, fuzzy embedded clustering has increasing advantage with nodes increasing, which proves that it would be fittest for the environment of all on the condition of 100% nodes alive.

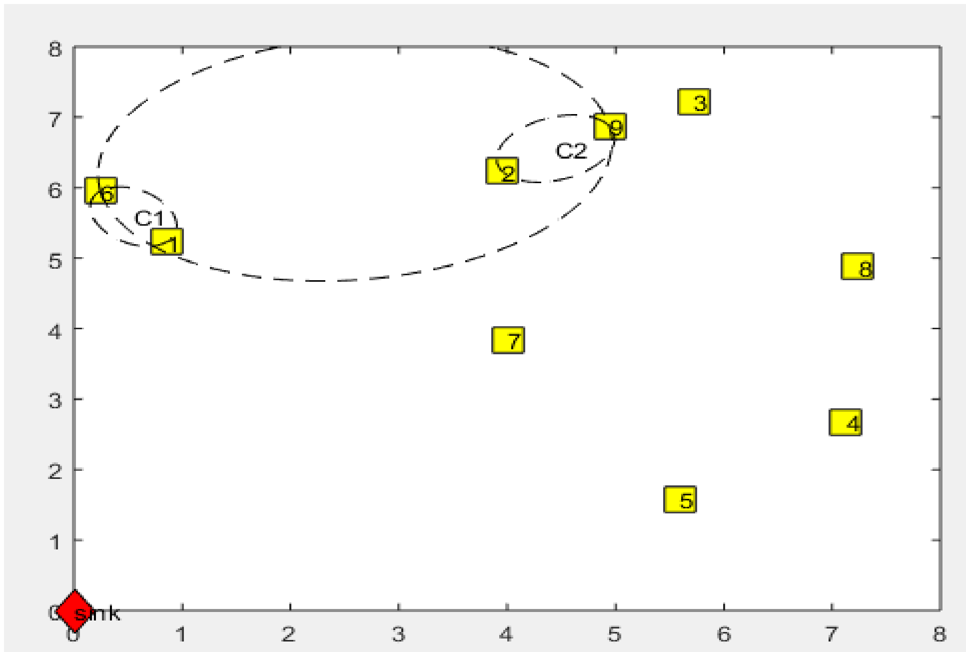


Figure 4.1 a: Developed WSN with clustering at first round and sink at origin.

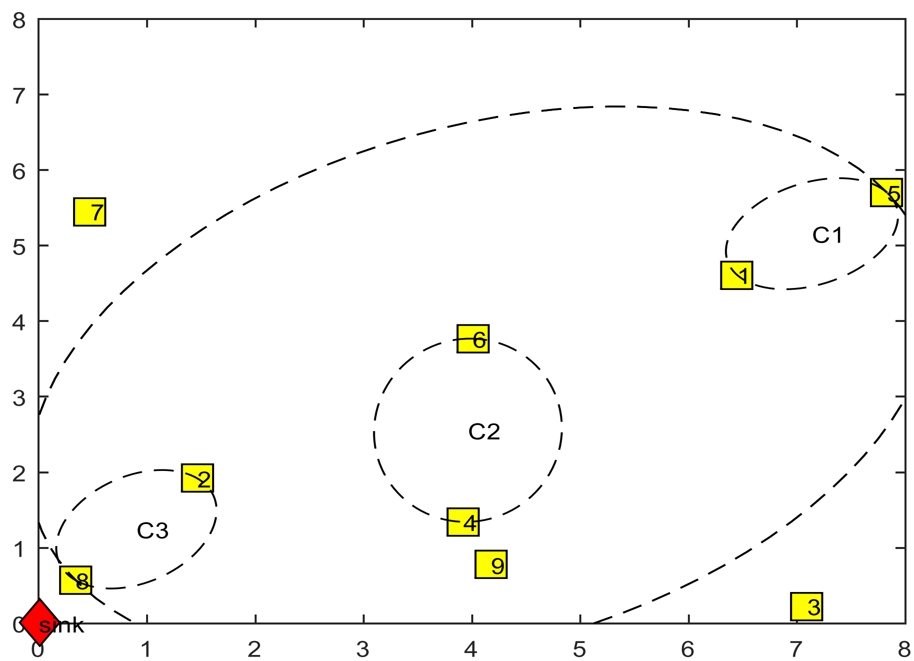


Figure 4.1 b: Developed WSN with clustering at second round and sink at origin.

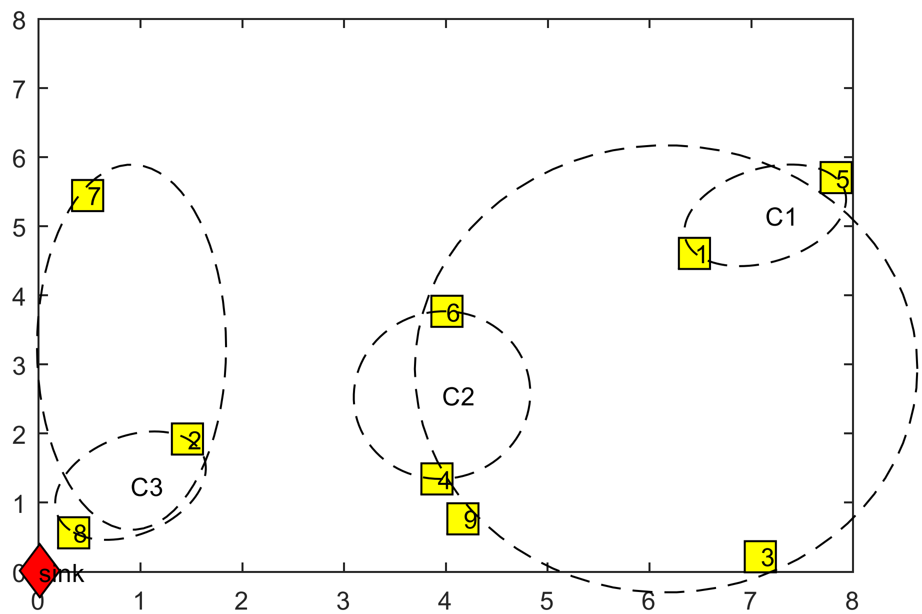


Figure 4.1c: Developed WSN with clustering at third round and sink at origin.

In figure 4.1 c the nodes are shown with second round of clustering. The cluster nodes pair are shown by the ellipse. It can be observed that some nodes are still left and to incorporate them fuzzy logic algorithm will be applied.

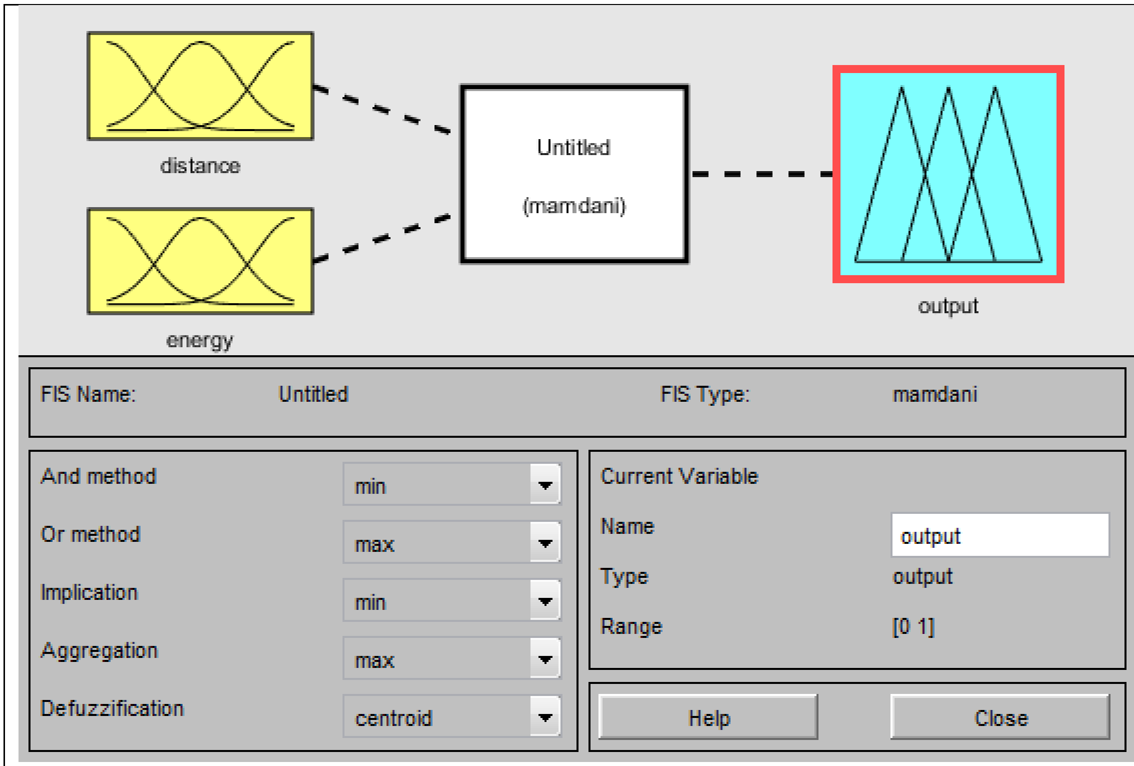


Figure 4.2 a:Fuzzuy logic model input variable

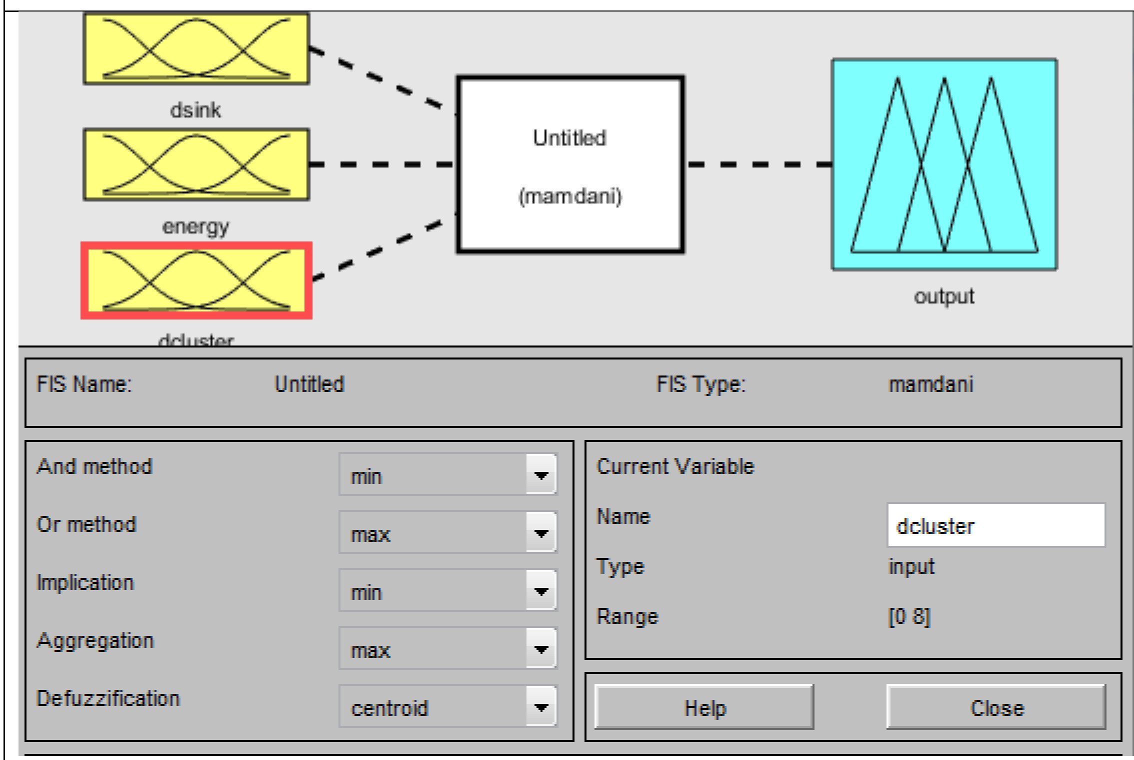


Figure 4.2 b : 3 input and output model development.

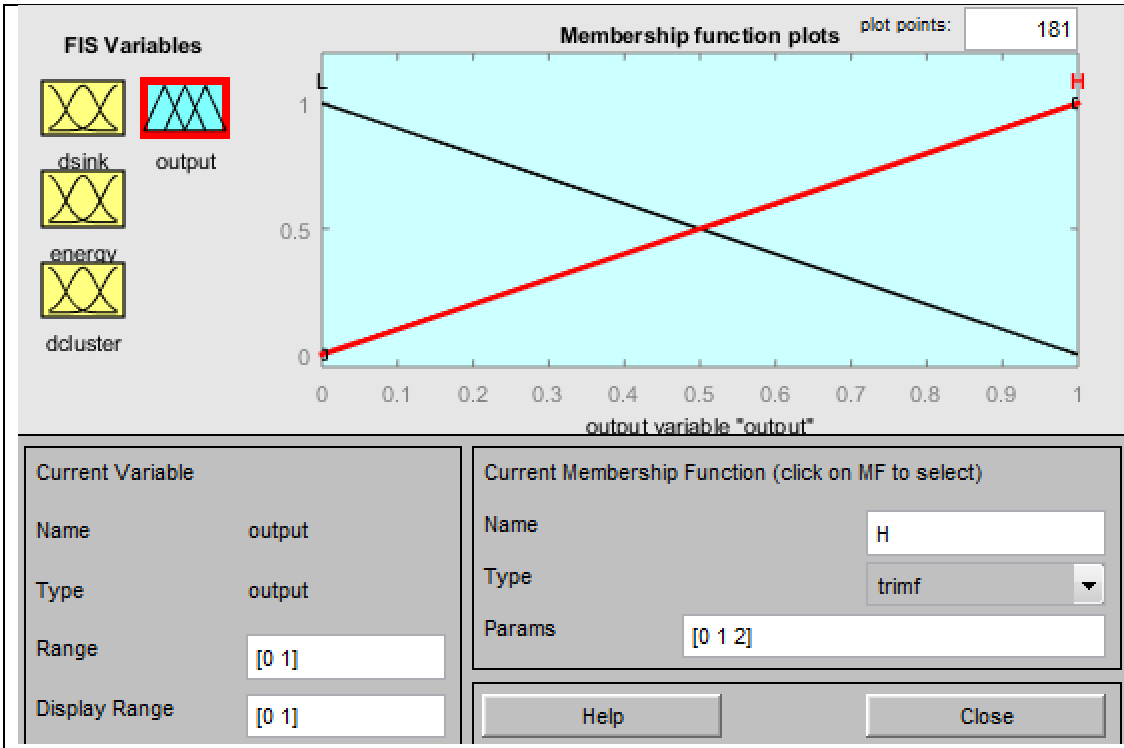


Figure 4.2 c: Membership function for all the input and output variables.

The required fuzzy logic model will take dsink, energy and dcluster as the input. dsink is the distance of nodes to the sink, energy is the cluster nodes energy and dcluster the energy of remaining nodes to the clusters centre. The algorithm of fuzzy rules will decide whether the remaining nodes should be incorporated with nearest cluster or direct send to the sink based on these three input.

Figure 4.4 shows the fuzzy logic rule base editor system. In this editor rules are uploaded for input dsink, energy and dcluster. The three inputs are partitioned in low medium and high membership functions and output probability is low or high.

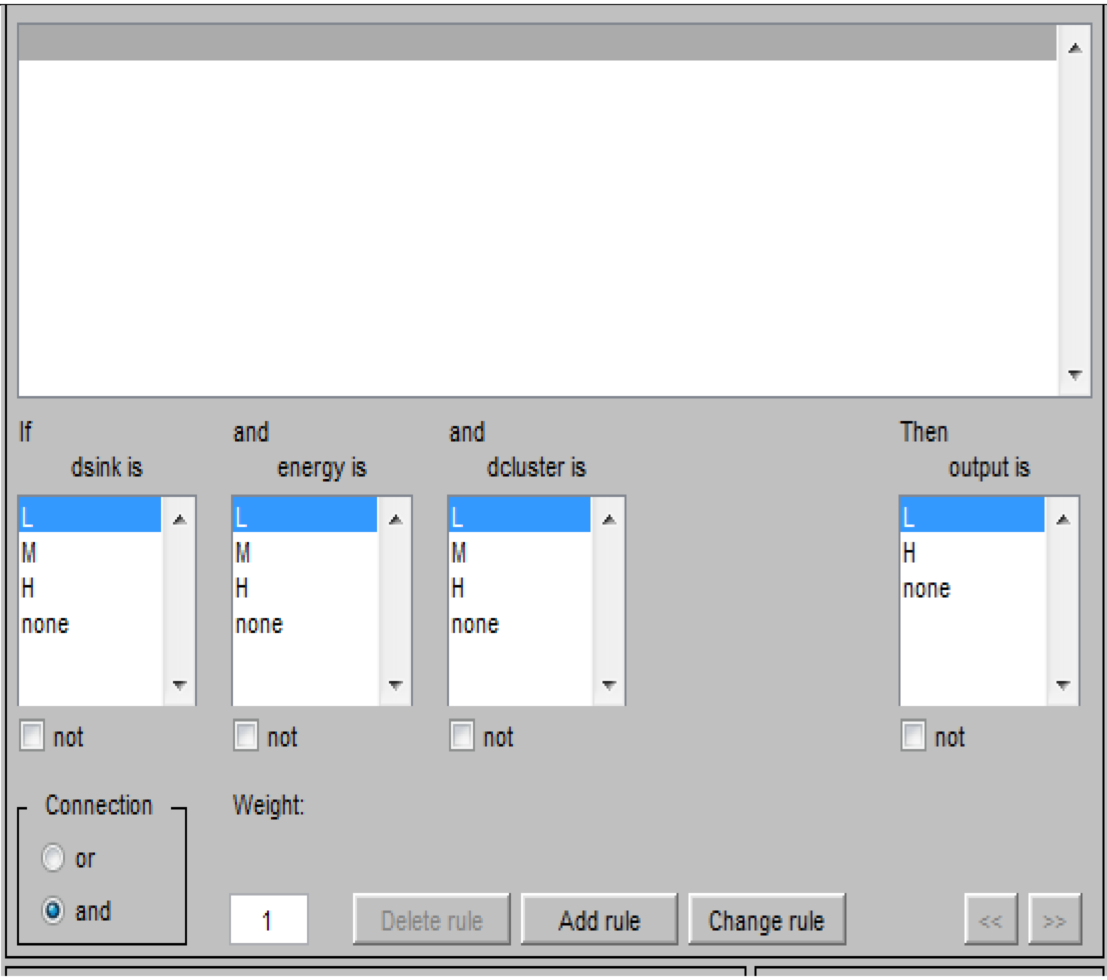


Figure 4.3: rule base development

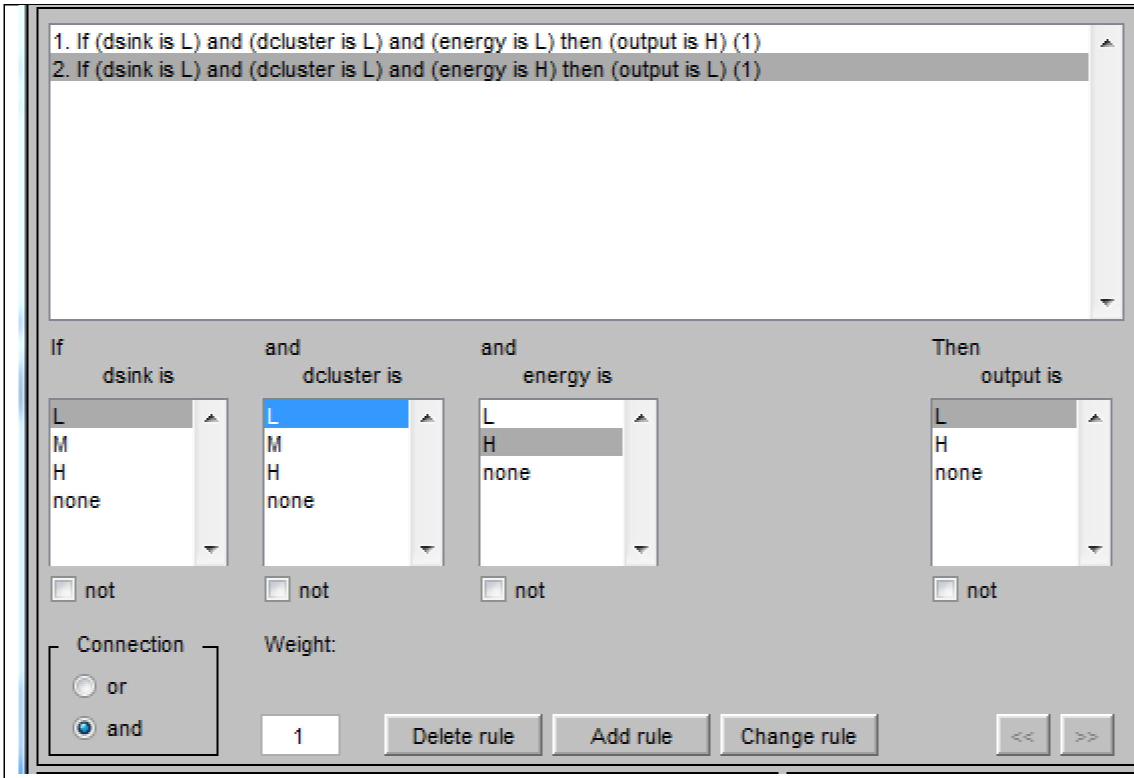


Figure 4.4:Rule at different fuzzy values

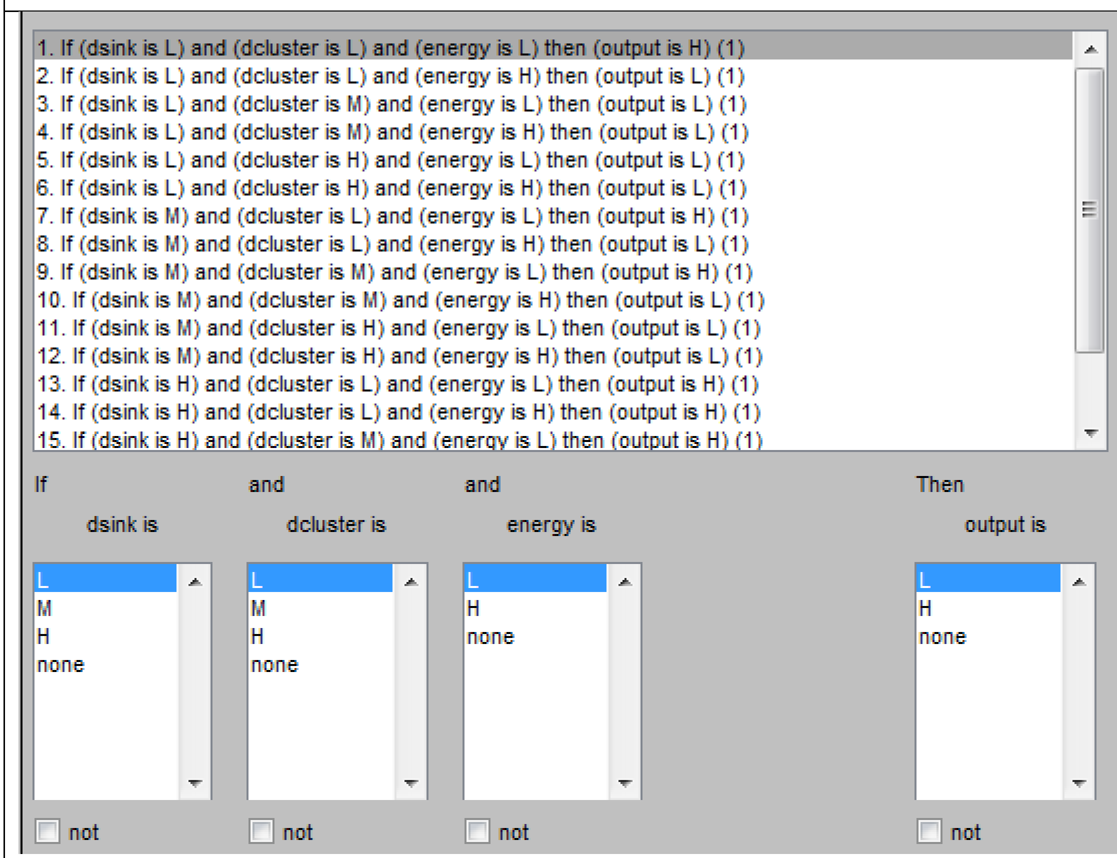


Figure 4.5:All the fuzzy rule sets

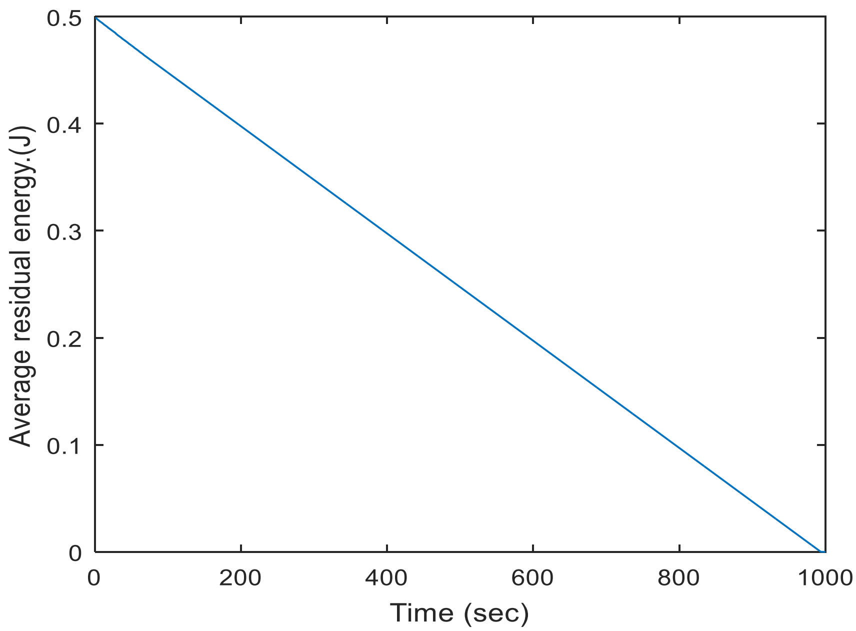


Figure 4.6: WSN energy at sink at origin.

Figure 4.6 shows the residual energy of the proposed work and the response observed in terms of time in seconds on x axis and average residual energy in joules. It's about 1000sec are consumed as network lifetime to reach to zero value of average residual energy.

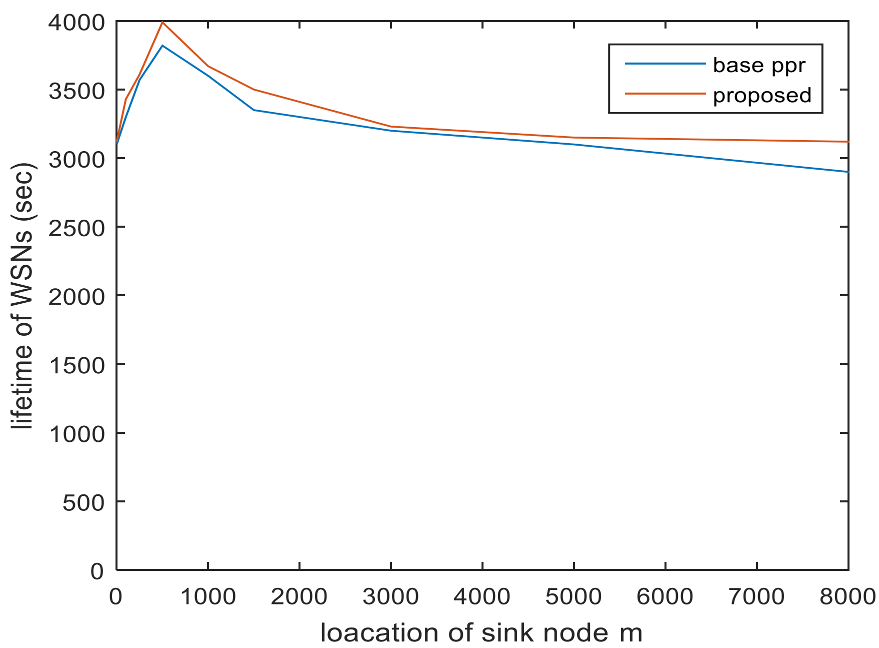


Figure 4.7: WSN lifetime at sink at different position.

Figure 4.7 shows the plot of lifetime of WSN with respect to different position of the sink node.The sink node position is varied from origin to 8000 m.It is observed that the life time increases as the node moves toward network centre then as it goes away from centre the lifetime reduce then its decreases but with very small rate.The proposed work of fuzzy based clustering gives higher lifetime as compared to non fuzzy approach.

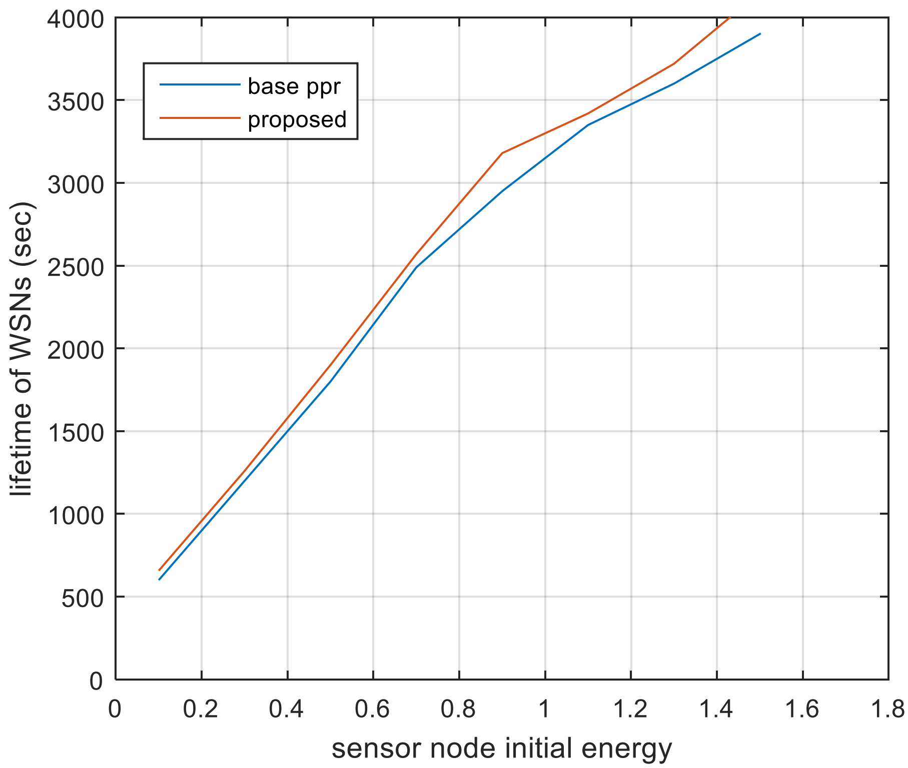


Figure 4.8: WSN lifetime at at different node initial energy.

Figure 4.8 shows the plot of lifetime of WSN with respect to different value of the initial node energy.The node initial energy is varied from 0.1 to 1.8J.It is observed that the life time increases as the initial node energy increases with sink at network centre then as it goes higher the lifetime increase has slighter small rate of increase.The proposed work of fuzzy based clustering gives higher lifetime as compared to non fuzzy approach.

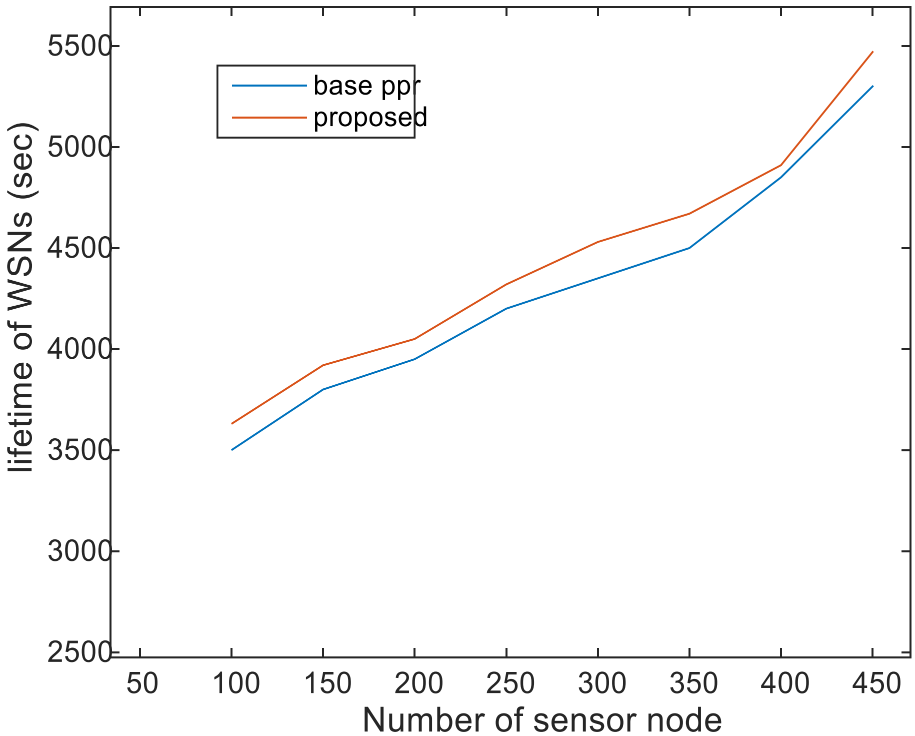


Figure 4.9 : Lifetime of WSN (sec) wrt number of sensor node

Figure 4.9 shows the plot of lifetime of WSN with respect to different number of the node.The number of the node is varied from 50 to 450.It is observed that the life time increases as the number of the node moves toward 450 for the same network centre as sink.The proposed work of fuzzy based clustering gives higher lifetime as compared to non fuzzy approach.

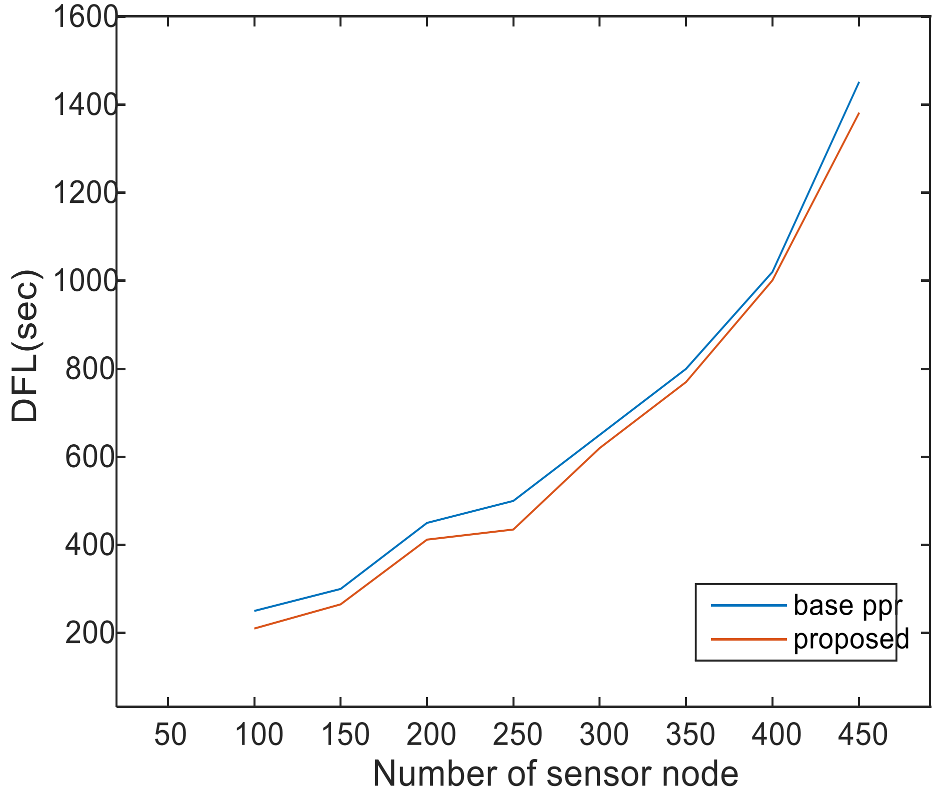


Figure 4.10 : DFL (sec) wrt number of sensor nodes.

Figure 4.0 shows the plot of DFL(sec) of WSN with respect to different number of the node.The number of the node is varied from 50 to 450.It is observed that the DFL increases as the number of the node moves toward 450 for the same network centre as sink.The proposed work of fuzzy based clustering gives lower DFL as compared to non fuzzy approach.

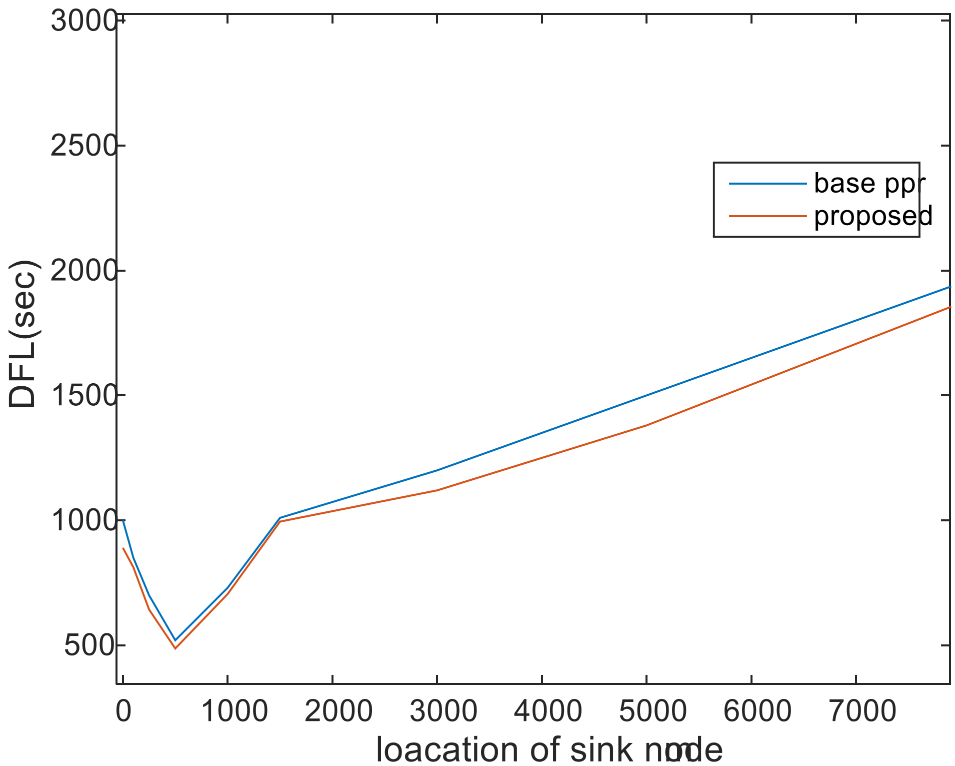


Figure 4.1 1: DFL (sec) wrt location of sink nodes.

Figure 4.11 shows the plot of DFL of WSN with respect to different position of the sink node.The sink node position is varied from origin to 8000 m.It is observed that the DFL decreases as the sink node moves toward network centre then as it goes away from centre the DFL increases then its further increases but with very small rate.The proposed work of fuzzy based clustering gives lower DFL as compared to non fuzzy approach.

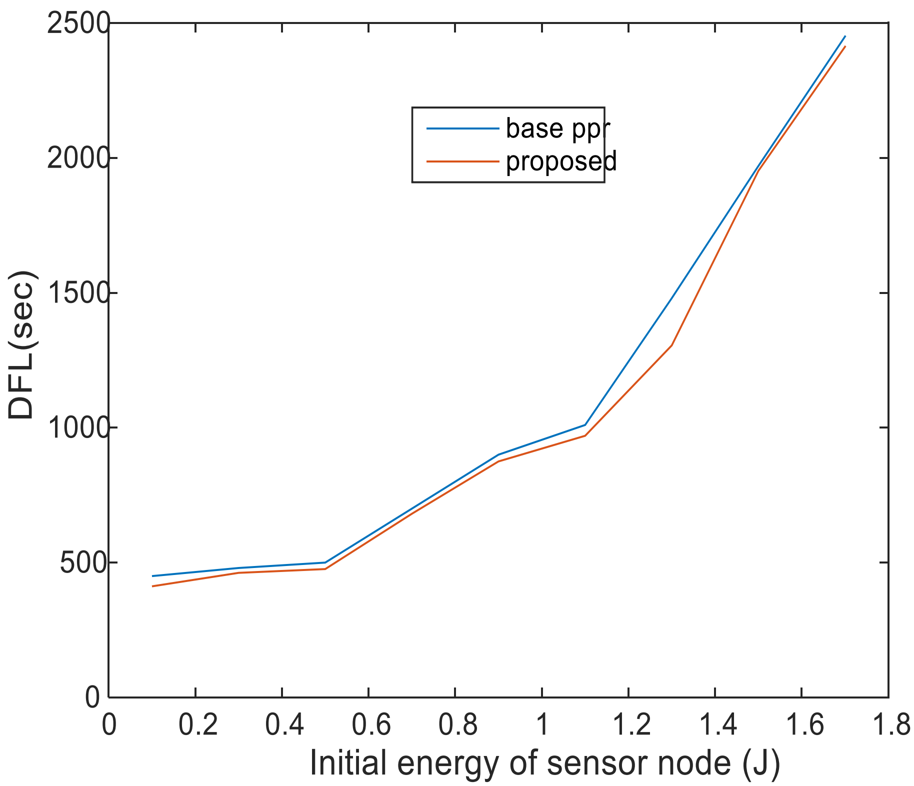


Figure 4.12 : DFL (sec) wrt initial energy of sensor nodes.

Figure 4.12 shows the plot of DFL of WSN with respect to different value of the initial node energy.The node initial energy is varied from 0.1 to 1.8J.It is observed that the DFL increases as the initial node energy increases with sink at network centre then as it goes higher the DFL increase has slighter high rate of increase.The proposed work of fuzzy based clustering gives lower DFL as compared to non fuzzy approach.

CHAPTER 5

CONCLUSION AND FUTURE SCOPES

To improve the performance of WSN, raising the sensor nodes's energy efficiency is one of the most important methods. ‘‘Hot Spot’’ and ‘‘Energy Hole’’ are two main problems to be resolved to improve energy efficiency, and many hierarchical routing algorithms have been designed to attain this goal. In this paper, after analyzing the mainly existing algorithms, a new energy aware hierarchical routing algorithm based on fuzzy logic is proposed. There are four innovations about this algorithm as: firstly, a new energy aware clustering method based on node energy and position based clustering is designed to make the cluster of sensor nodes more reasonable; secondly, a special kind of list storing cluster member nodes is defined to rotate CH automatically; thirdly, a special packet head is designed to dynamically update the nodes's residual energy information when transmitting message; at last, one kind of re-clustering mechanism is designed to optimize the clusters' distribution. A typical hierarchical routing algorithms are simulated with fuzzy embedded clustering by Matlab. Through the comparison, it can be concluded that proposed algorithm has advance in energy efficiency of all algorithms, and resolves the problems of ‘‘Hot Spot’’ and ‘‘Energy Hole’’.

In future the advanced approach can adopts the thought that sink node is answer to choose CHs by collecting all sensor nodes' information. This method will have advantage that the CHs would be well chosen and the global energy balance would be well controlled; thus the restriction restriction that all nodes in WSNs must be able to communicate with sink node directly, and this restriction would lead that the nodes faraway from sink node consume much more energy than the ones near the sink node, and it will restrict the scale of WSNs. The sensor nodes's residual energy may also be taken into account when CH is being chosen, and there would be two candidate CHs in every cluster. Every candidate CH would send inviting message to other nodes to campaign for CH, and other nodes in cluster would elect the final CH according to the signal's strength it received. It can dynamic adjust CHs' deployment based on the nodes' residual energy and it would consume much lower energy. Energy at the choosing CH phase which would shorten the lifetime of WSNs. In future work we can add on two thresholds including a hard threshold and a soft threshold to reduce the number of sending message and to conserve nodes energy or to send information in time would be balanced in this algorithm. But the value of threshold is difficult to be set, and this algorithm would lead to the network congestion. Another typical hierarchical algorithm with thought that is also origined with the communication cost May be taken into account during clustering.

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