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A Novel Approach Towards Achieving Energy Efficient and Load Balancing for Wireless Sensor Network used in Wearable Physiological Monitoring

S.Kannan

Research Scholar, Department of Mathematics, CEG, Anna University,Chennai-600025, India.

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ABSTRACT

An individual quality of life can be improved by using collection of sensors which can be embedded into the fabric of wearer is called as wearable physiological monitoring system. This system can continuously monitor vital signals and transmit wirelessly to a remote monitoring system. Wireless sensor network can be used in wearable physiological system which has limited availability of energy on network nodes. Clustering can be used to increase lifetime for wireless sensor networks. Energy efficient is possible in wireless sensor network by reselecting cluster heads according to the ratio of residual energy of each node to their distance from base station. Load Balancing among cluster heads can also increase lifetime of wireless sensor network. In this paper, an extension of Reselection-based Energy Efficient Routing Algorithm (REERA) for WSN and minheap algorithm is used for achieving energy efficiency and load balancing among cluster heads. Simulation results show that the Reselection-based approach is more efficient in saving energy and load balancing among cluster heads in WSNs compared to traditional LEACH,WLEACH, ELEACH, and LEACH-FL Algorithm.

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INTRODUCTION

Traditional healthcare system monitoring setup is not very comfortable and does not provide any freedom to patients (Kannan.S, 2012). Also, this system cannot be used for wearable physiological monitoring applications because of their large size it could not be wearied(D.Raskovic and *et al*, 2000) (D.Raskovic and *et al*, 2004). Over a period of time gels used in electrodes can be harmful to skin and can affect signal quality(P.S.Pandian and *et al*.,2008). Hence wearable physiological monitoring systems need to be developed.

The wearable physiological monitoring system consists of three systems namely integrated sensors, wearable data acquisition and processing hardware and remote monitoring station. There are number of wearable physiological monitoring systems such as smart vest, AMON, vivometrics, life shirt, life guard and MagIC were developed to monitor the health status of wearer.

The traditional wearable physiological systems has drawbacks such as noise problem, location of sensors cannot be changed, heavy load for processing unit, and cables of sensors can get damaged very easily due to turning of cables. These drawbacks can be solved by wireless sensor networks.

A number of small wireless sensor nodes placed on human body can create a wireless body area network which can monitor vital signals of the wearer and it can send the report to the user and doctor. A network can be formed by deploying sensor nodes in an adhoc manner with no predefined routes.

Physiological monitoring can be done by wireless sensor network which has three modules such as integrated sensor nodes, wearable data acquisition and processing hardware (sink node) and remote monitoring station. Since sensor nodes in wireless sensor network have limited energy that energy should be preserved to maintain network life time. Clustering is an effective technique which is useful in extending life time of wireless sensor network. Low-Energy Adaptive Clustering Hierarchy (LEACH) uses single-hop communication; it cannot be deployed in networks spread over large distances.

LEACH cannot provide actual load balancing. Cluster heads are elected only on the basis of probability, not taking energy into consideration and uniform distribution cannot be ensured. Thus, nodes

Corresponding Author: S.Kannan, Research Scholar, Department of Mathematics, CEG, Anna University, Chennai-600025, India.
Tel: +919840663345; E-mail: kannan_s10@rediffmail.com

with lower energy will be selected as cluster heads, which leads to death of these nodes very quickly.

Reselection-based Energy Efficient Routing Algorithm (REERA) is an improvement of LEACH (Jin Wang and *et al*, 2013). In this paper REERA has been extended and compared with Energy LEACH (E-LEACH), Weighted LEACH (W-LEACH), and LEACH implemented using fuzzy logic (LEACH-FL) and Load Balancing among cluster heads using min heap algorithm is discussed.

Related Works:

A number of clustering algorithms for WSN have been addressed in (AmeerAhamedAbbasi and *et al*. 2007),(OlutayoBoyinbode and *et al*, 2010), (Congfeng Jiang and *et al*, 2009) etc. In 2002, (Heinzelman W. B. and *et al*, 2002) have developed LEACH. LEACH is a popular clustering technique that forms clusters by using a distributed algorithm. However, the main disadvantage of this approach is that a node with very low energy may be selected as a CH which may die quickly. Therefore, a large number of algorithms have been developed to improve LEACH such as PEGASIS (Lindsey S. and *et al*., 2003), HEED (Younis O. and *et al*., 2004), EEPSC (Amir SepasiZahmati and *et al*., 2007) etc. Compared to LEACH, PEGASIS improves network lifetime, but it requires dynamic topology adjustment and the data delay is significantly high and it is unsuitable for large-sized networks. In 2011, (Pratyay K. and Prasanta K. J., 2011) proposed an algorithm of execution time *O* (*n* log *n*), in which no energy consumption issue has been addressed in this algorithm.

Overview Of Leach:

LEACH is a kind of cluster-based routing protocols, which uses distributed cluster formation. LEACH randomly, selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. In LEACH, the Cluster Heads compress data arriving from member nodes and send an aggregated packet to the BS.

In order to reduce the amount of information that must be transmitted to the BS. In order to reduce inter & intra cluster interference LEACH uses a TDMA/code-division multiple access (CDMA) MAC.

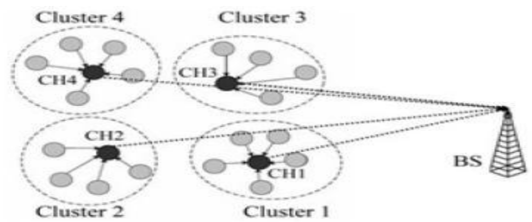

Fig. 1: LEACH Clustering Hierarchy Model.

The operation of LEACH is done into two steps, the setup phase and the steady state phase. In setup phase the nodes are organized into clusters and CHs are selected. The node is selected as a cluster head for the current round if the random number is less than the threshold value T (n), which is given by

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

In the steady state phase, the actual data is transferred to the BS. To minimize overhead the duration of the steady state phase should be longer than the duration of the setup phase. The CH node, after receiving all the data from its member nodes, performs aggregation before sending it to the BS. After a certain time period, the setup phase is restarted and new CHs are selected.

Leach Family:

LEACH is a totally distributed approach and requires no global information. There are several modifications of the LEACH scheme, and together they form the LEACH family, such as Two-Level hierarchy LEACH (TL-LEACH) (V. Loscri and *et al*, 2008), Energy-LEACH (E-LEACH) (K. Akkaya and *et al*, 2005), Multihop-LEACH (M-LEACH) (K. Akkaya and *et al*, 2005), LEACH with Centralized clustering algorithm (LEACH-C)(Xuxun Liu ,2012) , LEACH with Vice-cluster head (V-LEACH)(M. BaniYassein and *et al*, 2009), LEACH implementation using Fuzzy Logic (LEACH-FL) (Jong-Myoung Kim and *et al*, 2008), Weighted-LEACH (W-LEACH) (HanadyM. Abdulsalam and *et al*, 2013), Threshold based LEACH (T-LEACH) (Jiman Hong, 2008).

Energy LEACH (E-LEACH):

Energy-LEACH protocol improves the cluster head selection procedure. It makes residual energy of node as the main matrix which decides whether these nodes turn into cluster head or not in the next round. In first round communication, every node has the same probability to turn into cluster head.

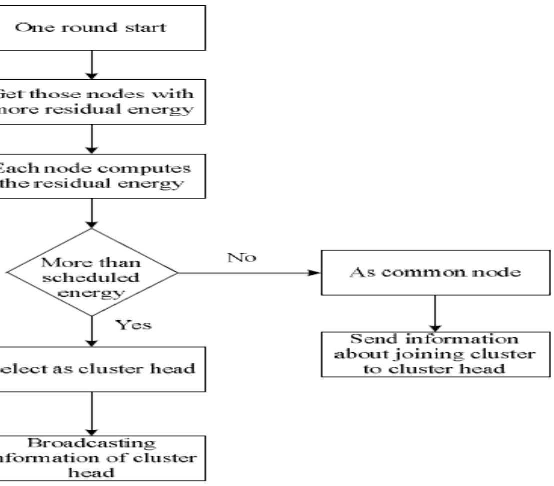

Fig. 2: Flow Chart of E-LEACH Cluster Formation Phase.

Weighted LEACH (W-LEACH):

Weighted Low Energy Adaptive Clustering Hierarchy Aggregation(W-LEACH), is a centralized data aggregation algorithm. As in LEACH, W-LEACH consists of a setup phase and a steady state phase. In the setup phase, W-LEACH first calculates a weight value, wi, and assigns it to each sensor si. Modified the definition of p to be the percentage of the maximum number of CHs instead of the actual number of CHs as it is defined in the original LEACH. A maximum of p% of alive sensors are then selected to be CHs based on the calculated weights, such that the higher the weights the better the chance for them to be CHs.

The weights are calculated as,

$$w_i = \begin{cases} e_i * d_i & \text{if } d_i > d_{threshold} \\ d_i & \text{otherwise} \end{cases}$$

LEACH implemented using Fuzzy Logic (LEACH-FL):

To achieve high energy efficiency, gathering and calculating other information that could affect the energy consumption may occurs heavy overhead. So, the overhead of cluster head election may be highly reduced by using fuzzy logic. Three fuzzy variables(energy, concentration and centrality) were used for fuzzy if-then rule. The base station collects the energy and location information from all sensor nodes and elects the cluster heads using fuzzy if-then rule according to the collected fuzzy variables.

Increasing Network Lifetime:

LEACH has some problems like the hot spots problem and LEACH does not consider the residual energy of each node. In order to address these two problems, Reselection-based Energy Efficient Routing Algorithm (REERA) is used in which cluster head selection mechanism takes residual energy and distance between each node and base station into consideration.

System model:

Network model:

A set of sensors are randomly dispersed to continuously monitor the surrounding environment. The entire network is divided into several clusters with different size as shown in network model. In each cluster, there is a cluster head, which can perform data fusion after collecting all the raw data from its ordinary members.

Energy Model:

The famous first order radio is used as the energy model. If the distance between the transmitter and the receiver is larger than a threshold d_0, the multi-path (d^4power loss) model is used; otherwise, the free space (d^2power loss) is used. Therefore, the energy spent to transmit an l-bit packet over distance d can be calculated as follows (Jin Wang and etal., 2013):

$$E_{Tx}(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs} d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp} d^4 & d \geq d_0 \end{cases} \quad (2)$$

Where E_{elec} denotes the electronics energy, which depends on factors such as the digital coding, modulation and so on; $\varepsilon_{fs}$and ε_{mp}denotes the amplifier energy to maintain an acceptable signal-to-noise ratio; d_0=sqrt($\varepsilon_{fs}/\varepsilon_{mp}$) is a constant. The energy spent to receive this message can be calculated as follows:

$$E_{Rx}(l) = lE_{elec} \quad (3)$$

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```
/* for every round*/
If rand()<P_opt then
Compute the chance using Fuzzy if-then rule;
AdvCandidate_Message(chance);
myCH = me;
while receiving Candidate-Message from node N
if chance < N's chance then
myCH N;
chance N's chance;
end if
end while
if myCH == me then
Adv CH-Message;
end if
else
On receiving CH-message
Select the closest CH;
Send Cluster_Join_Message to the closest CH;
end if
```

Fig. 3: Clustering Algorithm using Fuzzy Logic.

	Energy	Local distance	Chance
1	Low	Far	Very low
2	Low	Medium	Low
3	Low	Close	Rather low
4	Medium	Far	Med low
5	Medium	Medium	Med
6	Medium	Close	Med high
7	High	Far	Rather high
8	High	Medium	High
9	High	Close	Very high

Fig. 4: Fuzzy if then rule.

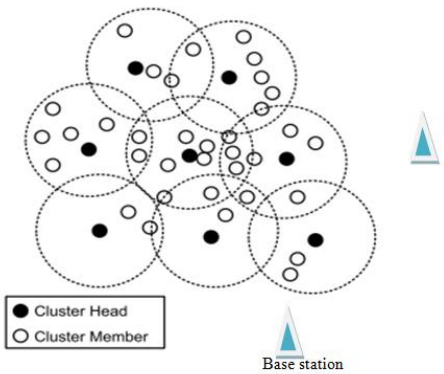

Fig. 5: Network model.

Reselection Algorithm:

Reselection-based Energy Efficient Routing Algorithm consists of three fundamental phases as follows: candidate cluster heads selection phase, cluster formation and final cluster heads selection phase and the data transmission phase (Jin Wang and *et al*, 2013).

Cluster Head Selection Phase

The base station broadcasts a BS_ADV message to all the nodes after network deployment at a certain power level. According to the received signal strength each node will compute its approximate distance d to the base station and also computes a parameter K^i which is set as following:

$$K^i = E_{residual} / d(i, BS) \quad (4)$$

where $E_{residual}$ represents the residual energy of node and d (i, BS) is the distance between node and the base station.

Here, d_{max} and d_{min} represent the maximum distance and the minimum distance between sensor nodes and the base station. The competition radius R^i of the node as following:

$$R^i = \frac{(d_{max}-d_{min})*d(i, BS)}{d_{max}} + d_{min} \quad (5)$$

Probability T(n) value helps each node to decide whether they can be able to compete to be a cluster head. Nodes are deployed randomly and when no of nodes are larger than the threshold value then the node becomes a member node. Otherwise, it can be

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within the cluster radius of other candidate cluster heads. If it is true, the node releases it from the competition and becomes a member node. If it is not true, then the node selects itself to be a cluster head and informs all the neighbor nodes through messages.

Cluster Formation and Final Cluster Heads Selection Phase:

According to the received signal strength all cluster members finds to which cluster they can be associated. After finding the cluster head they inform that they wish to join as a member by sending a JOIN_MSG (ID, K^i). After receiving all the JOIN_MSG from its own cluster members cluster head finds member node which has the large K value. The cluster head die early due to transmission distance and heavy traffic. So to the save energy consumption in the entire network, nodes close to the base station and which has more residual energy can be selected as cluster heads.

According the value of K, the final cluster heads is selected. All nodes and previous cluster head in each cluster sends a message which contains the ID to the node which has the biggest value of K and becomes member of this node. The final cluster head is the node which receives all these messages and creates a TDMA schedule, according to the schedule it informs their member nodes to forward the data which is sensed by them.

Data Transmission Phase:

After the final cluster heads selection and the TDMA schedules is decided then data transmission can be started. According to the TDMA schedule member nodes belongs to their cluster head will send their sensed data based on their slot allocated to them.

In order to save energy consumption all node radio signal will be turned on only when their allocated slot comes. The cluster heads by using multihop transmission sends data to the base station after doing data fusion. Data fusion is done after receiving all the data from their member nodes. Like this next round begins over a period of time which is predefined.

Load balancing:

Clustering mechanism can be used for load balancing. Cluster–Head is responsible for the creating cluster and performance of cluster is affected by cluster nodes (Pratyay Kuilab and *et al*, 2012).

A min binary heap is a complete binary tree which has keys and objects stored at the nodes, such that a node's key is greater than or equal to its parent's nodes. Heap is described as smallest ones will be at the top.

Cluster head which is at root from the min-heap is picked which has the minimum number of sensor nodes allotted to it and assign a sensor node to that Cluster head. Therefore, the cluster heads which is minimum loaded is distributed with the available loads; thereby load balancing among Cluster heads is shown in the figure 6. Distance between two nodes decides energy consumption.

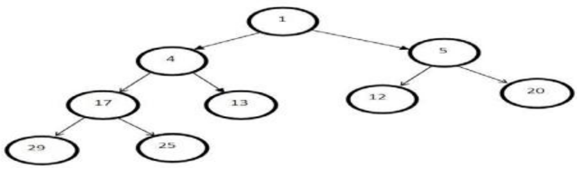

Fig. 6: Min Heap tree.

By assigning the sensor node to nearest minimum loaded Cluster head in their assignment round. Energy consumption of all sensor nodes has been reduced. Thus the min heap algorithm considers load balancing of the Cluster heads and the energy efficiency of the sensor nodes.

Types of Sensor Nodes:

Depending on the communication range between the sensor nodes and the gateways, there can be two kinds "restricted node"and "open node".

- **Restricted Node**: Restricted nodes are those sensor nodes, which can communicate with one and only one gateway
- **Restricted Set**: Restricted set is the set of all restricted nodes in the WSN. We refer this set as 'R_{set}'. It is obvious to note that sensor S_i belongs to R_{set}, if it is satisfies the following criteria:

$$S_i \in R_{set} \Leftrightarrow [\{G_j \in Com(S_i) \mid G_j \in \zeta\} \wedge \{G_k \notin Com(S_i) \mid \forall G_k \in (\zeta - G_j)\}]$$

Where, *Com* (S_i) is the set of all those gateways, which are within communication range of $S_i$and ζ is the set of all gateways.

- **Open Node**: Open nodes are those sensor nodes, which can communicate with more than one gateway.
- **Open Set**: Open set is collection of all open nodes in the WSN. We refer this set as'O_{set}'.A sensor node Si is belongs to O_{set}, if it satisfies the following criteria:

$$S_i \in O_{set} \Leftrightarrow [S_i \notin R_{set}]$$

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Min Heap Algorithm:

Input:

A set of sensors T={S_1,S_2…….S_n}

A set of cluster heads ς={G_1,G_2…..G_n} where m<n

d_{ij}=For each S_i and G_j,the distance between S_i to G_j; where $G_j \in$ Com(S_i)

$R_{set}$and O_{set}

Output:

An assignment A:T-> ςsuch thatthe overall maximum number of sensor node of CHs and total consumed energy is minimized.

Step 1:While($R_{set} \neq$ NULL)

Assign successive sensor nodes S_i to their corresponding gateway $G_j$such that $S_i \in$ R_{set} and $G_j \in$Com(S_i) and delete S_i from R_{set} and T

}

Step 2:Build a min-heap using the gateways on the number of allotted sensor nodes to the gateways

Step 3: While(T≠NULL)

{

Step3.1 : Pick up the root node of the min-heap say G_j

Step3.2: Select and assign a sensor(Open) node Si to $G_j$such that $G_j \in$ Com(S_i) and Si is nearest sensor node to G_j

Step 3.3: Delete S_i from T

Step 3.4: Adjust the min-heap so that the minimum loaded gateway will be at root

}

Step 4: Stop

Simulation Results:

Performance Evaluation:

MATLAB is used to evaluate the performance of the algorithms discussed above. Assumptions are made by creating 100 sensor nodes with the same initial energy which are distributed randomly in a square region of *100 x 100 m*^{2} and relevant simulation parameters are listed in Table1

Table 1: Simulation Parameters.

Parameters	Definition	Unit
N	Number of sensor nodes	100
E_0	Initial energy of sensor nodes	2J
R	Transmission radius	50m
E_{elec}	Energy dissipation to run the radio device	50 nJ/bit
ε_{fs}	Free space model of transmitter amplifier	10 pJ/bit/m2
ε_{mp}	Multi-path model of transmitter amplifier	0.0013 pJ/bit/m4
L	Packet length	2000 bits
d_0	Distance threshold	$\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$
BS_Location	Base station position	(200,50)

The network performance is analyzed by comparing REERA with conventional LEACH protocol. Figure 7 illustrates the comparison in terms of residual energy. Therefore, in a given period of time, REERA can save more energy.

The following figures shows the comparison results of REERA with WLEACH, ELEACH, LEACH using Fuzzy logic in terms of residual energy.

The figure 11 shows the comparison of before load balancing and after load balancing in REERA algorithm in terms of residual energy using min-heap based clustering algorithm.

Conclusion:

A wearable wireless sensor network of physiological integrated sensors placed in user collects data and transmits continuously to a remote monitoring station where the user health status is remotely monitored. The wearable physiological monitoring systems should provide accurate data recordings compared to traditional monitoring systems. The devices used should have time stamped data storage without any failures it should do continuous monitoring. Monitoring continuously will help to detect disease earlier and increase the level of confidence among patients and in turn it can improve quality life of user. This allows user to do their daily activities without any problem. There is no need for the user to stay at home. Users are free to move around without any problem.

One of the most problem in wireless sensor network is energy on network nodes is very limited. Hence, energy efficient is needed for increasing network lifetime. The maximum energy is lost by data transmission and communication. Clustering helps to solve this problem. Leach is one of clustering mechanisms which can help in prolonging the network lifetime. Reselection based energy efficient routing algorithm discussed in this paper can improve better than LEACH. Hence, simulation results show that this Reselection technique is better

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in energy efficient compared with WLEACH, ELEACH and LEACH-FL. Also, by using min heap algorithm load balancing among cluster heads is done to improve energy efficiency.

Future work is to integrate Wireless Body Area Network (WBAN) and Wireless Sensor Network in an energy efficient manner to improve quality life of an individual. Also, to reduce noise in data recordings of WBAN and wireless sensor network and to implement Expected Transmission Count (ETX).

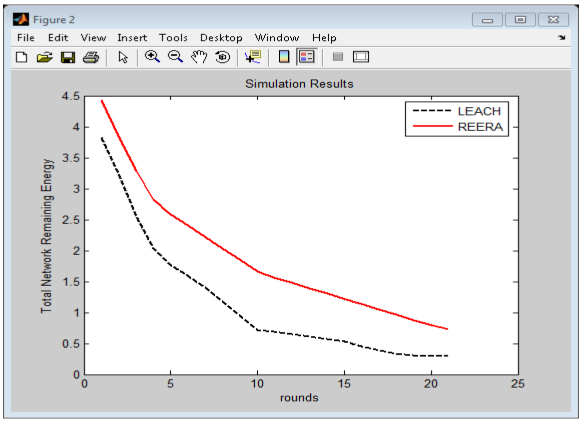

Fig. 7: Network Lifetime Comparison of REERA-LEACH.

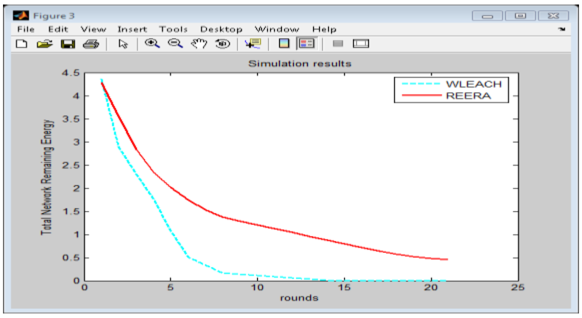

Fig. 8: Network Lifetime Comparison of REERA-WLEACH.

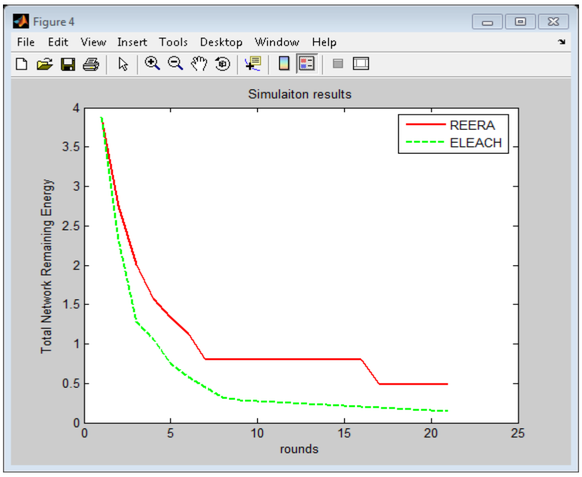

Fig. 9: Network Lifetime Comparison of REERA-ELEACH.

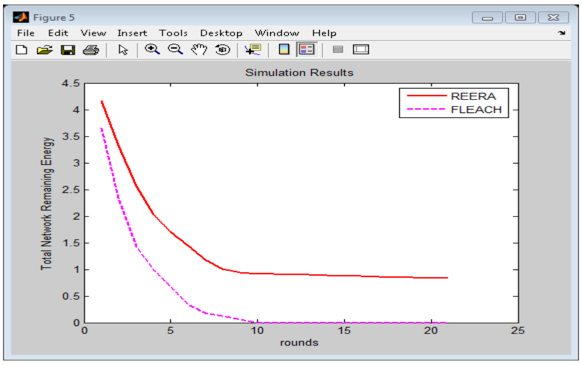

Fig. 10: Network Lifetime Comparison of REERA –LEACH-FL.

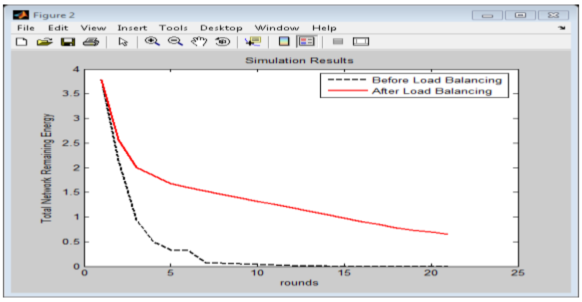

Fig. 11: Load Balancing.

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