MAP: The New Clustering Algorithm based on Multitier Network Topology to Prolong the Lifetime of Wireless Sensor Network

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***Abstract*—Wireless sensor network and its applications are interesting research that have been focused recently. Battery consumption of sensor nodes is the main problem in the family of wireless sensor that should be solved. So, to increase the scalability of the network, and to reduce the energy usage for overall sensor operations, clustering techniques and data aggregation are the main focus in this paper. The multi tier techniques has been designed precisely and the selection of the cluster head using Fuzzy Logic based on the three selected parameters are well used along with its limited resources of wireless sensor network. In this study, the main primary and secondary cluster head are the important entities of the algorithm for receiving and transmitting data to the base station. The contribution of this paper is mainly on the selection of a secondary cluster head and the routing protocol which the data transmission will involved the nearest cluster head for both tier one and tier two. Due to multi tier clustering in sensor network, the operations of the sensor network will eventually increase the lifetime of the network compared to LEACH and SEP protocols.**

Index Terms—wireless sensor network, primary cluster head, secondary cluster head, multi tier, energy efficiency.

I. INTRODUCTION

Wireless sensor network, (WSN) are tiny devices that are contain thousand or extra sensor nodes which are distributed in the area of sensor environments [1]. There are many ways to distribute the sensor nodes in its field such as using manually or by randomly. The main purposes of the deployment is to monitor certain phenomena of interest such as military surveillance, landslide detection, physical environment, health field and so on [2]. The main problem in wireless sensor network is it on battery consumption. The sensor node battery cannot be recharge after certain period of time where there is no power supply to recharge the battery once it is depleted [3]. So, to harmonize and maximize the lifetime of the sensor networks is an important challenge in order to achieve the energy efficiency of sensor nodes. Clustering is one of the effective methods that use data aggregation to reduce the energy usage in WSN [4-6]. In clustering, there are a cluster head at each of the clusters that has been identified. The cluster head acts as an intermediary between the sensor nodes and it is responsible to send the data it receives from the other sensor nodes to the base station. This communication reduces the energy consumption of sensor nodes because the data is not directly send to the base station [7]. Thus, clustering is helpful in minimizing the usage of sensor node energy.

LEACH is one of the established clustering based routing protocol in WSN [8]. The selection of cluster head in LEACH is done randomly and the data that transmit between the cluster head and the base station is done directly which tend to exhaust the sensor battery quickly.

In this paper we proposed new cluster head algorithm known as Multitier Algorithm Protocol (MAP). The cluster head selection algorithm in MAP is done on the second level of multitier network. Additionally, data transmitting between the cluster head and the base station is using multi hop communications. These transmission will passed through two cluster heads at each tier called primary and secondary cluster head before it reach to the base station.

The rest of this paper is organized as follows. In section II, we describe the related works of this research. Section III explains the proposed algorithm with details of this experiment. Section IV describes the parameters and simulation result

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analysis. The final section is concluding the overall experiments and some future research are mentions.

II. RELATED WORKS

In WSN, reorganize the cluster periodically is called round when the particular cluster head is dead. In each round, the cluster go through set up phase and steady-state phase head selection. The selection of cluster head is done at the setup phase whereas the data transmitting is done during steady state phase [9].

There have been many approaches being implemented such as Low Energy Adaptive Clustering Hierarchy (LEACH) [2], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [6], Stable Election Protocol (SEP) [10], A Hybrid Energy-Efficient Distributed Clustering Approach for Ad-Hoc Sensor Network (HEED) [11], and An Energy Aware Fuzzy Unequal Clustering Algorithm For Wireless Sensor Network [12]. Due to that, LEACH was the first algorithm that proposed clustering routing protocol which is adaptable for a huge network and can drastically prolonging the lifetime of the sensor network.

In LEACH, during the startup phase, each of the sensor nodes will become a cluster head (CH) with fixed probability. The next rounds in LEACH only start after the election period is elapsed. At this stage, all other members nodes in the cluster decide whether it can becomes a CH. The previous cluster head or other sensor nodes that have not become a cluster head will join the cluster which is the nearest to the CH and this CH used more energy rather than the non CH. All communication from the sensor node to the base station will go through the cluster head for each of the cluster. The cluster head will aggregate the data and then send the data to the base station. There are maximum number of data packets that can be carried out by CH from each of the sensor nodes [13] and this might make CH reaching its capacity to handle the data. Therefore, CH normally die on early phase [14]. So, the effective techniques should be considered to prolong the lifetime of the sensor node and the network lifetime.

III. METHODOLOGY

As mention above, MAP is the clustering algorithm which used two tier of the network topology. MAP consists of two cluster heads known as primary cluster head and secondary cluster head. Primary cluster head located at the first tier of the network topology which its responsibility to transfer data to the base station either from tier two or from its member nodes at tier one. While, secondary cluster head is used to receive data from its member nodes, compile, compress and transfer the data to the primary cluster head at the tier one. This is the description of the MAP:

A. Assumption

i. All nodes are fairly distributed for tier one and tier two.
ii. Nodes are static and not mobile
iii. The initial energy for all nodes is same.
iv. The base station of this network is located at the centre of the field.

B. Node Distribution

The sensor nodes are distributed into tier one and tier two based on the area of circle formula as follows;

$$\text{Area of big circle, (C)} = \pi (2r)^2 \quad (1).$$

$$\text{Area of level one, (LO)} = \pi r^2 \quad (2).$$

$$\text{Area of level two} = C - LO$$
$$= 4\pi r^2 - \pi r^2$$
$$= 3\pi r^2 \quad (3).$$

From the above formula, it is seen that tier two has three times the quantity of nodes of tier one, which there are 25 sensor nodes distribute at tier one and 75 sensor nodes at tier two. The distribution of the sensor nodes are shown in Fig.1.

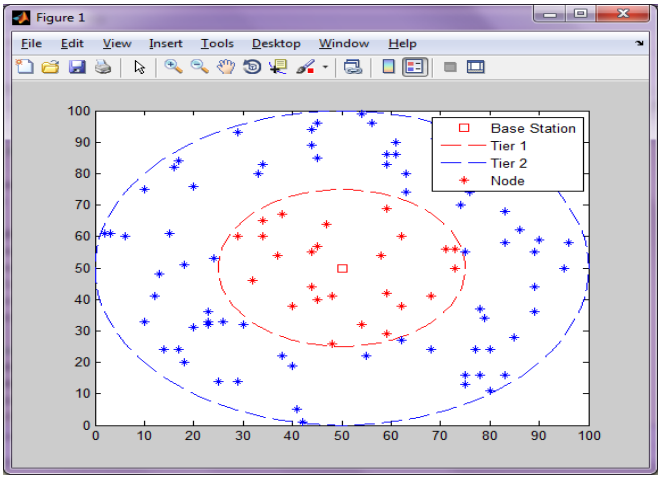

Fig. 1. Nodes distribution for 2-tier networks

The base station is located at the centre of the sensor network which the coordinate is (50, 50).

C. Kopt

We use formula of Kopt [15] to identify the number of nodes to become a cluster head for each of the tiers.

$$K_{opt} = \frac{\sqrt{N_s}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d^2_{toBS}} \quad (4)$$

where

k_{opt} : optimal number of cluster,

N_s: no. of nodes fairly distributed in a region M x M,

$\epsilon_{fs}\, d^2$: amplifier energy,

$\epsilon_{mp}\, d^4$: amplifier energy (multi path transmission).

d_{toBS}: average distance between nodes and base station

This formula is used to identify the optimal primary cluster head (PCH) and secondary cluster head (SCH) for each tier. From this formula, optimal number of PCH for tier one is seven. While, optimal number for SCH in tier two is twelve. This PCH is used to transmit data to the base station. The PCH receiving data from sensor nodes member in the same tier, compile and compress the data before transmitting to the base station. While, the PCH only receiving data from SCH at second tier and transmit the data to the base station. The SCH act as intermediary and receiving data from other sensor nodes in the second tier, compile, compress and transmit to the nearest PCH.

After PCH and SCH identified, the nearest nodes will join and form the cluster based on the Euclidean Formula;

Distance = sqrt((S(i).xd-(S(n+1).xd))^2 + (S(i).yd-(S(n+1).yd))^2)

Nodes nearest to the PCH and SCH will join and form clusters as shown in Fig. 2

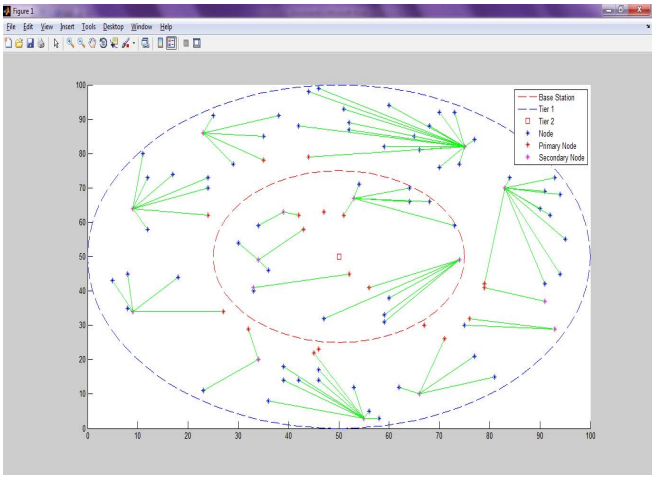

Fig. 2. Nodes join cluster

At this stage, all the nodes have its own cluster and each cluster will have a cluster head to act as intermediary medium between the other nodes and the base station. Nodes start to send the data to its cluster head, at the tier one, node send the data to the PCH at its own cluster and then the PCH will send the data to the base station. This is a normal transmission for the tier one. For the tier two, nodes send the data to SCH in their cluster and then SCH will aggregated and compress all the data that have been received from their cluster members and then will transmit the compress data to the nearest PCH at tier one. After received the data from SCH, PCH will immediately send the data to the base station. This process keep continuing until the SCH and PCH died and next cluster head selection will take place.

IV. RESULTS AND DISCUSSION

This experiment was running using Matlab programming. There are 100 nodes involved in this experiment and the iteration for this experiment was done with 5000 iterations and up to 8000 iterations. The parameters that are used in this experiment are residual energy, communication cost and the centrality. All these parameters are blended together to get the higher chances to become the cluster head using Fuzzy Logic techniques.

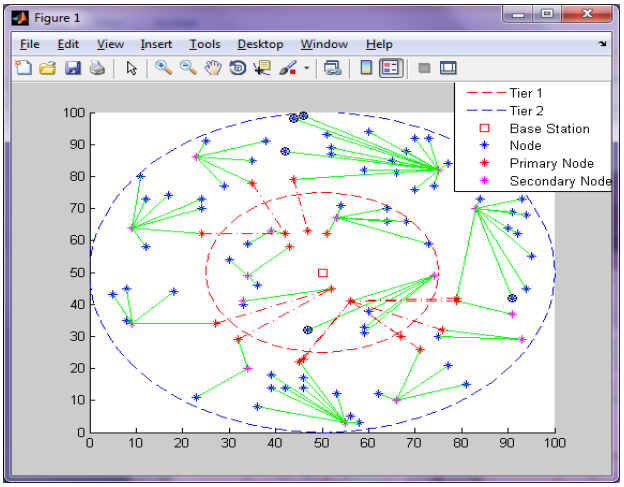

Fig. 3. Data transmission and dead nodes

As shown in Fig. 3, the data transmission has occurred for each of the cluster and the PCH at tier one. The black dotted circle signified that, there are some nodes going dead after the respective iterations.

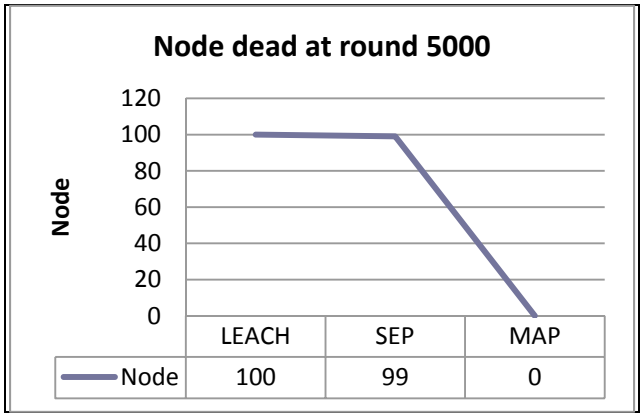

Fig. 4. Total nodes dead after 5000 iterations

As compared with the LEACH and SEP protocol, all nodes are dead after 5000 iterations for LEACH and 99 nodes are going dead for SEP protocol. However, using MAP, there are still no nodes going dead after the 5000 iterations. The comparison between these three protocols as shown in Fig. 4 for the total dead nodes.

TABLE I. NUMBER OF NODE DEAD AFTER 8000 ITERATIONS

Node ID	Round
35	7444
46	7542
39	7548
22	7672
66	7877

Table 1 shows the dead nodes after 8000 iterations for MAP. As we can see, there are only 5 nodes dead after 8000 of iterations. Node ID 66 is the fifth node dead at rounds 7877. There are still another 95 nodes survived in this experiments.

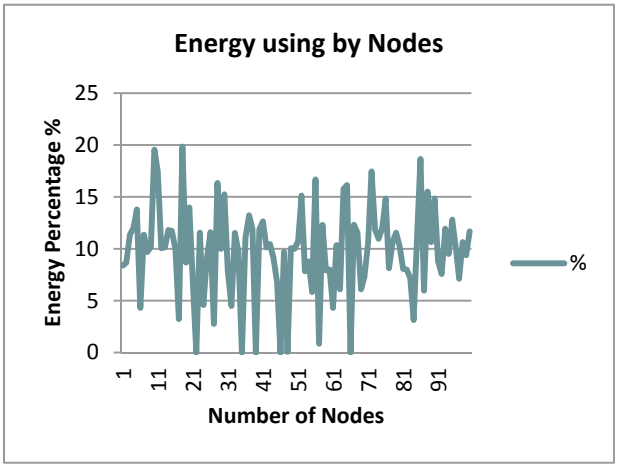

Fig. 5. Energy usage for each nodes

Energy usage for the data transmission for each node is the important elements to be addressed. In this experiment, the maximum of energy usage is 19.84% that has been used for node ID 19. This situation occurred because node 19 is a standalone node so it fully depends on its own energy. The average usage for all nodes in this 8000 iteration is 9.79% which is quite small percentage of energy usage.

V. CONCLUSION

Clustering is one of important method to be applied in order to prolong the network lifetime of wireless sensor network. The selections of cluster head also are important parts to be considered so that the lifetime of sensor nodes remains longer than usual. This experiments test on two tier of network layer and the selection of cluster head are based on fuzzy logic occur on secondary cluster head (SCH). Based on this method, it can be concluded that, MAP can prolong the lifetime of the sensor network where the data transmission to the base station runs up to 8000 iterations and there are still another 95 alive nodes at the network. Compared to LEACH and SEP protocols, the iteration is up to 5000 and all the sensor nodes dead. This convinced that MAP is capable of prolonging the lifetime of the sensor network.

Future experiments will focus on selection of next cluster head after the first cluster head is dead. The selection of the next cluster head will probably change all the nodes members in the cluster and the energy of the data transmission will be captured at this stage. We will see at which iteration can all nodes going dead using this protocol

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