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# Low Energy Consumption Scheme Based on PEGASIS Protocol in WSNs

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**Abstract**

Wireless Sensor Networks (WSNs) are composed of a collection of rechargeable sensor nodes. Typically, sensor nodes collect and deliver the necessary data in response to a user's specific request in many application areas such as health, military and domestic purposes. Applying routing protocols for sensor nodes can prolong the lifetime of the network. Power Efficient GAthering in Sensor Information System (PEGASIS) protocol is developed as a chain based protocol that uses a greedy algorithm in selecting one of the nodes as a head node to transmit the data to the base station. The proposed scheme Multi-cluster Power Efficient GAthering in Sensor Information System (MPEGASIS) is developed based on PEGASIS routing protocol in WSN. The aim of the proposed scheme is to introduce a transmission power control system based on the residual energy level and the energy harvesting status of each sensor node to extend the overall lifetime of WSN and to balance the energy usage, this leads to increasing network lifetime and decreasing energy consumption. MPEGASIS outperforms PEGASIS protocol by about 19%, and LEACH protocol by about 34%. For the sake of performance evaluation, MPEGASIS protocol besides PEGASIS and LEACH protocols are simulated and compared using Network Simulator (NS2).

**Keywords:** Wireless Sensor Networks (WSNs), PEGASIS protocol, Clustering mechanism, LEACH protocol, Residual energy, K-means algorithm.

# طريقة لتقليل استهلاك الطاقة بالاعتماد على PEGASIS بروتوكول في شبكات الاستشعار اللاسلكية

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**الخلاصة**

شبكات الاستشعار اللاسلكية هي تتكون من مجموعة من عقد الاستشعار القابلة للشحن. عقد الاستشعار تجمع وتقدم البيانات اللازمة للمستخدم ردا على طلبه المحدد. تطبق شبكات الاستشعار اللاسلكية في العديد من المجالات مثل الصحة والأغراض العسكرية والمنزلية. تطبيق بروتوكولات التوجيه لعقد الاستشعار يسبب استهلاك البطارية وهدر الطاقة فالحفاظ على الطاقة مهم جدا لإطالة عمر الشبكة. لهذا السبب (PEGASIS) هو البروتوكول الذي يعتمد على طريقة السلسلة للربط بين العقد باستخدام خوارزمية الجشع والتي تحدد واحدة من العقد كعقدة رئيسة لنقل البيانات من جميع العقد إلى المحطة الأساسية. المخطط المقترح (MPEGASIS) تم تطويره بناءاعلى بروتوكول (PEGASIS) والهدف من هذا المقترح هو إدخال نظام السيطرة على الطاقة

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على أساس مستوى الطاقة المتبقية وجمع الطاقة لكل عقدة استشعار لتمديد عمر شبكات الاستشعار اللاسلكية وتحقيق التوازن في استخدام هذه الطاقة. تفوق (MPEGASIS) بروتوكول بنحو 19٪ على (PEGASIS) بروتوكول وبنحو 34٪ على (LEACH) بروتوكول. من اجل تقييم الاداء ومحاكاة لـ (MPEGASIS) بروتوكول الى جانب (PEGASIS) و (LEACH) والمقارنة بينهم باستخدام محاكي الشبكات (NS2).

**Introduction:**

Wireless sensor networks (WSNs) are specially distributed networks composed of a lot of sensor nodes. It is always deployed in a special area to complete a task of sensing and monitoring. There are many technical challenges associated with sensor networks, such as self-organizing algorithm, energy-efficient routing protocols, data aggregation technology and network lifetime improvement. One of the most important keys for sensor networks is energy. Because of inability of replacing sensor battery, conserving energy is so important to prolong the network lifetime [1]. Since the turn of the 21st century, researchers throughout the globe have proposed various energy efficient routing algorithms to maximize the network lifetime of WSNs. Large number of sensor nodes response to the detected event and suddenly become active after they were in an idle mode to transport data to the base station (BS) [2]. The sensing circuitry measures ambient conditions related to the environment surrounding the sensor and transform them into an electric signal and sensor sends such collected data, usually via radio transmitter, to a command center (base station) either directly or through a data concentration center a gateway [3].

There are some limitations in LEACH and PEGASIS protocols such as data redundant which happened in each cluster head and random selection of cluster head in LEACH protocol, and some delay that occurs from a long chain in PEGASIS protocol, this paper try to introduce a compound and optimized scheme in the WSN domain for low energy consumption and outperform the LEACH and PEGAISIS performances in terms of energy savings and consequently to prolong the lifetime of WSN, by designing a system that can cater for node placement in a given area to achieve a high degree of information processing task and to optimize energy consumption by way of monitoring battery power. Hence, node distribution and clustering in a predefined area is managed by K-means so that each cluster represents the best number of current energetic nodes.

The rest of the paper is organized in the following sections; a related work section which focuses on the existing techniques of energy consumption routing protocols in WSNs. Followed by two sections in which the behavior, structure and formulation of the energy consumption of LEACH and PEGASIS protocols are discussed respectively. Then, the principle and steps of the k-means algorithm are given and deployed to satisfy the nodes clustering in our developed scheme. Next, the performance evaluation of the proposed scheme, called MPEGASIS, is discussed in details compared to LEACH and PEGASIS performances using five experiments. Finally, the last section concludes the paper work.

**Related Work:**

Many new algorithms have been proposed, putting in mind the features of WSNs along with the application and architecture requirements.

- Wendi B. Heinzelman, proposed distributed cluster formation technique that enables self-organization of large numbers of nodes. The developed algorithm was designed with rotating cluster head positions to evenly distribute the energy load among all the nodes. Thus, the technique enables distributed signal processing to save communication resources. The results show that LEACH can improve system lifetime [4].
- Kemei D., Jie W. and Dan Z., proposed a chain-based protocol. Also, presented multiple-chain scheme which outperforms the existing ones in the sparsely-node distribution case and they are developed an energy-efficient chain construction algorithm which uses a sequence of insertions to add the least amount of energy consumption to the whole chain [5].
- Sung-Min Jung proposed Power Efficient Gathering in Sensor Information Systems protocol (PEGASIS). It is a chain-based protocol. The PEGASIS protocol causes the redundant data transmission from one of the nodes in the chain which is selected as the head node regardless of the base station's location. An enhanced PEGASIS protocol based on the concentric

clustering scheme solved this problem to prolong the lifetime of the wireless sensor networks [6].

- Yanlin Gong and Gong Chen proposed a balanced serial K-means based clustering protocol (BSK-means) for clustering the sensor nodes. It tried to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head. BSK-means implementation balances the energy consumption in each cluster and consequently helps in balancing the whole system load by considering the load on each cluster head. Thus, it is concluded that (BSK-means) can achieve better load-balance and can prolong the system lifetime for the networks compared with LEACH [7].

**LEACH Protocol:**

In the original Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, LEACH divides the network into many clusters, and the run time of network is broken into many rounds. The nodes in a cluster contend to become cluster head according to a predefined criterion in every round [8]. LEACH protocol provides a balancing of energy consumption by random rotation of cluster heads meanwhile assuring uniform load balancing in one-hop sensor networks [9] as shown in figure-1. All source nodes send their data to their cluster heads and the cluster heads perform data aggregation/fusion through local transmission and send aggregated data to the BS using single direct transmission [10].

**PEGASIS Protocol:**

Power Efficient GAthering in Sensor Information Systems (PEGASIS) is an improvement of the LEACH protocol. Rather than LEACH protocol forming multiple clusters, but PEGASIS forms chain of sensor nodes. Each node transmits and receives the data from a neighbor node and one node is selected from that chain to transmit the data to the base station. Gathered data moves from node to node, aggregated and eventually sent to the base station via the leader node [3]. This protocol distributes the energy equally among the sensor nodes in the network. The nodes are scattered randomly in the sensor field, so the node is at a random location. The nodes are organized to form a chain, the chain formed the nodes can be accomplished by the sensor nodes using a greedy algorithm starting from the node. Also the BS can compute this chain and broadcast it to all the sensor nodes [11].

In PEGASIS routing protocol, construction phase assumes that the network has knowledge about the sensors, particularly, their positions. When a sensor fails or dies due to low battery power or external condition, the chain is constructed using the same greedy algorithm by bypassing the failed sensor[12]. PEGASIS performs data fusion at every node except at the end nodes of the chain. The node fuses its own data with neighbor's data to generate a single packet of the same length and transmit it to the other neighbor [13] as shown in figure-2:

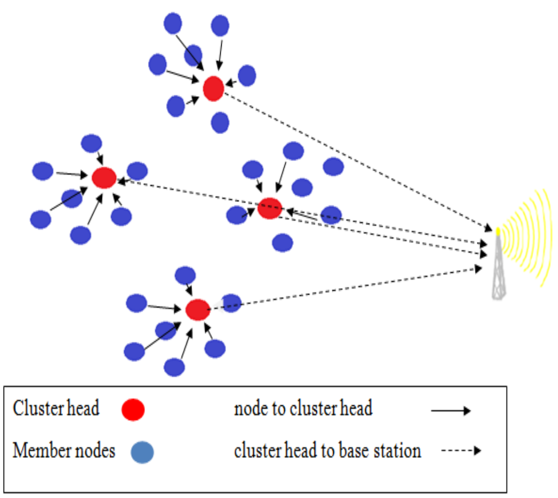



**Figure 1-** Structure of LEACH protocol.

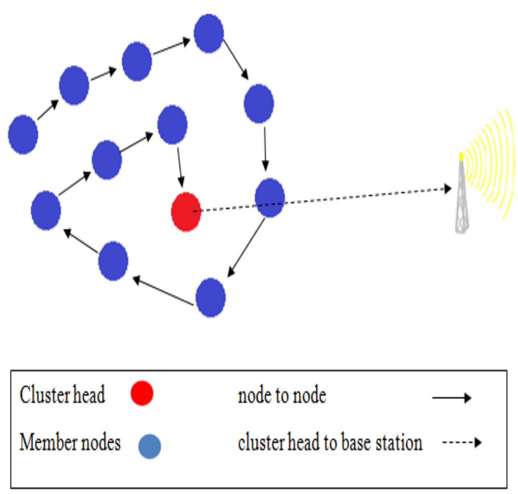



**Figure 2-** Structure of PEGASIS protocol.

**Energy Consumption using PEGASIS:**

The energy consumption of the PEGASIS protocol was calculated using the formal radio model [14] as follows:

For example, to transmit *L-bit* message via distance *d* using the radio formula model, the radio expends:

$$E_T(k,d) = E_{elec} \times L + Eamp \times L \times d^2 \qquad \text{………….. (1)}$$

And to receive this message, the radio expends: ………….. (2)

$$E_R(k) = E_{elec} \times L$$

**Data is received from a neighbor node**

When *n* nodes receive the data from the neighbor node using PEGASIS protocol, the energy consumption per round can be formulated as follows:

$$E = n \times E_{elec} \times L \qquad \text{………….. (3)}$$

**Data aggregation**

The energy consumption required for data aggregation at one node is represented by *Eagg* variable, and can be defined as follows:

$$E = n \times E_{agg} \qquad \text{………….. (4)}$$

**Data transmission to a neighbor node**

When *n* nodes transmit the data to the cluster head on the chain in the current PEGASIS protocol, the energy consumption per round can be formulated as follows:

$$E = n \times E_{elec} \times L + Eamp \times L \times \sum_{i=1}^{n} [d(i-1,i)^2] \qquad \text{…………. (5)}$$

In this formula, the *(long chain)* indicates the distance from *i-1* node to *i* node for all node n form long chain as follows:

$$E = n \times E_{elec} \times L + Eamp \times L \times longchain \qquad \text{………….. (6)}$$

**Data transmission to the base station**

After the head node *i* collect the data from nodes in the wireless sensor networks, it transmits the data to the base station. The energy consumption can be formulated as follows:

$$E = E_{elec} \times L + Eamp \times L \times {d_{(i,BS)}}^2 \qquad \text{………….. (7)}$$

$$E = E_{elec} \times L + Eamp \times L \times ch1bs \qquad \text{………….. (8)}$$

In sum, the contributed nodes of PEGASIS protocol consume energy per round for performing the data transmission, data reception and data aggregation [6].

**The Multi-cluster Power Efficient GAthering in Sensor Information System Protocol Algorithm (MPEGASIS):**

This section explains the structure of MPEGASIS protocol, the proposed scheme, which is designed, based on PEGASIS protocol using k-means algorithm for cluster head selection. In MPEGASIS protocol, the data is transmitted from far node to the cluster head using the shortest path based on the Euclidean distance equation. It is characterized by the division of the network area into four clusters to reduce the transmission delay and to save the nodes energy besides considering the shortest distances among the cluster heads themselves, such that the far cluster head transmitted the data to the nearest cluster head down to the base station. Figure-3 shows the structure of MPEGASIS.

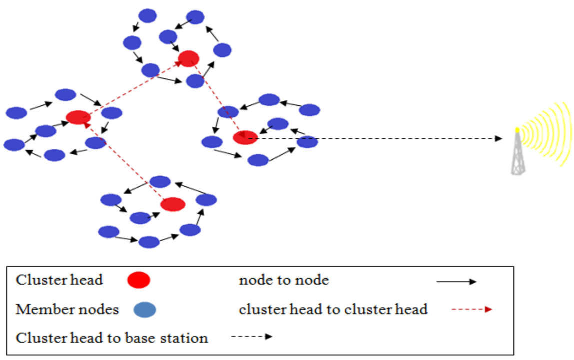



**Figure 3-** Structure of MPEGASIS protocol.

**Structure of MPEGASIS Protocol:**

The structure of the proposed system consists of six main stages. Each stage has specific functions. These six stages are:

1) *Random deployment of Nodes*: this stage defines and configures nodes randomly in the given topography.
2) *Selecting cluster heads*: this stage selects cluster heads randomly from all nodes, these cluster heads are excluded from the total number of nodes.
3) *Apply Euclidean's distance on four colonies*: this stage calculates the distance from the first cluster head with respect to all nodes of network area and repeats this operation for the remaining cluster heads.
4) *K-means algorithm loop*: after choosing a cluster head randomly as in step(2), This algorithm loop is used to determine cluster head correctly by re-nominate another node as a new cluster head using Mean computation until stability of cluster head on the same node. As follow:

   ***Step1***: in general, ask the user how many clusters *k* the data set should be partitioned into. (in this paper k = 4).

   ***Step2***: randomly assigns *k* records to be the initial cluster center locations.

   ***Step3***: for each record, find the nearest cluster center. Thus, in a sense, each cluster center "owns" a subset of records, thereby representing a partition of the data set. Now therefore *k=4* cluster, *C1, C2, C3 and C4* .

   The "nearest" criterion in *step3* is usually Euclidean distance:

$$Euclidean\ Dis(x,y) = \sqrt{\sum_{i=1}^{n}(xi-yi)^2} \quad \ldots\ldots\ldots\ldots (8)$$

   ***Step4***: for each of the *k* clusters, find the cluster centroid and update the location of each cluster center to the new value of the centroid. The cluster centroid in *step4* is found as follows. Suppose there is *n* data point *(a1, b1, c1, d1), (a2, b2, c2, d2), …, (an, bn, cn ,dn)*, the centric of these points is the center of gravity of these points and is located at point *(* $\sum a_i/n$, $\sum b_i/n$ , $\sum c_i/n$, $\sum d_i/n$ *)*. The algorithm terminates when for all clusters *C1, C2, C3 and C4* , all the records "owned" by each cluster center remain in that cluster. Alternatively, the algorithm may terminate when some convergence criterion is met.

   ***Step5***: repeat *step 3 to 5* until convergence or termination [15].
5) *Apply transmission and receiving data in sensor node* : each node transmits data to close neighbor node and receives data from it, without redundant data (using data fusion which based on PEGASIS protocol) in order to save the same length of the message.
6) *Calculate the energy of sensor nodes*: each node consumed energy in each round to transmit and receives data. Member node consumes energy less than the cluster head node. The energy of EPEGASIS is calculated by using the above equation from (1 to 4) in addition to:

   The (*chain1, chain2, chain3 and chain4)* indicate the distance from *i-1* node to *i* node in each cluster as follow:

$$E = n \times E_{elec} \times L + Eamp \times L \times (chain1 + chain2 + chain3 + chain4) \ldots. (10)$$

The (*ch1ch2*, *ch2ch3*, *ch3ch4 and ch4bs)* indicate the distance between each cluster head node *i* to near cluster head, the last *ch4* collect the data from CHs and transmit the data to the (*bs*) base station. The energy consumption can be formulated as follow:

$$E = E_{elec} \times L + Eamp \times L \times (ch1ch2 + ch2ch3 + ch3ch4 + ch4bs) \cdots\cdots (11)$$

In sum, it expected that MPEGASIS protocol consume less energy per round for performing the data transmission, data reception and data aggregation comparing with PEGASIS protocol.

**Behavior of MPEGASIS Protocol:**

The workflow of the proposed method (the MPEGASIS protocol) is presented in figure-4. It starts with the initialization process followed by nodes deployment in the network area, then selected the cluster heads randomly. Also, it introduces the distance calculation of nodes from their cluster head. In terms of MPEGASIS lifecycle, a k-means algorithm is applied in the first round to select a cluster head, which in turn collects the data from the closed nodes and combines them to its own data down to cluster head. Finally, the last node in the chain of cluster heads transmits the data to the base station. MPEGASIS round ends with the calculation process of energy consumption formula per node. It is assumed that the node is stopped when the residual energy reaches (0.26J) and then could be recharged using harvesting energy. Another assumption is stated such that when the number of die nodes became more than (30 node out of 100), the system dispatches the queued nodes from the charging queue to start again from the first step.

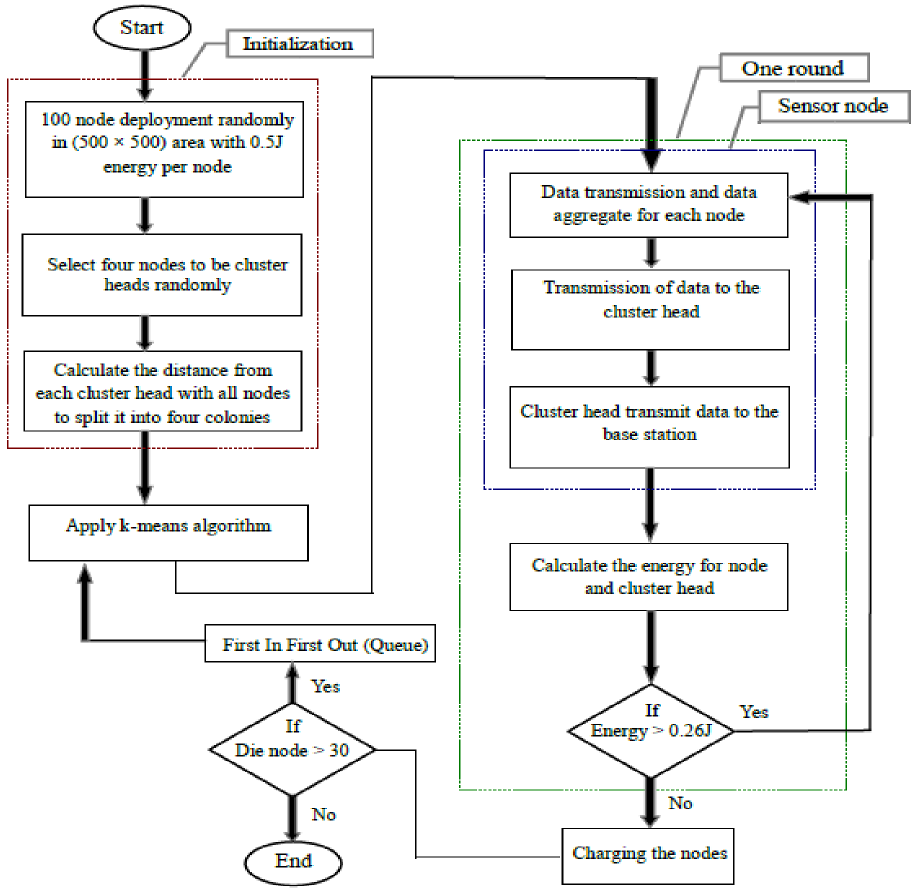



**Figure 4-**Behavior of MPEGASIS Protocol.

**Simulative Environment:**

For our experiments, we simulate an environment with 100 sensor nodes in the field of size (500m x 500m) and the base station is located at (1650, 700) at outside the wireless sensor area. We assume that sensor node has the initial energy of 0.5 joules. Therefore, the total initial energy of all nodes in the field is 50 *joules*. The length of the data message *L* is 2000 *bits*. The energy consumption to transmit and amplify one bit is 50 *nj* and 100 *pj* respectively. In addition, the energy consumption to aggregate one bit is 5 *nj*. Many experiments have been done to evaluate the performance of the

MPEGASIS protocol using the clustering scheme and comparing the results with LEACH and PEGASIS protocols.

**Experiment 1(500mx 500m) Network Topology:**

This test shows and discusses the simulation result of the average residual energy of all sensor nodes in each round for a (500m x 500m) network topology. In figure-5 the data curve of MPEGASIS shows the energy consumption of member nodes including the cluster heads from round 10 to 68 is less than the consumption using LEACH and PEGASIS protocols because k-means algorithm improved the performance of the network and assisted to prolong the lifetime of the network compared to the other two protocols. Moreover, the results show that when LEACH and PEGASIS are implemented, the reaching to the recharging state was faster (at rounds 45 and 55 respectively) whereas MPEGASIS behaved and performed better since it reached the recharging state at round 68 or later.

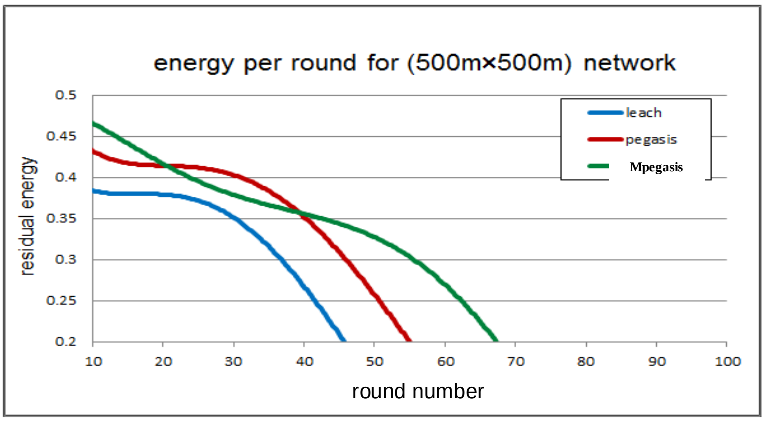


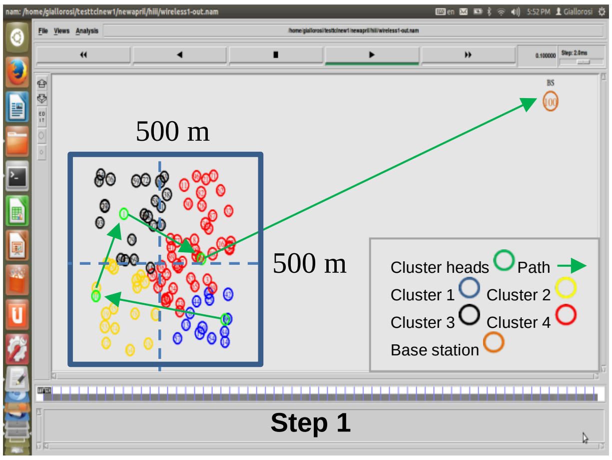

**Figure 5-** The Average of Residual Energy per round of LEACH, PEGASIS and MPEGASIS Protocols for (500m x 500m)

From a competition point of view to the residual energy, two curve intersections can be pointed in figure-5 between MPEGASIS and PEGASIS protocols at rounds 20 and 40, whereas LEACH is out of that competition because of its high energy consumption comparatively.

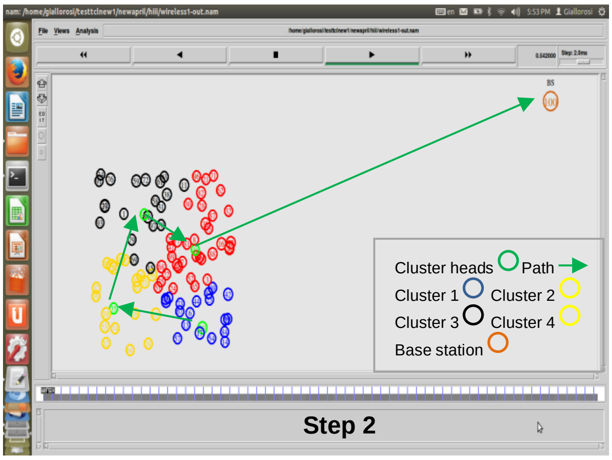
**Cluster Head Selection using K-means Algorithm**

Figure-6 shows the necessary steps or screenshots produced from NAM/NS2. It explores how the cluster head is selected based on k-means algorithm through 100 nodes, deployed in (500m x 500m) area and divided into 4 clusters with 4 cluster heads. In step 1 of figure-6, the 100 nodes are divided into 4 clusters with four cluster heads; all are randomly distributed in the first round of simulation to initialize the system. The k-means algorithm is deployed to select the cluster heads based on Mean equation. From step 2 to step 4 the cluster heads are changed based on the computation of the Mean equation of k-means algorithm. The cluster heads consumed energy down to threshold (0.26J), thus stopped as shown in step 5 and 6 of figure-6.

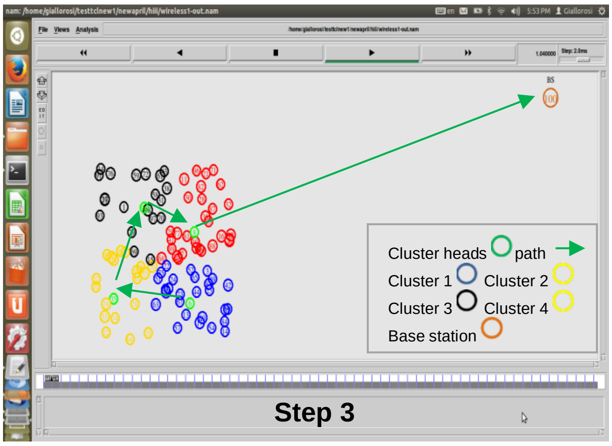
Basically the member (sensor node) consumes less energy than cluster heads. Thus, from step 7 to 10, some of the member nodes are stopped continuously in each round when their energy passes the threshold due to the processing of data aggregation, receiving and transmission of data. It was noted that from step 11 to 12, there were more than 30 member nodes switched to the stop state. Also the system starts recovering the first stopped group of nodes in step 4 and makes them nominated nodes to work in the system. The nodes are stopped again because of energy consumption and the passing of the threshold. Finally, the system repeated the behavior from the beginning that is the life cycle of all nodes.



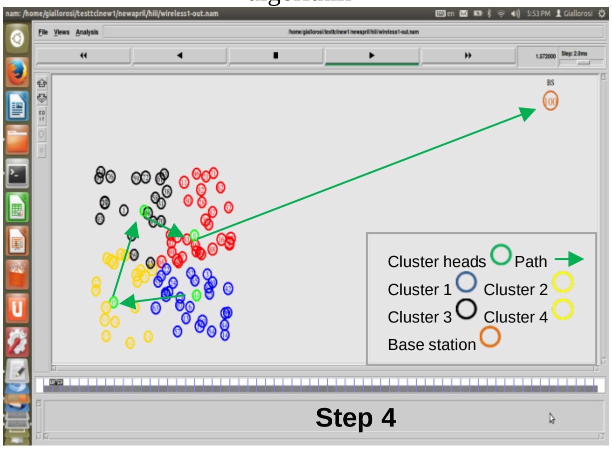

Initialization of 100 nodes randomly in WSN



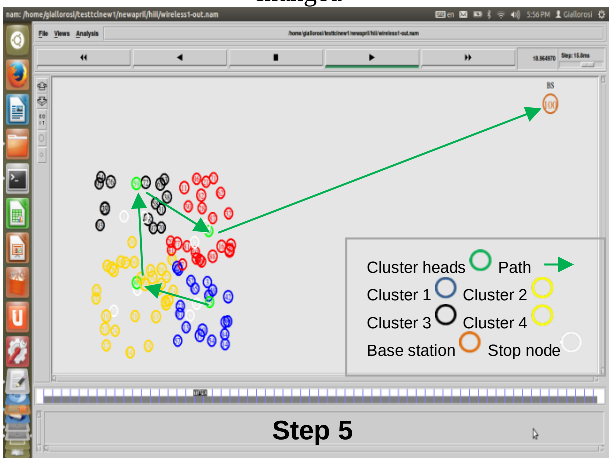

Selection of new cluster heads (CHs) based on kmeans algorithm



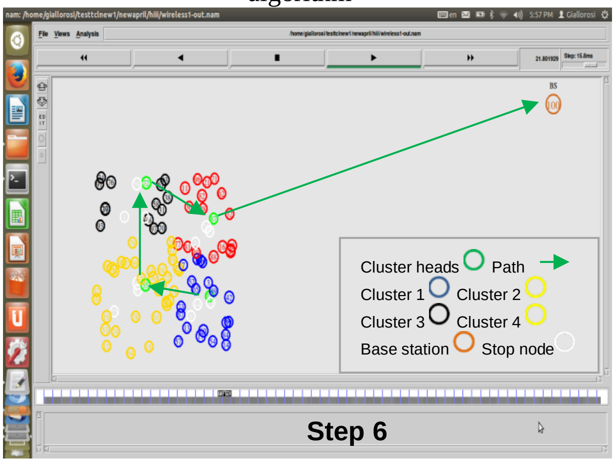

CH2, CH3 and CH4 kept their position while CH1 changed



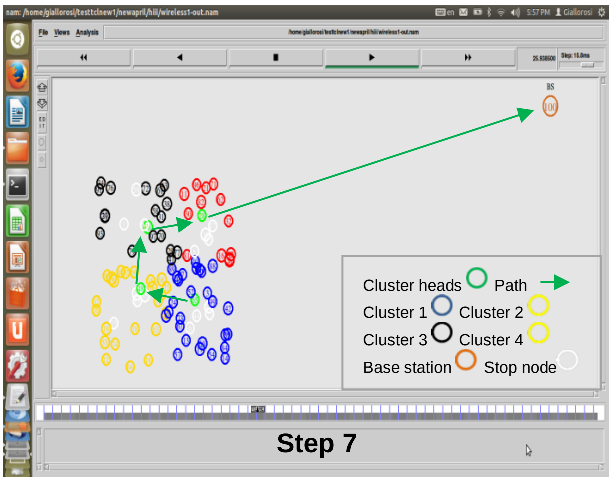

CH1 changed according to Mean equation of k-means algorithm



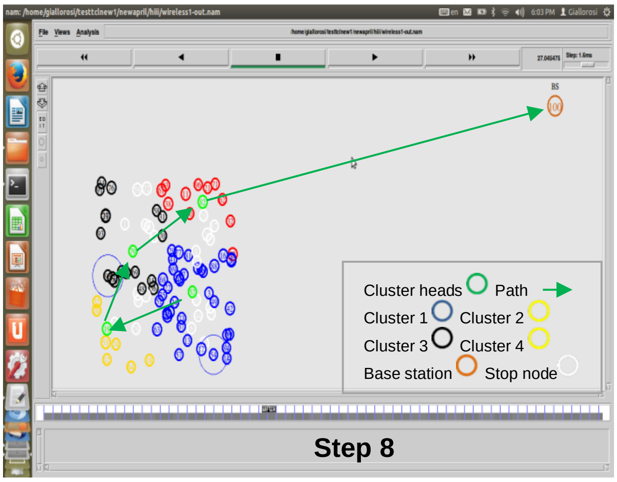

CH1, CH2, CH3 and CH4 are changed to new CHs



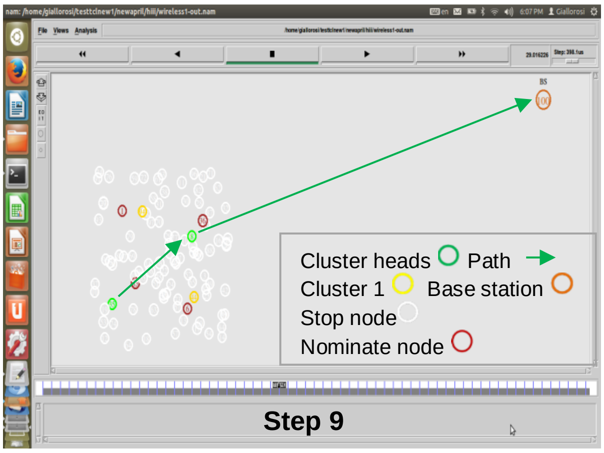

The old CH1, CH2, CH3 and CH4 are stopped and select new CHs



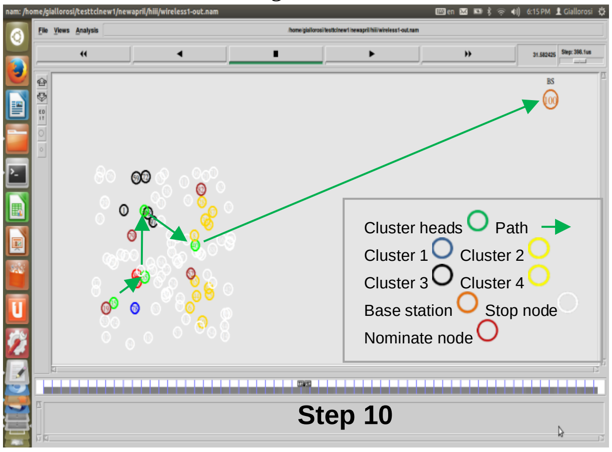

CH1, CH2, CH3 and CH4 are changed and the stop nodes increased



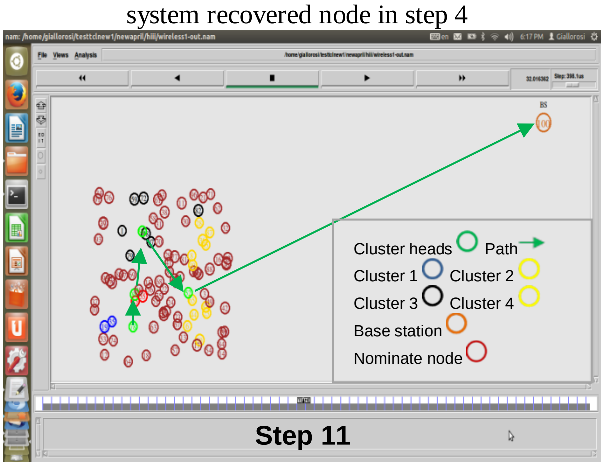

All CHs are changed according to Mean equation of k-means algorithm



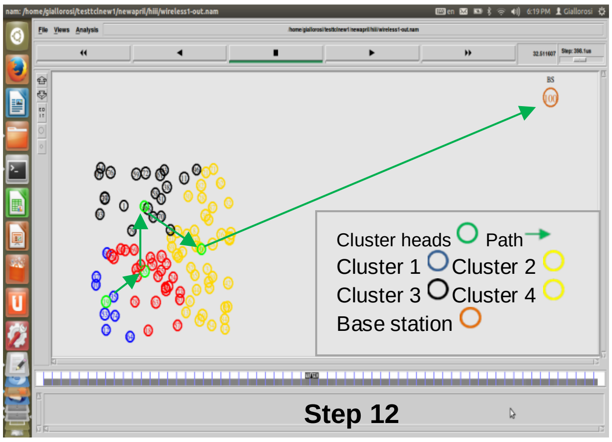

Two CHs are active, many nodes are stopped and the system recovered node in step 4




The system selects CHs from a set of nomination nodes




The system distribute the nominated nodes to be CHs




Selection of new CHs, the system work is similar to the previous steps

**Figure 6**-MPEGASIS protocol using NAM of NS2

**Experiment 2 (700mx 700m) Network Topology:**

Geographically the distance between all nodes with their own cluster head is increased for this experiment, so the distance from the cluster head to the base station is decreased because the position of the base station is fixed. Figure-7 shows the simulated result of the average residual energy of all sensor nodes at each round. In experiment 2, the system residual energy was examined using (700m x700m) area that means the distances among sensor nodes are increased. In figure-7, the initial behavior of the MPEGASIS protocol (the curvature) represents high energy consumption compared to PEGASIS protocol during round 1 down to 16. Graphically, after the intersection (the equality point between MPEGASIS and PEGASIS protocols), the MPEGASIS saves better as energy and stopped late in round 33 compared to LEACH and PEGASIS which are stopped at rounds 18 and 27 respectively.

**Experiment 3 (1000mx1000m) Network Topology:**

The testing for larger area such as (1000mx1000m) network, topology is targeted in this experiment. Figure-8 shows the simulation result of the average residual energy of all sensor nodes at each round, the distance between all nodes to their own cluster head were increased much more, so the distance from the cluster head to the base station was decreased more because the position of the base station was fixed. Typically, when the area becomes large, the nodes waste the energy fast and consequently the system stopped quickly, but MPEGASIS converged the advantages of PEGASIS and LEACH towards the base station. Therefore the lifetime of MPEGASIS protocol is stopped late in round 10 whereas LEACH and PEGASIS protocol are stopped at rounds 6 and 8 respectively.

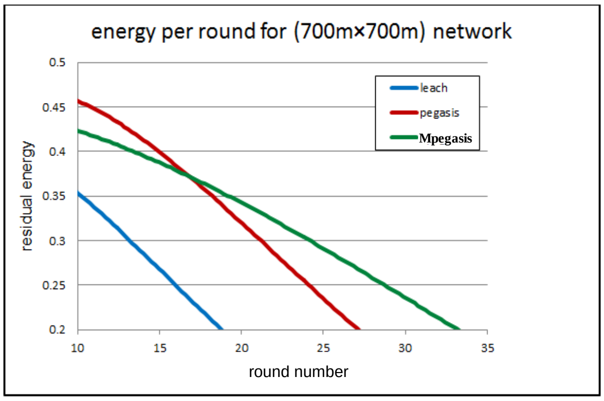



**Figure 7-** The average of residual energy per round of LEACH, PEGASIS and MPEGASIS protocols for (700m x700m)

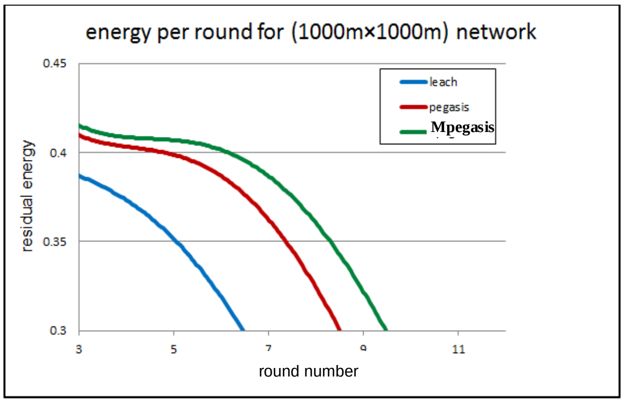



**Figure 8-** The average of residual energy per round of LEACH, PEGASIS and MPEGASIS protocols for (1000m x1000m)

**Experiment 4 (500mx500m) Network Topology with Centroid Base Station:**

In this experiment, the base station is placed at the center of the network at (250m,250m) to evaluate the system behavior for an area of (500m x500m). As appears in figure 9, LEACH protocol showed superiority over PEGASIS protocol because the distance from the cluster head in any cluster to the base station is less than the distance of chain nodes to the cluster head for the same cluster down to the base station. On the other hand the MPEGASIS protocol outperforms LEACH and PEGASIS protocols by making the balance between the two important parameters, distance and clustering, and consequently affected the overall performance of the system positively. Also, from the presented results in figure 9, it can be concluded that the behavior of LEACH protocol outperforms PEGASIS protocol at the beginning and more at the end rounds in terms of residual energy. Curves intersections occur at rounds 13 and 27 because of the distance parameter towards the base station in PEGASIS protocol was less than the counterpart distance in LEACH protocol. Anatomically, it is clear that clustering and aggregation besides the center position of base station has significantly contributed to low energy consumption of MPAGASIS as compared with LEACH and PEGASIS on average. As a result, MPEGASIS proved that it performs better than other protocols, although the other protocols consumed less energy in some rounds but finally they are stopped before the MPEGASIS protocol.

**Experiment 5 (500mx500m) Network Topology with Two Base Stations:**

In this experiment, the placement of two base stations on the left and right sides of an area of (500m x500m) network topology is considered. The first base station is placed at the left of the network topology in which cluster head (CH1) collects data from its own member nodes using chain mechanism to transmit the data to the cluster head (CH2) which in turn transmits the data to the left base station after combining the source data to his own data. In the opposite direction, the second base station found at the right of the topology deals with the cluster head (CH3) as a source of data which collects data from its own member nodes using a chain mechanism, then transmits the data to the cluster head (CH4) and finally forwards it towards the right base station after combing the received data with its own data.

The implementation result of the two base station scenario is shown in figure-10. It was noticed that MPEGASIS protocol stopped in round 58 whereas the same protocol was stopped in round 68 using one base station in figure-5. The reason is that the distance between four cluster heads using one base station is less than the distance between the cluster head and another cluster head using two base stations. Generally, when residual energy per round is considered, the investigation of the result shows that MPEGASIS performs better than LEACH by 36% and PEGASIS by 28%.

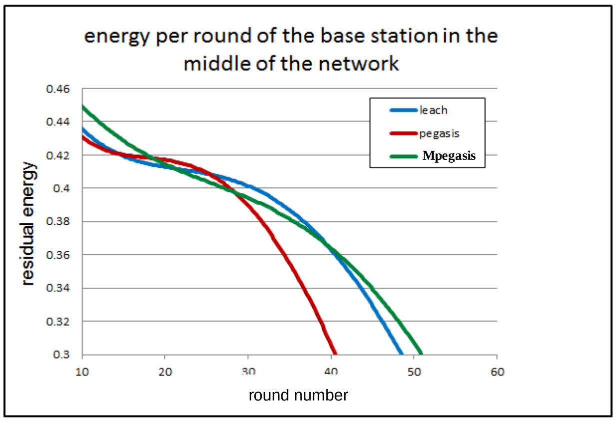



**Figure 9-**The Average of Residual Energy per Round of LEACH, PEGASIS and MPEGASIS Protocols, with Centroid Base Station

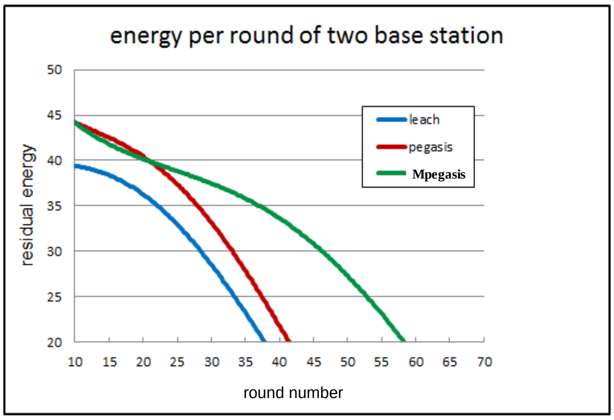



**Figure 10-**The Total of Residual Energy per Round for LEACH, PEGASIS and MPEGASIS Protocols of two Base Stations for the given Network.

**Conclusions:**

- Our proposed method (MPEGASIS protocol) is designed to avoid the main disadvantage of the existing PEGASIS protocol by selecting 4 cluster head rather than the PEGASIS protocol which select one cluster head and form a long chain, the MPEGASIS apply clustering of nodes in order to reduce the average distance between the member nodes and cluster head per colony.
- The Multi-cluster PEGASIS protocol outperforms LEACH and PEGASIS protocols since it minimizes the distance between nodes in one cluster by connecting far node to the next closest node down to their own cluster head. The front cluster head transmits the data to the closest cluster head and finally the rare cluster head transmits the fusion data to the base station. These cluster heads are chosen using the k-means algorithm.
- Energy consumption in MPEGASIS protocol has been reduced by about 21% as compared with PEGASIS protocol and about 33% less than LEACH protocol on average. The power of MPEGASIS scheme is derived from its two main activities that affected the distances indirectly; firstly, the effect of K-means deployment as a global solution for clustering as well as the promoting criteria of cluster head, and secondly the selection of the shortest path in the chain construction locally per colony. Both solutions prolong the lifetime of the system significantly.

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