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Design and Implementation of Grid Based Clustering in WSN Using Dynamic Sink Node

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Abstract:
A wireless sensor network (WSN) has important applications, especially in remote environmental monitoring, which has been possible with the availability of smqller, cheqper, qnd more intelligent sensors. The equipment of these sensors are with wireless interfaces linked together to create a network, that contains many distributed nodes. The closest nodes to the sink are exploited with the huge traffic load since data from the entire region is forwarded through them to reach the sink. Consequently, their energy is rapidly tired and the network is divided. This is solved by changing the sink node position in Grid based clustering technique, which considers the optimal method for this purpose. A simulation with MATLAB can be applied for Grid based clustering technique to evaluate the performance of WSN. The expected results deal with outperforms in term of output, reduction in energy consumption , the residual energy imcrease, and the sensor network lifetime prolongation.

Keywords: *WSN; Grid based clustering; Static & dynamic Sink node position\.*

I. INTRODUCTION

Currently, a Wireless Sensor Networks (WSNs) are among the most essential technologies, which consists of huge amount of small nodes chqrqchterized by computing, communicating, and sensing capabilities. These nodes are restricted in terms of battery, range of transmission, energy, memory, processing capability, and are distributed over a large area [1]. The data loosing results from undesired physical and environmental damage, unavailability of power or blockage of any kind of obstacle.

WSN is beneficial for monitoring numerous applications, like surveillance, security, disaster management, military, healthcare and environmental studies, thus, WSNs have become the most tremendous area of research [2]. The energy consumption rate and the transmission overhead in WSN might be diminished through a group of aggregated data, and a forwardable data aggregate. The nodes may be distributed in small groups called clusters to allow the data aggregation within the network. Clustering refers to the nodes division process into sets based on a specific mechanism. clustering has been adopted to improve the network lifetime, which represents a significant parameter for sensor network performance evaluation[3].

The energy of the nodes can be considered very important criteria to extend the lifetime and to increase the performance of wireless sensor network. As a result, the energy of nodes closer to the sink is instantly exhausted in hierarchal protocols where the sink node in fixed position leading the network disconnection. A sink node can be used under dynamic position for improving energy balancing entire network to overcome this problem and to extend the the network's lifetime [4]. As a result, the data collected from the sensors to the sink node will be transferred with less energy and in an efficient manner, avoiding the delay in relaying events [5].

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Many discussions were presented in previous works that had been approved with the purposing of addressing issues associated to the prolonged lifespan of the network, while balancing the energy consumption in wireless sensor networks.

Amrutha & Ashwini (2013) [6] described WSN as a group of small, low-cost and self-powered devices that capable of sensing, computing and communicating with other devices with a view of collecting limited information that can enable global decision-making about the physical environment.

The performances of the most three routing protocols in WSN grid based clustering were compared by Pratibha & Laxmi (2014) [7]. The sensor nodes limited energy and battery power were maintained by energy sensor networks; the major task of the sensor network, is the energy consumption of sensor nodes. In addition, the functions of the grid based sensor were based on the locations that are divided into many parts, while the cluster head in grid based WSN, considered as a base station. The three routing protocols were; Dynamic Manet on demand routing (DYMO), Ad-hoc on demand distance vector routing (AODV) and Dynamic source routing (DSR) through the use of Qualnet simulator.

Cunxiang & Zunwen (2014) [8] proposed a LEACH protocol to decrease the energy cost, due to the insufficient energy of WSNs. The routing role for improving energy efficiency can't be underestimated. LEACH problem concentrated on no attention paid to the residual energy of sensor nodes and long distance communication, thus high energy consumption resulting and low network coverage. They proposed a grid-based energy efficient routing protocol (GEERP) that focused to improve these three things (energy consumption, network coverage and energy efficiency).

According to Bhaskar, et al. (2016) [2], major factors were considered in the WSN design which are the energy conservation and load balancing. The methodology of clustering assists in energy reducing that is consumed by the network nodes, thereby results in an increasing in the network lifespan.

Shrijana & Kalpana (2016) [9], design an energy efficient cluster head selection and rotation mechanism, which leads to a whole communication can be occurred between the base station and the cluster that take care of by the cluster head. In a cluster, originally, the cluster members are consuming less energy than a cluster head, because it receives data from all members, senses the data, processes the data and communicates the process result in the base station.

According to Ashwini & Asha (2017) [10], they explained that the consumption of energy is the key issue in the WSN design. They used a clustering method which considered a way through which the energy consumption by each node can be reduced, so that the lifetime of the network can be prolonged. The paper also aimed to address the energy loss problem which occurs in the clusters that are located close to the BS as a result of more data handling.

Based on a grid structure in WSNs, a new algorithm for routing and clustering was proposed by Lalitha et al. (2017) [11]. They designed a suitable grid size and constructed a virtual structure, based on the size of the area and range of transmission. The selection of a cluster head within a grid is done from the smallest distance to the center of the grid. Bilal et al (2017) [12], noted that minimizes energy consumption has been achieved by clustering hierarchical schemes. In their paper, the hierarchical schemes were broadly classified as cluster-based and grid-based approaches. Cluster-based approaches involve the grouping of nodes into clusters, with one relevant sensor node selected as the cluster head, while grid-based approach involves the division of the network by the base station into confined virtual grids.

Najma, et al. (2018)[13] demonstrated a dependable data communication with maximum lifetime of the network are essential by WSN applications, that are more fundamental in Mobile Wireless Sensor Networks (MWSN) compared with static WSN. This is due to the reliability of receiving data at the cluster head in cluster based MWSN is very challenging.

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Zhansheng & Hong (2018) [14], proposed a reliable grid-based multi-hop routing approach for WSNs, with the aim of minimizing and balancing the consumption of energy. The proposed protocol has the capability of optimizing the process of cluster head selection through a combination of individual ability.

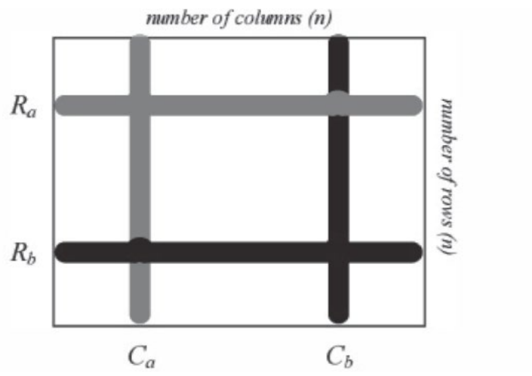
This paper is focused on proposing a grid-based clustering design under dynamic sink node position for balancing the traffic load in the network and, to implement a design of the grid-based clustering in multiple cases and compare between them for identifying appropriate network design in WSN by using MATLAB.

II. Methods and Materials

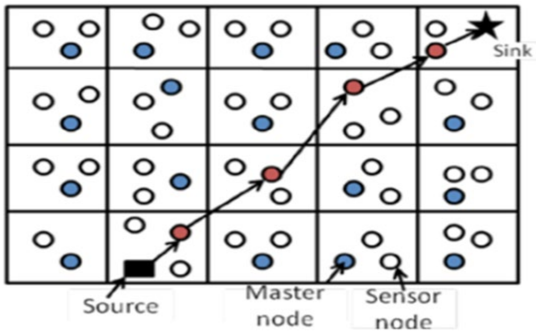
A. Grid based in WSN (Wireless sensor network)

WSN model is characterized by a squared grid shape whereas each square is a zone made. The number of rows and columns is denoted by n×n. The grid constitutes a combination of rows and columns, left to right and top to bottom. The rows' beginning is the left side (n), and the columns's beginning is the top (n). The 2 x 2 grid-based network model is shown in Fig 1(a), Ri representing the rows and Cj the columns [15]. Fig 1(b) demonstrates the field of sensor network, which has been grids divided. The network area contains a non-overlapping square grid of equal sizes and each grid must have one working node at any time. The nodes of the grid must operate in sequence one after the other, and thus, extending the network's lifetime [16].

Every grid is predictable to contain one node operating as a head in charge of forwarding routing information and transmitting data packets. Routing is carried out in a grid-by- grid method. The objective of grid-based multi-path routing protocol is summarized in enabling the rapid routing of packets, using and extending the energy of sensor nodes, while avoiding the network overcrowding, or at least handling it if it occurs [17].



(a) n×n Grid



(b)

Fig. 1. Grid Topology a) n×n Grid b) Grid in Wireless Sensor Network

The purpose of a WSN grid based clustering technique can be concerned for enhancing the minimization of power consumption in any node by decreasing the traffic load. The utilities of grid based cluster head (GBCH), comprise the partitioning of sensing field with equal square size grids, the selection of CH in each grid, increased the lifespan of the network, and improved the energy efficiency [18,19]. This technique contains two important phases, the first is initial clustering and the second is data transmission. The initial clustering includes the grid construction, the selection of CHs, in addition to the scheduling of TDMA, while the data transmission phase focuses on the packets forwarding from CHs to the destination [9].

On the other hand, the high rate problem of the energy consumption remains a matter of great attention in WSNs. So that, a reducing of the energy consumption is essential to enhance the performances of prolonging network lifespan and to decrease the sensor node congestions that is

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considered the actual responsibility to balance the load of the network. At the sink, a larger number of packets will be received in different topologies like mesh, circular and grid mostly.

B. Sink node position in WSN

WSN with sink node architecture can be distributed with static and dynamic positions, It consists of sensor nodes, or mobile sink nodes, which sometimes it can be used as a data collector that is installed within the sensing area.

The static sink node position could be utilized for data collection in WSN by using multi hop forwarding which gives an advantage of consumption more energy nearby nodes around base station in addition to relay the data from another one. The second is the dynamic sink node position that is also could be used for collecting data from sensor nodes and storing it at the base station through a single round in the network, thus with a new round the sink node consumes a new position to balance the energy consumption within multiple nodes full network.

C. Research Methodology

The proposed techniques for the improvement of WSN performance are demonstrated in details with a suggested algorithm for grid-based cluster. Two proposed scenarios for simulation design are realized using a set of nodes. The construction of these scenarios is carried out by using MATLAB, which is currently top used simulation design. Many parameters are used to evaluate the WSN performances with grid-based clustering techniques including essentially consumption of energy during transmission, throughput, in addition to network lifetime.

The proposed flow chart consists of two phases that will be implemented with two scenarios static and dynamic sink node position and then a comparison will be made to reach an appropriate network design Building as shown in fig 2. These two phases are construction and connection, in construction, the design of two scenarios in different algorithm are built, while a connection phase is responsible for creating a connection between nodes.

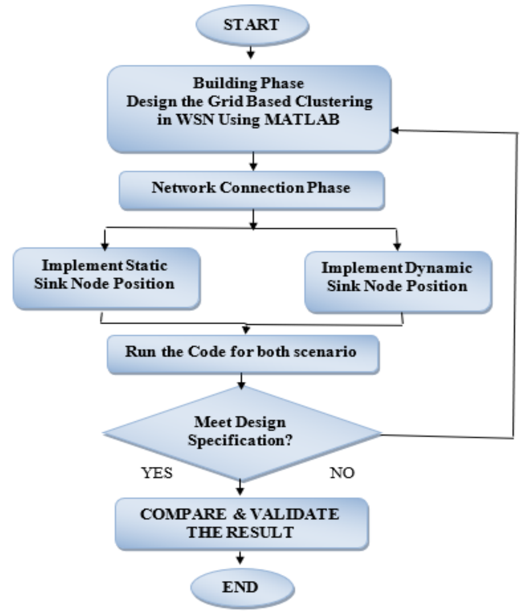

Fig. 2. Overall methodology

D. Simulation Scenarios

A simulation of two scenarios has been done; the first is the grid-based clustering design under static sink node position while the second is for dynamic. Each scenario consists of 1500 sensor nodes in the simulated design, these nodes distributed randomly on number of grids is $4 * 4$ at a surface area of 800 by 800 m^2, the grids have 16 cluster head in both scenarios. The first scenario which considers static deployment based on the specified distance between CH, and the second scenario that focused on random clustering is based on random deployment of the CH. The time duration of the simulation is 120 seconds, maximum packet size to be sent is 512 bytes using SEP-E Routing protocol, Data Rate is 11 Mbps, Initial energy is 3 J, Nodes deployment is random**,** Position Dynamic Channel type is Wireless Communication Bi directional. The simulation was implemented using MATLAB.

E. Performance Metrics

There are many performance metrics used for measuring the network quality of service, they are based on the network design and environment [20-

22]. In this paper, we focused on the performance metrics used in evaluating the residual and consumption of the energy during transmission, network lifetime, and throughput. These metrics include; consumed energy, residual energy, throughput which can be referred to the no. of the packets has been received at the BS during the rounds.

1) Energy Consumption

The energy consumed by the transmitting nodes, it may be determined by its distance from the receiver. The transmitted energy is calculated for the transmission of p bits of data over a distance x as [11] [21]:

$$E_T(p,x) = (E_{el} * p + p * \epsilon_{fs} * x^2) \quad for \quad x < x_0 \qquad (1)$$

$$E\_T(p,x) = (E\_el * p + p * \epsilon\_mp * x \hat{} 4) \quad for \quad x > x\_0 \quad (2)$$

Where:

E_{el} refers to electronic energy specified by factors

ϵ_{fs} denotes to the amplified energy at free space model.

ϵ_{mp} amplifier energy for multi-path fading model.

x_0 threshold distance:

$$x_0 = \sqrt{\epsilon_{fs}/\epsilon_{mp}} \qquad (3)$$

Energy consumed though receiving p data bits:

$$E_R(P) = (E_{el} \times P) \qquad (4)$$

Energy consumed by the nodes in aggregate excessive m messages of p bits each:

$$E_{DA}(m,p) = (E_{agg} \times p \times m) \qquad (5)$$

E_{agg} represents the energy consumed per bit for aggregation of the message.

2) Rounding Time

The total time for a complete round is calculated at BS. The BS also recognizes the cluster with the highest node number, and then calculates the number of nodes in it. If u is the number of nodes in the cluster, the total time desired for one round is given by:

$$T = (u-1)t_{CM-CH} + (n-1)t_{CH-CH} + \frac{x}{v} + i \times t_M \qquad (6)$$

t_{CM-CH}: slot time given to the node to send data to CH.

t_{CH-CH} : slot time assigned to a CH to send data to its upper level.

n : the number of levels.

v : the velocity of the data mule

x : the network horizontal width

i : the number of vertical lanes, number of APs where data mule halts collect the data

t_M : time required for the data mule at each AP to collect data from the CH.

3) Packet Delivery Ratio (PDR)

PDR represents the packet ratio, which is sent by the application layer through simulation is being performed. It can be calculated theoretically by equation 7

$$(PDR)\% = \frac{\sum packet\ Received\ by\ destination}{\sum packet\ sent\ by\ Source} \times 100 \qquad (7)$$

4) Throughput

It is an important parameter that is used in evaluating the packet numbers with successfully transferred between the source and destination. It can be resulting from dividing the communication channel to simulation time. Several factors influence the success of throughput at any network, like propagation losses, traffic and network congestion. Throughput has a negative effect with these factors [22]. It may be represented and calculated theoretically by equation 8:

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$$\overline{Thr} = \frac{8 \times N_{rx}}{T_{Sim}} \quad (8)$$

where

$\overline{Thr}$: the average throughput (bps).

N_{rx} : the successfully received packet number (byte).

T_{Sim} : the simulation time (second).

5) Network Lifetime

It is the minimum time duration (sec) of network operation in which the number of sensor nodes is dying or shut down at long simulations run performed.

III. Proposed Approaches

From the simulation, the detailed results, including design, analysis, and the specifications for achieving appropriate WSN performances will be shown. The aim is to keep the energy balancing among the cluster heads in order to prolong the network lifetime, by comparing the two scenarios, the first one is grid-based static sink node position, and the second scenario is grid-based dynamic sink node position network design. The performance of the two scenarios will be validated and compared via simulation using Matlab, and all simulation parameters for both scenarios are described above.

A. Grid Based Clustering Under Static Sink Node Position

Although the design of the grid based-clustering in WSN improved the performance of the network, several observations can be made based on the following Fig 3, the number of clusters increases and distributed in equal distance in every grid of the network depending on the highest energy node to become the head in grids. But, the value of energy consumption of the nodes increases, because the sink node located in static position since the hole nodes in the network are characterized with an equal initial energy, so the nodes closest to the sink node tired their energy quicker compared to the ones far from the sink.

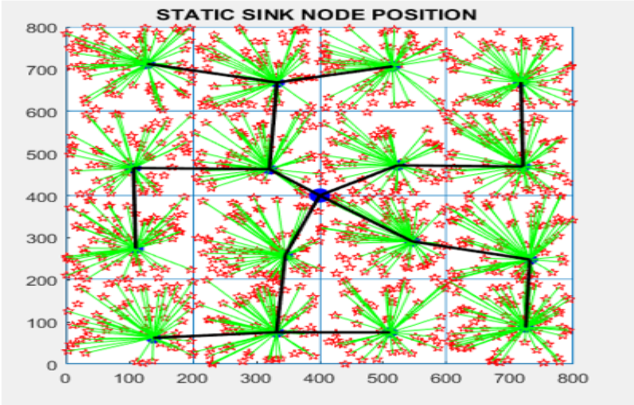

Fig. 3. Grid Based Cluster Head Under Static Sink Node Position

This result could be explained by the fact that sensor nodes become closer to the cluster-head in grid-based clustering, and the 16-cluster head deployment based on the specified distance between them. The sensor nodes consume more power by sending the its packets and pass the packets from the farthest nodes to the sink nodes.

B. Grid Based Clustering Under Dynamic Sink Node Position

After implementing the scenario of static sink node position in the grid-based clustering network which was designed to collect data via a wireless sensor network through the use of a multi hop forwarding in order to ensure a higher energy consumption nearby node around Base station and to relay on data from other one.

To solve the problem of energy consumption dynamic sink node position used to gather information from the sensors' node and store it into the base station throughout one round as represented in fig 4(a, b, c, d). Every new round in the network the sink node has new position for balancing the energy consumption among multiple nodes entire network. Comparative study of the two scenarios (static, dynamic) had been implemented with different metrics been simulated using MATLAB, depending on the static sink node and dynamic sink node results. Thus, it elects which procedure is more effective to collect and gather data from the sensor's nodes.

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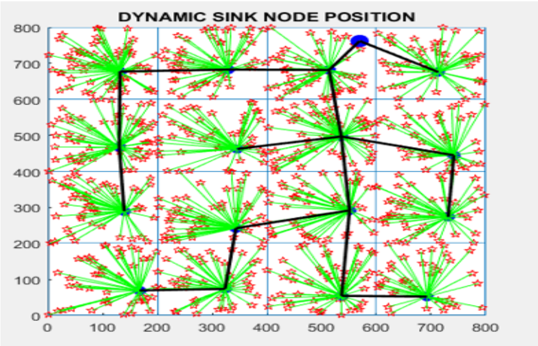
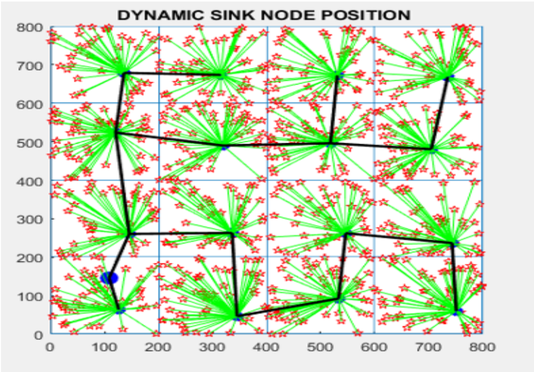


(a)



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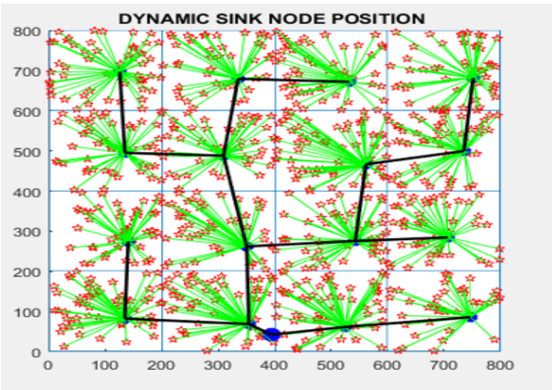

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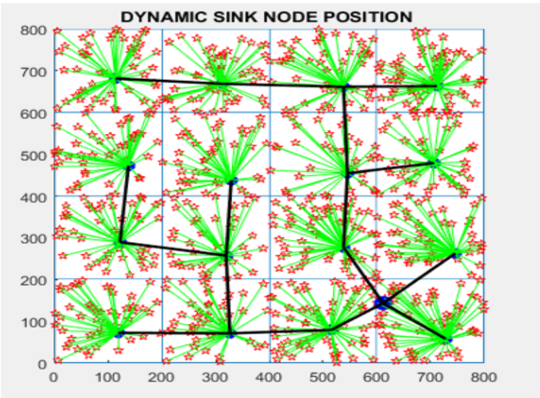

Fig. 4. Dynamic Sink Node Position in Grid Based Cluster Head Network

IV. Results and Discussion

Various performance metrics have been analyzed such as consumed and residual energy, and the number of packets sent to the base station, and the lifetime.

A. Consumed and Residual Energy

1) Grid Based Clustering Energy Under Static Sink Node Position

The consumed and residual energy for the first scenario under static sink node position in WSN can observe in Fig 5 which shows the value of energy in term of residual and consumed energy. So, in this scenario's design, the consuming energy is more compared to residual, because the nodes closer to the sink are overburdened with the huge traffic load and the farthest nodes in the grids will try to communicate with its neighbor cluster as the data from the whole region are transmitted through them to connect and send its packets to the sink node.

2) Grid Based Clustering Energy Under Dynamic Sink Node Position.

The energy consumed and residual for the grid-based clustering using the dynamic position of the sink node is shown in Fig 6. This scenario minimized the energy consumption that cause maximized the residual energy in order to enhance the performance of the network. The energy consumed by sensor nodes per cluster decreases significantly as the position of the sink node had been changed in every round which solving the energy balancing problem. In contrast, static sink position does not guarantee such issues because in some cases data flow will go through a long path to reach the sink node consuming more energy with high traffic load around the sink node.

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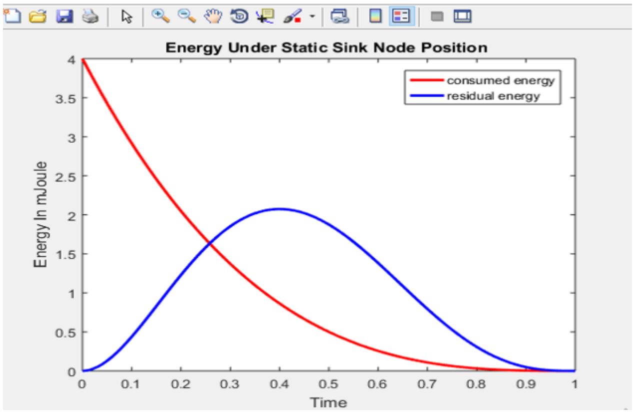

Fig. 5. Residual and Consumed Energy for Grid Based Clustering under static

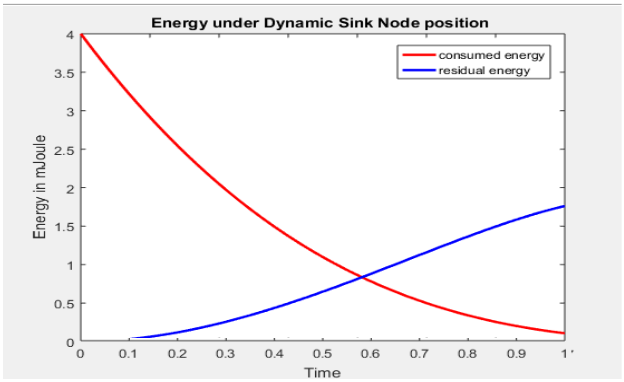

Fig. 6. Residual and Consumed Energy for Grid Based Clustering under dynamic

It can be noted from the comparisons between the static and dynamic sink node position that the residual energy increased, and energy consumption reach to the minimum value when positioned the sink node in multiple locations in the network, but the consumed energy increased when used the static position for the sink node in the wireless sensor network as shown in fig 7.

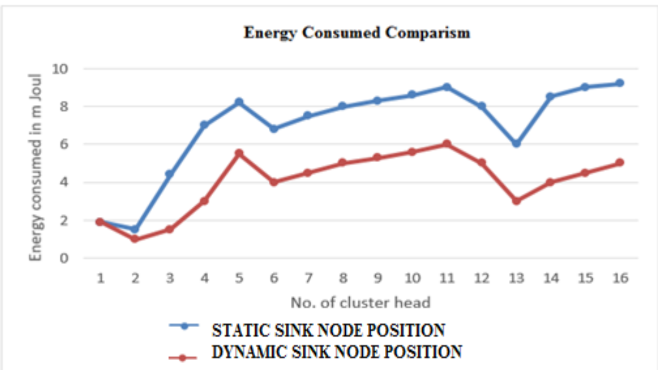

Fig. 7. Energy Consumed for grid-based clustering in WSN

As shown in Fig 7, the relationship between the number of clusters (16 cluster head) in grid-based in WSN of 1000 nodes and energy consumption for cluster-head based on the scenarios of static and dynamic position of the sink.

B. *Throughput*

The performance of the two-design depending on the packet number being sent in one round can be analyzed with corresponding to the values of a throughput can be shown in Fig 8. A throughput comparison value between grid-based clustering under static and dynamic position of the sink node are shown. After round number 11 (11 iteration) the grid based static position will drop down, but the value of grid based dynamic position will increase continuously, in this round can compare the value of both scenarios as shown in Figure 8.

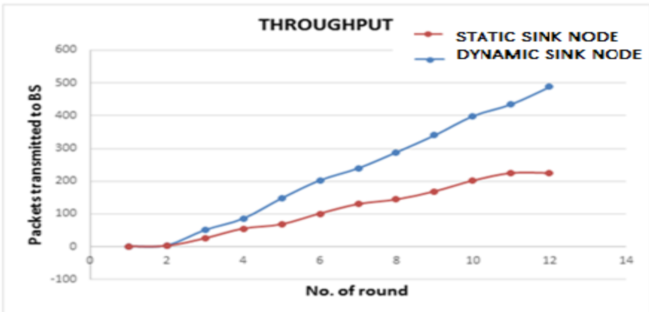

Fig. 8. Throughput comparison between static and dynamic sink node position

C. *Network Lifetime*

The lifetime of the network design under different transmission range is shown in fig 9. When the number of the rounds increased with rising of network transmission, the grid based dynamic sink node position lifetime will be better than static position.

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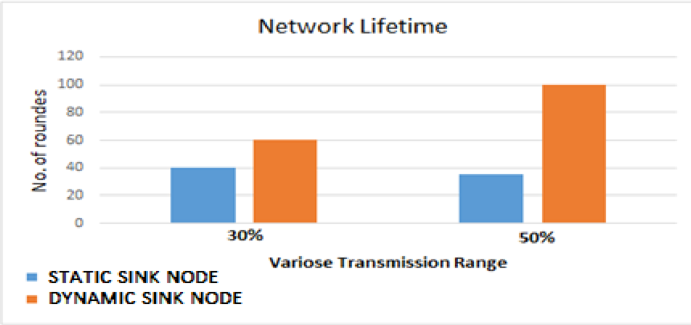

Fig. 9. Network Lifetime in Different Transmission Range

V. Conclusion

Grid based clustering is simpler and more feasible, and has so much advantage with respect to other method. In this paper, we proposed a grid-based clustering under sink node mobility for balancing the traffic load, and minimizing energy consumption among all the nodes. Multi-hop routing protocols suffer from hot spot problem due to huge traffic load near the BS. In this static and dynamic algorithm, data are transmitted through vertically rectangular, as parallel lanes which reduces hot spot problem to balance energy consumption at different levels.
However, Grid based clustering head obtained to enhance results in terms of energy, with dynamic sink node position for balancing traffic load entire network, its used in long transmission sensor network, arrangement of packets scheduling doesn't take into account yet to reach an optimal solution in terms of synchronization of the packets. although routing protocol is taking into consideration, a trade-off will be produced between transmission range and communication distance. The optimal route can be created by all components of sensors which must consider and produce negligible energy procedure for transmission data in the future.

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