CLUSTER HEAD ELECTION MECHANISM-BASED ON FUZZY LOGIC (CHEF) WITH TDMA IN WSN

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Submitted: May 27, 2017 ***Accepted: June 15, 2017*** ***Published: Sep 1, 2017***

Abstract- ***Wireless sensor networks (WSN) are being used for huge range of applications where the traditional infrastructure based network is mostly infeasible. The most challenging aspect of WSN is that they are energy resource-constrained and that energy cannot be replenish. the wireless sensor network of power limited sensing devices called sensor deployed in a region to sense various types physical information from the environment, when these sensors sense and transmit data to other sensors present in the network, even the cluster head is elected according to check their residual energy considerable amount of energy will drain automatically to overcome this drawback by considering the protocol a fuzzy logic approach is used to elect the cluster head based on three descriptors-energy, centrality & distance and second CH is elected according to TDMA to overcome the data lost during energy drain occur in the CH .NS-2 simulation shows that proposed protocol provides higher energy efficiency. This paper proposes the mechanism or device is capable of utilizing its own system of control simply called as self-configurable clustering mechanism to detect the disordered CHs and replace them with other nodes. And results have been derived from simulator ns-2 to show the better performance.***

Index terms: WSN; CH; fuzzy logic;TDMA; NS-2 simulator; base station.

I. INTRODUCTION

A wireless sensor network (WSN) consists of sensor nodes capable of collecting information from the environment and communicating with each other via wireless transceivers. The collected data will be delivered to one or more sinks, generally via multi-hop communication.

In all data transmission process, the user wants data will be transmitted from transmitter to receiver with full efficiency without loss of any information. In general transmission and reception process precedes the message to base station by the distributed sensor network nodes; probability of direct communication may not be possible i.e. from every node to base station. **B**ecause, during the direct communication all information transmits from nodes to base station at a time, so traffic may occurs.

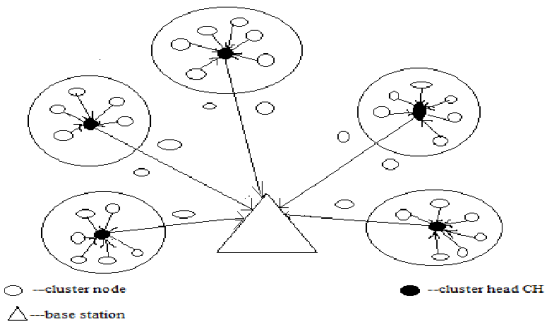
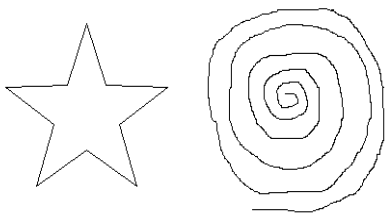


fig.1. GENERAL SYSTEM MODEL FOR CLUSTERED WSN

It leads to data lost .indirect transmission may taken into account. Clustering methods in WSN lead the sensor nodes to be organized into small disjoint groups, where each cluster has a coordinator referred as cluster head CH [9] as shown in fig.1. To choose a node as a CH in the cluster group, it is necessary to check the eligibility. That is calculated based on local information of every node in the cluster group such as its residual energy. There is another limitations arises in the CH transmission.



Paths taken by base station

CH drains its energy due to collect and transfer data. However, there is possibility that the CHs may drop and function incorrectly due to a number of reasons such as power

instability. During the failure, the CHs are unable to receive and transfer data correctly. This affects the performance of the WSN.

LEACH has been developed based on a clustering mechanism to select CHs using optimal probability. The protocol works on periodic randomized rotations of the CH within the cluster range between zero and one. If the random number is less than the pre-determined threshold value, the node becomes a CH for the current round. The authors have succeeded to achieve a reduction in energy dissipation compared to direct communication and transmission protocols. In the proposed protocol an improvement has been suggested over self configurable mechanism, which results in better election of the cluster head (CH). The ultimate goal of this paper is to provide high energy efficient life time management system for WSN. The rest of the paper is organized as follows: Section 2 delineate the review of the related work in the field of wireless sensor clustering protocol. Section 3 will itemize the energy model that has been used in the proposed protocol. Section 4 sketches the proposed protocol cluster- head election mechanism using fuzzy logic (CHEF) and its phases. Section 5 has simulation results and the comparison of the suggested protocol with the existing LEACH and proposed CHEF protocol. Finally, section 6 illustrates the conclusion and the future works for further improvement.

II. Related work

During the past research, some considerable research efforts have been investigated in developing cluster mechanism for deployed sensor nodes in WSN. In this section, a few well known hierarchical protocols are discussed where the cluster heads are elected in efficient manner. We focussed on some fuzzy based clustering scheme protocols. Each cluster head is representative for the cluster group for transmitting and receiving messages to base station either directly or indirectly. Some of the protocols are presented here

A. Hierarchical clustering protocol based on routing

1) LEACH (Low energy adoptive clustering hierarchy):

LEACH [3] [4] is a routing protocol which elects CH based on probabilistic and each node is equal to become CH this will operates in two equal parts there are, set up phase and steady phase. Nodes form the cluster in set up phase and original data transmitted in steady phase. Each node chooses a random number [0, 1] to become a CH, The node gets a chance to CH for the current node by when number is less than T (n) threshold value. The threshold value T (n) is defined in equation (1).

$$t(n) = \begin{cases} \dfrac{P}{1-p^{*}\ (r \bmod \frac{1}{p})} & , \text{if } n \in G \\ 0 & ,\text{otherwise} \end{cases} \quad \text{.....2.1}$$

r is round which already ended P is Probability of node to be CH. G is set of node which newer has CH I last l/p rounds.

These are:

1. There is no guaranty in this protocol a number of CH is elected in each round.
2. LEACH uses probabilistic model to decide CH in this case there is a possibility of two Cluster Head are elected which is close to each other, it may deplete the energy of whole network.
3. If the elected node is locate near the network boundary other nodes to despite no energy transfer the message to CH.
4. In each round more CPU cycles are consumed because in each round one random number is generated ad threshold value is calculated.

2) **LEACH-C**: In LEACH-C [4] CH is elected by the BS using a centralized algorithm.BS knows the location of information and energy of each node. So, it can produce better clusters by dispersing Cluster Head nodes throughout the network. The main drawback of this centralized protocol is that the position of all nodes must be known of all the nodes must be known. In [3]-[8], many clustering protocols have been discussed. As we are interested on fuzzy logic based clustering protocols, few of them are highlighted below.

B.Fuzzy logic based clustering protocol

Many researches are come up with different protocols for how fuzzy logic (FL) is employ in utilized manner to elect the Cluster head so, increase the number of packets send and receive and substantial life time will be accomplished. Some of the well known fuzzy logic (FL) based algorithms are discussed below,

[7]GCHE-FL: CH election using Fuzzy logic in heterogeneous WSN (GCHE-FL) [7] is a developed protocol. That uses two evaluate the chance of sensors to become a gateway and CH. In the first election (gateway election), the qualified nodes are selected based on their energy and distance to base station. Then in second election (CH election) residual energy of each node and

cluster distance are used. Cluster distance is sum of the distance among the cluster member simulation results. Shows that the proposed approach enhance the energy efficiency in the network.

All the proposed approaches to some extend increase the energy efficiency in WSN. In those approaches they didn't take the CH failure into the account. The main drawbacks of the existing mechanisms in the sensor node didn't noticing the current status of the nodes whether they are capable receiving the information are not. Traffic problems are not fully addressed in the existing approaches. While considering the F-MCHEL: In F-MCHEL [6] CH is elected by applying fuzzy rules based on energy and proximity of distance. The node which as the maximum residual energy among the cluster head is elected as the Master Cluster Head (MCH) and sends the aggregated data to the base station. F-MCHEL[6] is an improvement of heterogeneous protocol. It provides more network stability as compared to LEACH and GCHE. In F-MCHEL, base station has been considered as static. In [5][8][10] many protocols have been discussed based on fuzzy techniques. In [8], we proposed a protocols which considered three fuzzy parameters such as remaining battery power, mobility, and distance to base station to elect a SCH, but the major drawback of this protocol is that when mobility increase or decreases. The lifetime of the network remains constant. Because, mobility indirectly proportional to the distance to base station. To overcome this problem by centrality has been considered as the third input parameter for the fuzzy module in this protocol. From the simulation results it is believed that the proposed protocol is stable and would be applicable in large scale or WSN application.

The performance is negatively influenced by dynamic errors for the implemented signal processing in the insufficient or noisy data in many real world applications. Therefore it is vital for WSN to be capable to cope with uncertainty related to the network. The data in the process is realistically less complexity and computation effect. This will reduced by using the fuzzy based logic system is flexible to minimize the failure and better capability to cope with uncertainty of data compare to many techniques includes statistical and covariance intersection.

III. ENERGY MODEL

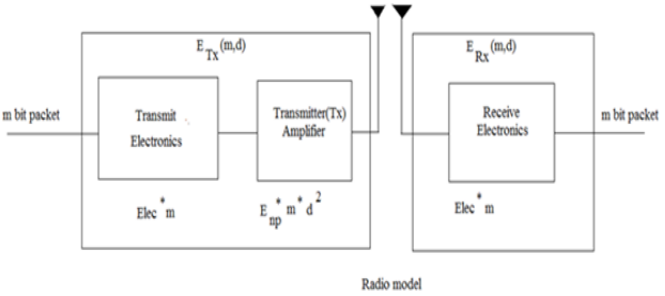


fig.3.1 energy radio model

Fig.3.1 shows the radio model which has been reffered from [6].

$$E_{Tr}(m,d) = E_{Tr}\text{-elect}(m) + E_{Tr}\text{-amp}(m,d)$$

$$\begin{cases} m*E_{elect} + m*E_{fs}*d^2 & \text{if } d<d_0; \\ m*E_{elec} + m*E_{mp}*d^4 & \text{if } d\geq d_0; \end{cases} \quad \text{.....(4.1)}$$

$$E_{Rr}(m) = E_{elect}*m \quad \text{.....(4.2)}$$

$$d_0 = \sqrt{E_{fs} / E_{mp}} \quad \text{.....(4.3)}$$

The amount of energy consumed from the transmitted or the receiver circuit. It depends on the factor like digital coding, modulation filtering and spreading of the signal .

Eelect represents the energy dissipated per bit to run the transmitter or receiver circuit. Receiver is less than the threshold value do, the free space model (d2 power loss) is used. Power control can be used to invert this loss by approriately adjusting the power amplifier. The equation (4.2) shows the amount of energy consumption to receive m bit of data while(4.3) represent the threshold value which is the ratio E_{fs} & E_{mp}.

E_{fs} & E_{mp} are the characteristics of transmitter amplifier where E_{fs} is used for free space and E_{mp} for multipath.

Apart from energy consumption, we analyse data loss ratio (DLR) of our proposed approach.DLR is a ratio of the difference of total data sent by the sensor nodes.DLR is calculated using (4.4)

$$DLR = \frac{\text{Total data sent a total data received}}{\text{Total data sent}} \quad \text{.....(4.4)}$$

Finally, the traffic overhead of the proposed protocol is also analyzed. To evaluate the traffic overhead of the distributed approach is WSN, the average amount of traffic transmitted within the network is tested.

IV. PROPOSED PROTOCOL

A. Self –Configurable Clustering (SCC)

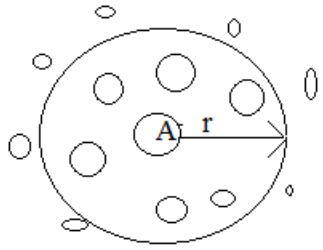


fig.4.1.Deployed node with neighbors

To develop SCC for elect the efficient cluster to transmit and receive the data, we first need to select an exact and appropriate Cluster Head (CH) for each clusters. As in previous works, the sensor nodes will be embedded with a fuzzy system. Synthetic data is used for each input. Gaussian distribution with its mean and covariance matrix representing the expected value and its uncertainty (value of 10%).Then the values are normalized to fit in the [0, 1] as the input of the fuzzy system. Then, extract linguistic variables used to represent them are divided into three levels: Low, Medium, and High.

Linguistic variables are extract out from the normalized data.20% of data is used to determine the membership functions and also the rules. The input of the systems is as follows:

1) Energy (E):

CHs with an acceptable energy level elected by using residual energy in CHs candidates.

2) Node Centrality (NC):

NC shows the value how central node is among its mobile neighbor within the entire network. Lower value of centrality, the lower amount of energy required by the other nodes to transmit a data through the node as CHs. NC is calculated using:

$$NC = \frac{\sqrt{m}}{NZ}$$

Where,

$m = \sum_{j \in s(i)} \frac{d^2_{(i,j)}}{|s_i|}$,d is the distance between CH candidate i and its member , NZ is number of sensing nodes.

3) Local Distance:

This is sum of the distance from the deployed node to its neighbors. Fig.4.1 shows the deployed sensor nodes (n) and its neighbor within r radius.

$$r = \sqrt{\frac{N}{\pi | L | P}}$$

In order to determine LD, we calculate the radius(r).Radius is calculated using.

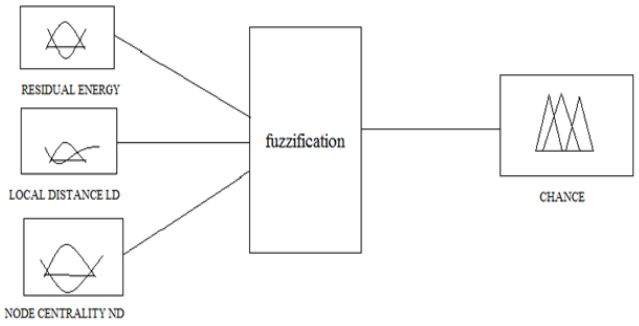


fig. 4.2. FUZZY SYSTEM FOR THE PROPOSED MODEL

Fig 4.2 presents the inputs and outputs interval fuzzy membership functions of the fuzzy logic systems (FLS).

Based on the fuzzy variables shown in fig 4.2, fuzzy rules are defined in table (4.3)(4.4).since each input variables have 3 fuzzy state e.g., Low ,Medium, High. Thus total member possible fuzzy interference rules for the developed system is, $3 \times 3 = 27$

The output for FLS of each node will be sent by a beacon message to neighbors to be informed.fig 4.3.Shows the structure of the beacon message for sending the output of FLS.

Packet Type	Node ID	FLS-OUT

fig.4.3. Eligibility of each node

Packet Type	CH-ID	BCH-IDs

fig.4.4 CH joining message

Where Packet Type presents the purpose of the message .Node-ID is the ID of the node that creates the message and FLS-OUT is the output of the fuzzy systems. The nodes that have received the message from the other nodes need to check FLS-OUT. They compare the received FLS-OUTs against its calculated fuzzy output as well as the received other node. A sensor nodes with highest FLS-out introduces itself as a CH .it also list the other sensor nodes, based on their FLS-OUT.in the list ,they are ordered from the highest to lowest FLS-OUT of the nodes. In fact, the list priorities the sensor nodes with higher FLS-OUT. That is to ensure there is always BCHs. Therefore a sensor with lower FLS-OUT knows that they are BCH of the node with higher FLS-OUT. That is ensure there is always a BCH for defined CHs.fig.4.3 presents structure of the CH joining message.

Where Packet Type presents the purpose of the message, CH-ID shows the ID of the elected CH and BCH-IDs is the list of sensors IDs are ordered from highest from lowest FLS-OUT. Next, each sensor node that received the CH joining message send an acknowledgement message to join to CH.

B .Time Division Multiplexing (TDMA)

Time-Division Multiplexing (TDM) is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line so that each signal appears on the line only a fraction of time in an alternating pattern. It is used when the Data rate of the transmission medium exceeds that of the signal to be transmitted.

Once the Clusters are created, the CH will allocate the Time Division Multiplexing (TDMA) schedule, and then the sensor nodes can start transmitting data packets in WSN.

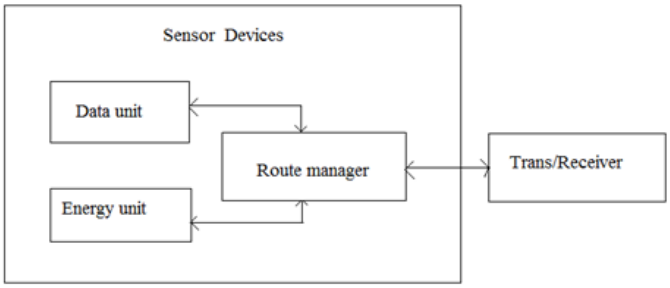


fig.4.4 sensor devices

In the proposed system, there are the main two classes will be there, one is sensor devices, which will send the data, and another one is base station, base station will collect the data from all the sensors through the cluster head.

As shown in the fig 4.4. explains how data will transmit and receive inside the sensor nodes. Fig.4.5.explains data transmission and reception in the base station .

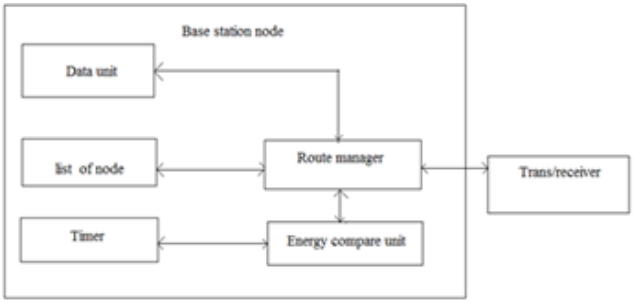


fig.4.5. base station node

In sensor network, if we forming the clustering mean we can improve the network life time is possible but the constant cluster head mean that particular node will lose more energy. To avoid this problem we need to use cluster head changes. There is the different cluster head changing algorithm is available like as LEACH[3][4]. In that algorithm cluster head changes will be in random manner, so that may chances to reduce the some particular node energy. To avoid this problem we are using the HERF[2] algorithm.

Each and every second calculated energy is going to store in energy list, whenever cluster head duration is over then we are comparing energy of each and every node in that list. And which one having high energy in that list we are selecting that node as the cluster head for that period.

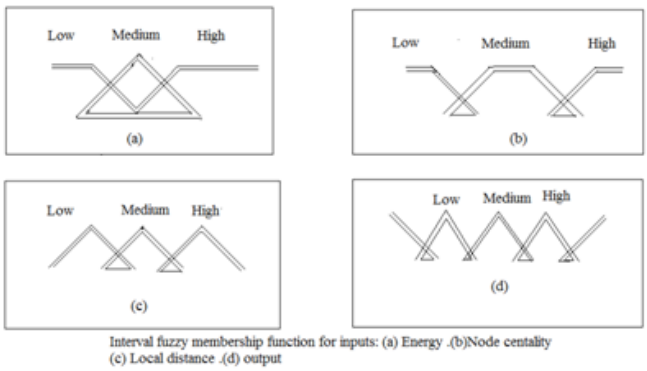
In the proposed system, we are considering only the communication part; the paper are not implementing any sensing part. The data unit is used to generate the data. Each and every node has the energy unit. Energy unit has the current energy level. Routing manager controls the all events such as sending, receiving and data transmission.

In base station, node has the node list and energy compassion unit and data unit. Data unit collects all info. Energy comparison unit compare the energy level and gives high remaining energy node name. Routing manger will selects CH by HEF. And timer used for trigger the event to compare the energy level.

In that stage there is a chance to fail CH in the cluster group because cluster Head loose energy during the transmit and receive data. Due to this failure, some of the data didn't reach the base

station. so a full data didn't have a chance to reach the destination. To achieve the 80 -90% energy efficiency attained in the data transmission by using the fuzzy logic mechanism. The mechanism will be elect the Cluster Head is based on three protocols *1) Energy (E), 2) Node Centrality (NC) 3) Local Distance(LD)*. And elect another cluster head that is called as Second Cluster Head (SCH) which is based on the same three protocols, it reduces the data lost. The cluster head election will be made periodically based on the three protocols with respect to TDMA the second cluster head will avoid the cluster head failure and reduces the data lost. By using the TDMA, data appears on the line only a fraction of time in an alternating pattern. Then, extract linguistic variables used to represent them are divided into three levels: Low, Medium, and High as shown in fig.4.6. In the internal membership function for inputs: (a) Energy (b) node centrality

(c)Local distance (d) output.



Interval fuzzy membership function for inputs: (a) Energy .(b)Node centality
(c) Local distance .(d) output

fig.4.6

V. SIMULATION RESULTS AND COMPARISON WITH EXISTING LEACH

A. Design constraints

The purpose of the design phase is to plan a solution of the problem specified by the requirement document. This phase is the first step in moving from problem domain to the solution domain. The design of a system is perhaps the most critical factor affecting the quality of the software, and has a major impact on the later phases, particularly testing and maintenance. The output of this phase is the design document. This document is similar to a blue print or plan for the solution, and is used later during implementation, testing and maintenance. The design activity is often divided into two separate phase-system design and detailed design. System design, which is sometimes also called top-level design, aims to identify the modules that should be in the system, the specifications of these modules, and how they interact with each other to produce the desired

results. At the end of system design all the major data structures, file formats, output formats, as well as the major modules in the system and their specifications are decided. During detailed design the internal logic of each of the modules specified in system design is decided. During this phase further details of the data structures and algorithmic design of each of the modules is specified. The logic of a module is usually specified in a high-level design description language, which is independent of the target language in which the software will eventually be implemented. In system design the focus is on identifying the modules, whereas during detailed design the focus is on designing the logic for each of the modules. In other words, in system design the attention is on what components are needed, while in detailed design how the components can be implemented in software is the issue. During the design phase, often two separate documents are produced. One for the system design and one for the detailed design. Together, these documents completely specify the design of the system. That is they specify the different modules in the system and internal logic of each of the modules. A design methodology is a systematic approach to creating a design by application of set of techniques and guidelines. Most methodologies focus on system design. The two basic principles used in any design methodology are problem partitioning and abstraction. A large system cannot be handled as a whole, and so for design it is partitioned into smaller systems. Abstraction is a concept related to problem partitioning. When partitioning is used during design, the design activity focuses on one part of the system at a time. Since the part being designed interacts with other parts of the system, a clear understanding of the interaction is essential for properly designing the part. For this, abstraction is used. An abstraction of a system or a part defines the overall behavior of the system at an abstract level without giving the internal details. While working with the part of a system, a designer needs to understand only the abstractions of the other parts with which the part being designed interacts. The use of abstraction allows the designer to practice the "divide and conquer" technique effectively by focusing one part at a time, without worrying about the details of other parts. Like every other phase, the design phase ends with verification of the design. If the design is not specified in some executable language, the verification has to be done by evaluating the design documents. One way of doing this is thorough reviews. Typically, at least two design reviews are held-one for the system design .one is NAM WINDOW (network animator) and X-graph .

B. SIMULATION APPROACH

Simulation is a process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.

Simulation modeling may leave out some details, since too many details may result in an unmanageable simulation and substantial computation effort. It is important to carefully consider a measure under consideration and not to include irrelevant detail into the simulation.

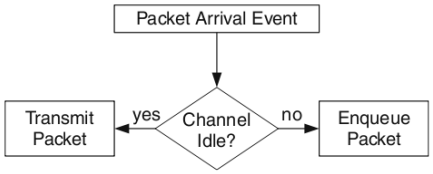


Fig.5.1. PACKET ARRIVAL EVENT

The above packet arrival event chart shows, if channel is idle during the packet arrival process, packet will be transmitted otherwise enqeue the packet.

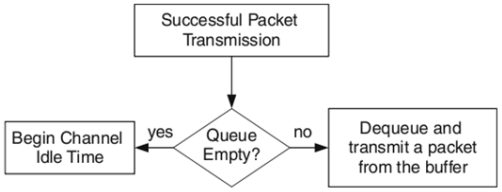


Fig.5.2. SUCCESSFUL PACKET TRANSMISSION

In the case of data transmission, it is denoted as successful packet transmission,if queue is empty ,channel makes as idle time, else the process will continue to Deque and transmitt the packet from the buffer as shown in fig.5.2. By this way packet transmission and reception process takes place.

Simulation steps based on Cluster Head formation:

(1) Cluster Head(CH) Selection: Cluster Head selects by the all the sensor nodes.

(2) All the nodes share their energy level to all the neighbors,

(3) All nodes check their energy into received energy level,

Cluster Head will select if the node satisfy FAF(Forward Aware factor)

(4) Cluster Members (CM) send the data to CH.

(5) CH can gather data after that analyze all CM data packets

(a) If any CM gives same data to the CH. CH can allow only one data to the base station. Remaining data can be ignored.

(b) If no one gives same data means CH can allow all data's to BS.

(c)It will continued for every round until communication stop.

The elected CH may failure during the above process.So, Second Cluster Head (SCH) which cluster member in the cluster group have to satisfies the three proposed protocols will automatically elect. This may reduce the data loss and increase the efficiency of the data transmission and reception process.

C. SIMULATED RESULT

In this section, presents the experimental simulation results of proposed algorithm. NS2 simulation output can be showed in two ways:

(1) Nam-window (Network animator window)

(2) X-graph

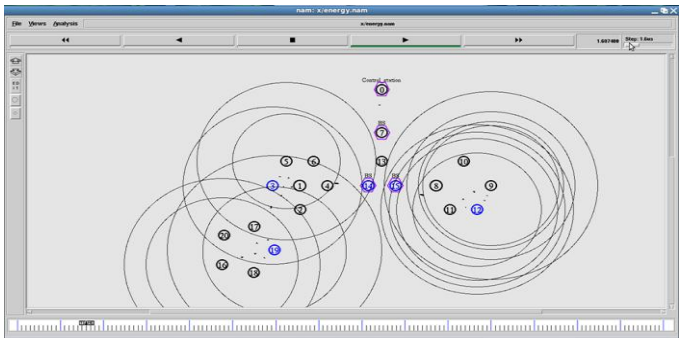


Fig.5.3.nam-window result

ns comparison network associate called Nam, hence it is called ns-Nam project. Our proposed output also viewed in Nam-window as shown in fig.5.3.in a Nam window result will show the node creation, cluster head election, nodes will send packet to CM and CH transmits packet to BS.

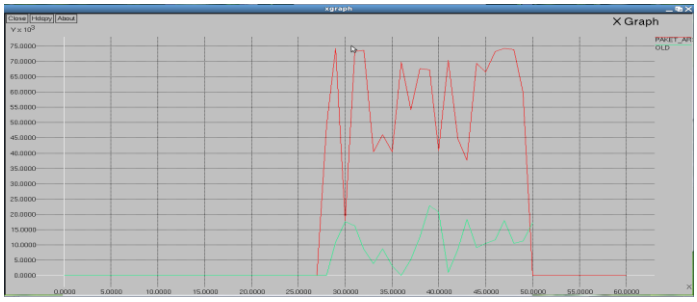


Fig.5.4.x-graph result

From the figure5.3. shows the CH in blue colour, CM in black colour,purple colour denotes the base station and destination node,the large circles are cluster formation.A small points are the packet transmit from CM to CH and CH to BS /destination. Achieve 80-90% of efficiency from the above process as viewed in the X-graph as shown in figure.5.4.

One of the part of ns-allinone package is 'x-graph', a plotting program which can be used to create graphic representations of simulation results.the graph shows that the number of packet transmit or receive with respect to time that is throughput is obtained according to source node.

D. ***comparison of proposed protocol with existing protocol***

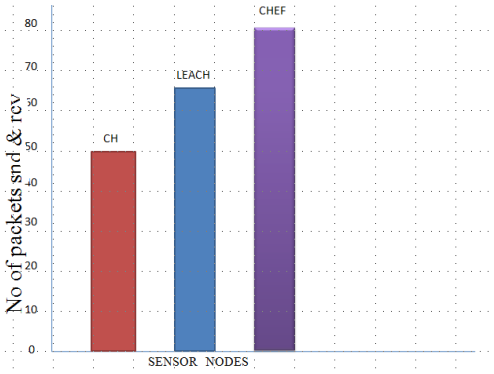


Fig.5.5.comparing results in bar chart representation

The cluster Head Election based on Fuzzy logic will definitely gives the high efficiency comparing to other protocols like CH, LEACH. As in the fig 5.5 gives the clear comparison of protocols with respect to bar chart representation.

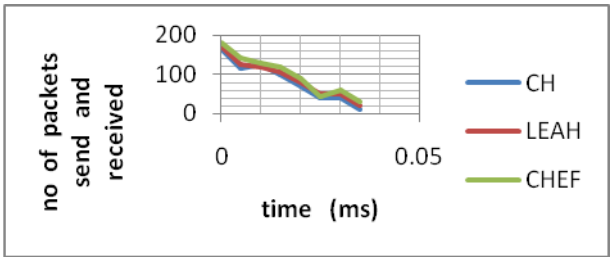


Fig.5.6.line chart comparison

The fig5.6. shows the line chart comparison of protocols.

In the Nam-window comparison throughput obtained by the proposed protocol is high when compared to other protocol models. The blue colour be the result of CHEF, green be the LEACH, red be the normal cluster formation protocols as shown in the fig.5.7.

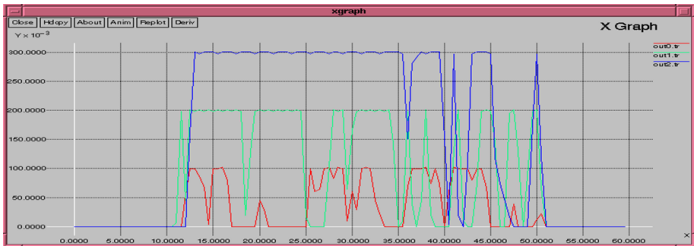


Fig.5.7.nam-window comparison

VI. Conclusion

While the proposed protocol will ensure the promising to obtain the high efficiency in WSN that makes the protocol more attractive and widely applicable. In this paper a Second cluster head election using fuzzy based logic and self configurable clustering mechanism makes the protocol less loss. This leads to high data transmission and reception. It is expected that it would be more useful in many practical application like in military applications, health centre, and disaster areas. Simulation result shows that the proposed protocol performs better than the LEACH protocol. In terms of first cluster head dies, second cluster makes active and attains the high energy.

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