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Performance Evaluation of Rb-Leach with Varying Number of Regions in WSN

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Abstract

Network lifetime has been an area critically and most extensively researched in wireless sensor networks (WSNs) due to the finite energy in the deployed sensor nodes. Diverse routing protocols have been proposed for use in WSNs for the main purpose of extension of the network lifetime without the degradation in the network throughput and efficiency. The aim of this paper is to evaluate the performance of RB-LEACH (a homogenous centralized routing protocol) deployed using different numbers of regions. The RB-LEACH has been implemented with 8 sub-regions and 12 sub-regions, which was compared with the performance of the RB-LEACH of 10 sub-regions. The result shows considerable improvement in the stability period of the network with a decrease in the number of sub-regions and vice versa.

Keywords: WSN, LEACH, Network Lifetime, Throughput, Energy Efficiency.

INTRODUCTION

Wireless Sensor Network (WSNs) is an interconnection of wireless sensing and computational devices (Arjun and Naveen, 2013). The proliferation of microelectromechanical systems (MEMs) has resulted in increase in the deployment of wireless sensor networks for the purpose of monitoring, sensing physical phenomena such as temperature, humidity, pressure and others; and data transmission to the sink or data center (Agrawal and Zeng, 2011). WSNs can be deployed for use in industries, agriculture, for military surveillance, forest area monitoring and security (Aponte-Luis et al. 2018). Sensors comprise of in-built transmitters and receivers (transceivers), processors, memory units, and finite power units, with optional units such as GPS, mobility.

The low energy deployed on the wireless sensor nodes and incessant energy loss due to packet collision, overhearing, idle-listening and overhead have posed diverse challenges for researchers in WSNs and is receiving significant attention from researchers (Minet, 2009). Routing protocols help to reduce the rate of energy consumption without degrading the quality of service (QoS) measured in terms of lifetime and number of data packets successfully transmitted (Heinzelman et al. 2000). The basic network configuration used in WSNs is the Flat network where all nodes act as both source and sink; and the Hierarchical network where few nodes which are selected as cluster heads receive, process and transmit data from their cluster members using one or multi-hop transmission (Gherbi et al. 2016).

Direct communication protocol for WSNs whereby all nodes transmit to the base station via a single-hop, results in rapid energy loss. The basic cluster-based protocol developed is the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol with a solution for increased network lifetime through cluster heads selections using the threshold value stated in equation (1) (Stefanos et al. 2013). LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication. (Kemal and Mohamed, 2005)

$$T_{(s)} = \begin{cases} \dfrac{Popt}{1 - Popt\left(r * \mathrm{mod} \dfrac{1}{Popt}\right)} & \text{if } s \in G \\ 0 & Otherwise \end{cases} \qquad (1)$$

where

Popt = percentage of cluster head

r = number of rounds

G = Set of nodes not yet cluster heads in $\left(\frac{1}{\text{Popt}}\right)$ rounds.

LEACH has 2 stages of operation, set-up phase; when the cluster heads are decided, broadcast their node IDs, then nodes which are not cluster heads decide to join a cluster based on the highest signal to noise ratio (SNR) received. Upon the completion of the set-up phase, the steady state phase starts with transmission of packets to the cluster heads using a time-division multiple access (TDMA) protocol to eliminate packet loss. LEACH has a random distribution of the cluster heads (CHs) across the network which results in fast depletion of node energy and short lifetime (Subhashree et al. 2014).

Power-Efficient Gathering in Sensor Information Systems (PEGASIS), an improvement of the LEACH protocol was developed which involves each node receiving and transmitting from and to their near neighbors, thereby forming a chain using the greedy algorithm to determine the starting point (Kemal and Mohamed, 2005). This led to an improvement of between 100 – 300% for different network sizes over LEACH (Toor and Jain, 2016). Hybrid Energy-Efficient Distributed clustering (HEED) is a hybrid protocol for WSN aimed at achieving better network lifetime using a distributed clustering algorithm which involves taking the residual energy of the nodes into account.

RB-LEACH is a centralized hierarchical clustering based algorithm where the CHs are selected by the Base Station. The protocol involves a mobile sink logically dividing the sensing area into smaller regions while sensor nodes are uniformly and randomly distributed across with each node's location determined with the use of a Global Positioning System and transmitting same information to the sink or central control (Salamah and Oyedeji, 2016). This protocol has achieved between 38-250% improvements in the network stability period for different network sizes over the LEACH protocol (Salamah and Oyedeji, 2016).

This paper evaluates the performances in terms of throughput and network lifetime, of the RB-LEACH protocol with different number of regions.

MATERIALS AND METHODS

RB-LEACH PROTOCOL

RB-LEACH protocol has been designed and developed to solve the functional shortcomings which affect the efficiency of the protocol during deployment in a sensing field. Some basic issues from LEACH that have been considered in RB-LEACH includes the level of randomness of the selection process of cluster heads without consideration of the residual energy which could lead to overload and fast energy depletion of the nodes. As a result of the distribution of the cluster heads, the average transmission distance of each node cannot be easily estimated across the sensing field. The number of cluster heads deployed per round is not strictly defined or determined in LEACH (Akyildiz et al, 2002; Heinzelman et al. 2002).

RB-LEACH which is a centralized hierarchical protocol was proposed to mitigate the effect of these basic problems. RB-LEACH, by dividing the sensing field into sub-regions and electing a CH from each region to form a cluster has been able to reduce drastically the average transmission distance of each sensing node in a region, which will lead to reduction in energy used. As each sub-region has only a CH per round, RB-LEACH has succeeded in limiting the number of CHs thereby reducing the energy of the WSN as CHs are high energy consuming node. RB-LEACH protocol has sought to reduce the network overhead cost by electing CHs for a few numbers of rounds by the BS based on the nodes residual energies (Salamah and Oyedeji, 2016). Figure 1 shows the flowchart of RB-LEACH.

The First Order Radio Model has been used for estimating the energy consumption of a sensor node in transmitting a packet of K-bits of data from the sender to the recipient and also calculates the energy needed for a receiver to correctly receive the packet of K-bits of data (Tudose et al, 2013). The energy or signal-to-noise ratio required and utilized by the First order radio model to transmit and receive a K-

bit message over a distance *R* are shown in the following equations 2, 3 and 4 respectively (Rezaei and Mobininejad, 2012).

$$E_{TX}(K, R) = E_{elec} * k + E_{amp} * K*R^2 \text{ when } R < R_0 \quad (2)$$

$$E_{TX}(K, R) = E_{elec} * k + E_{FS} * K*R^4 \text{ when } R \geq R_0 \quad (3)$$

Where

R_0 = Distance Threshold Value

$$E_{rx}(K) = E_{elec} * K \quad (4)$$

RB-LEACH was implemented with base station mobility and has been divided into the following stages;

- Set-up phase whereby cluster heads are decided for all the sub-regions of the wireless sensor field and clusters subsequently formed with sensor nodes joining to the CHs with the highest SNR.
- Steady-state phase whereby all forms of packet transmission takes place from cluster members to CHs using TDMA timeslots, and from CHs to sink.

RB-LEACH as a result of its regional-based algorithm is a great option for utilization and deployment in real life scenario with specific application areas which include;

- Forest fire detection
- Air pollution detection
- Weather change detection such as for temperature, humidity, pressure in fields, data centers and industrial areas.
- For intrusion detection across boundaries.

RB-LEACH is well suited for these applications as the data collected are location stamped which results to prompt attention to the area of interest.

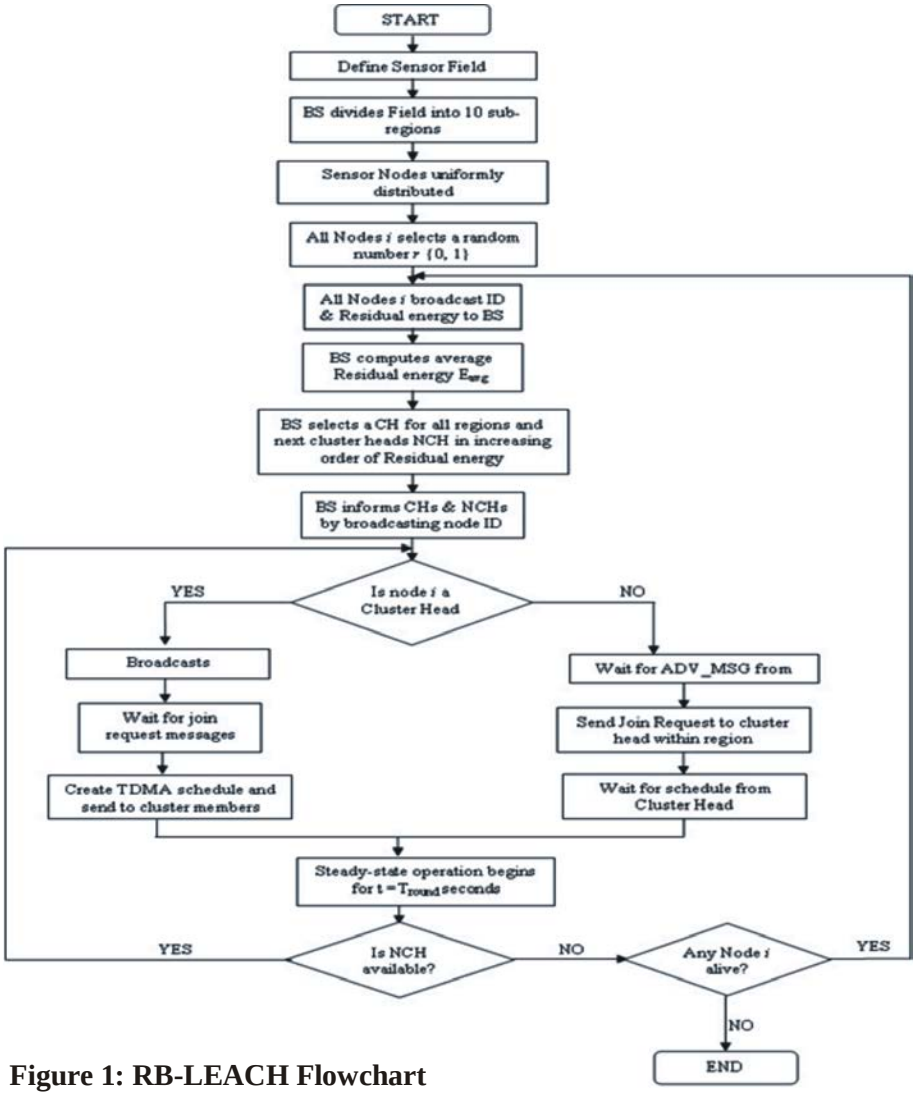

Figure 1: RB-LEACH Flowchart

MODELLING AND SIMULATION

The RB-LEACH has been simulated in MATLAB with 2 variations; one with 8 sub-regions of sizes 50m * 25m for 100m * 100m sensing field, and the other with 12 sub-regions. Figure 2 shows the sensing field for RB-LEACH (V8) with the blue squares as the sensor node and the red circle the mobile sink.

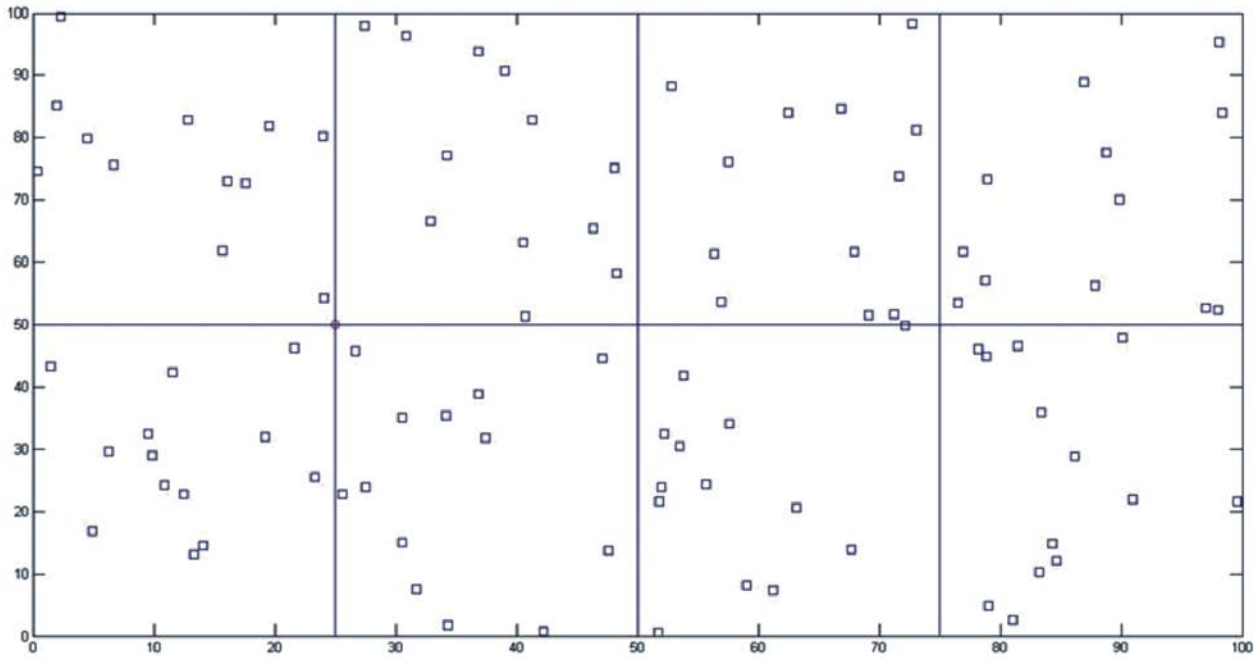

Figure 2: RB-LEACH (V8) with 100 Nodes in a 100m * 100m Field

The metrics used in evaluating the performance and efficiency of the protocol with the varying number of sub-regions are;

- Network Lifetime which is the duration of time from the deployment of the network to the death of the first node measured in terms of number of rounds.
- Network Throughput is the number of data packets sent over the network both from all the nodes to the CHs and from the CHs to the sink. This is defined as the measure of the data transfer rate of the network.

The radio model parameters used for the simulation are shown in Table 1.

Table 1: Basic Parameters Used

Parameters	Values
Simulator	MATLAB R2013a
Initial Energy	0.5J
Packet Size	4000 bits
Control Packet Size	400 bits
Energy used to transmit over short distance E_{fs}	10 pJ/bit/m^2
Energy used to transmit over longer distance E_{mp}	0.0013 pJ/bit/m^4
Energy needed for transmission or receiving E_{elec}	50 nJ/bit
Data aggregation energy E_{DA}	5 nJ/bit/report

The same parameters used in the LEACH protocol have been utilized for the simulation.

RESULTS AND DISCUSSION

Figure 3 is the graph showing the network lifetime for the different protocols with the RB-LEACH (V8) showing extended stability period over the RB-LEACH and LEACH protocols. With fewer regions, the network lifetime was longer while the RB-LEACH (V12) network had a shorter lifetime than the RB-LEACH. With greater number of regions, the network has more CHs which results in energy loss.

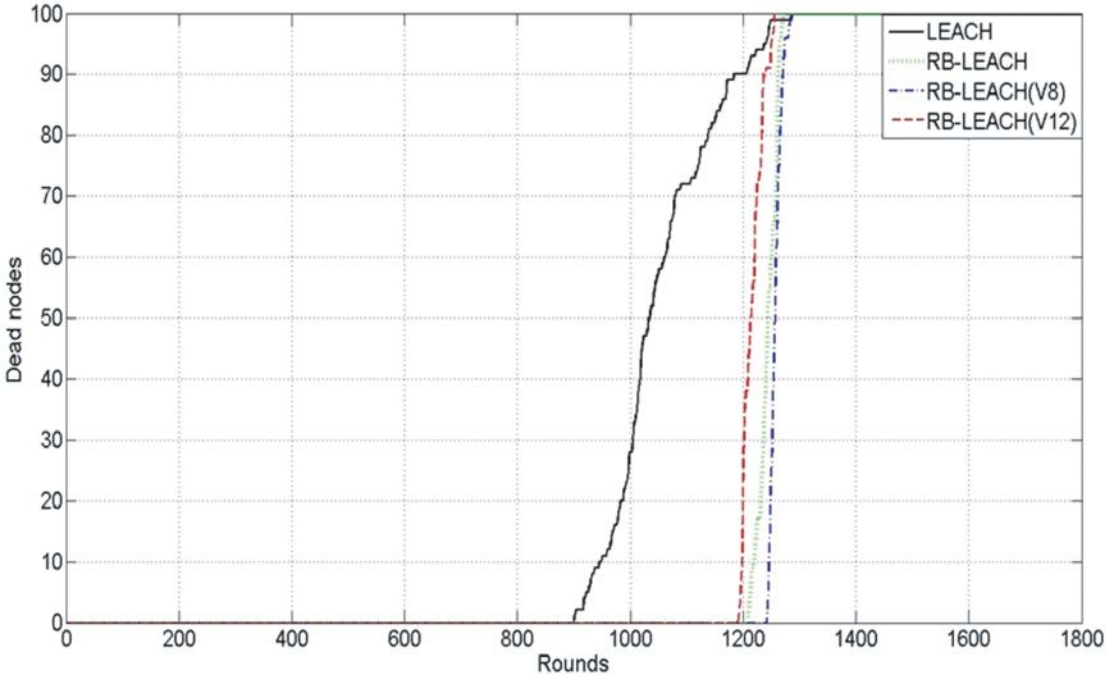

Figure 3: Network Lifetime for 100 Nodes in 100m*100m Field

RB-LEACH protocols including the RB-LEACH (V8) and RB-LEACH (V12) have shown increase in the number of data packets sent to the CHs over LEACH Protocol. Figure 4 shows the total number of data signals received by CHs and indicates that RB-LEACH(V8) is the most efficient in data gathering. These data signal are thereafter aggregated and sent to the sink thereby reducing the number of data sent.

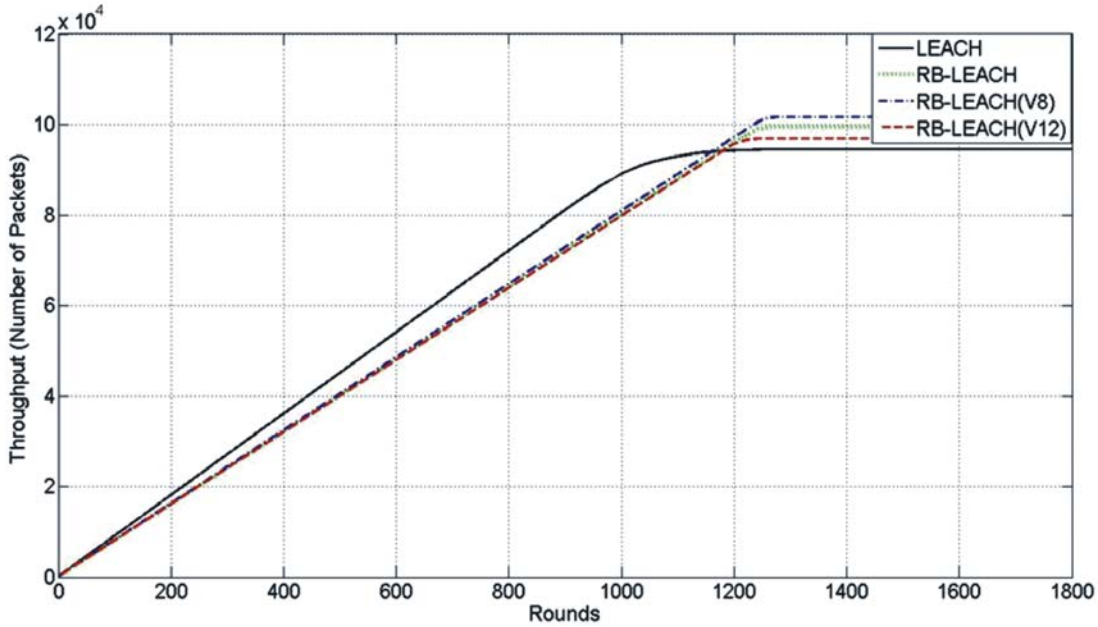

Figure 4: 100 Sensors in a 100m*100m Field a) Number of Packets to Chs

To achieve an energy efficient WSN, the energy required for transmitting and receiving data signals across the network to the BS should be optimally minimum. Figure 5 shows the rate of energy consumption and utilization of the wireless sensor network per round for the network lifetime. RB-LEACH(V8) has better clusters that utilize less energy for data transmission as shown in Figure 5 resulting in longer lifetime.

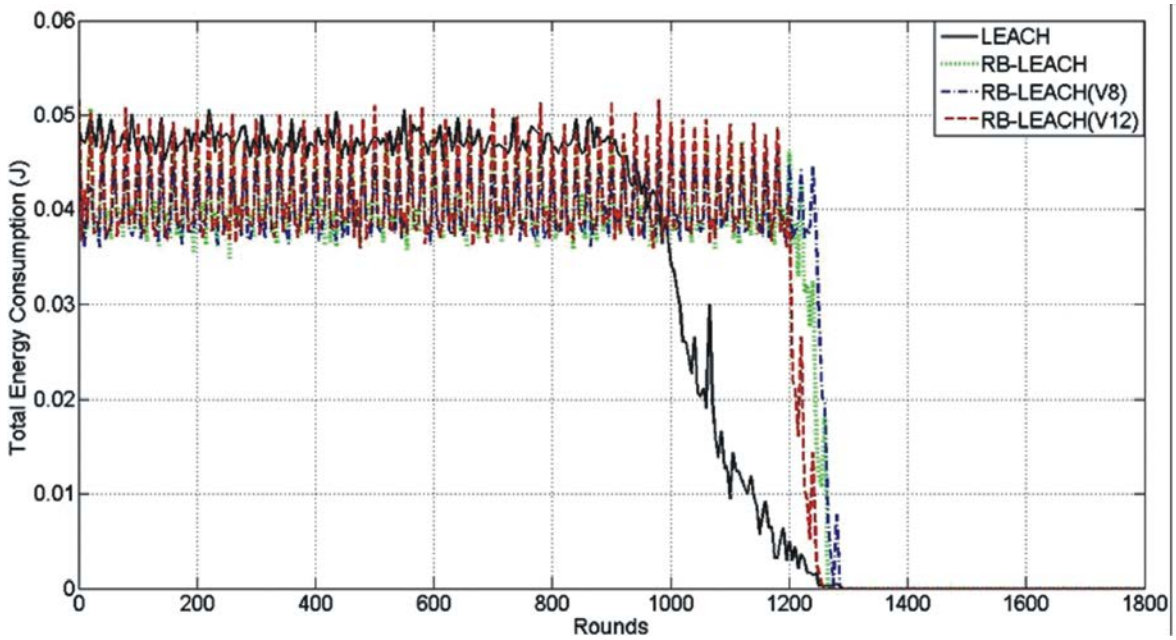

Figure 5: Energy Consumption per Round for 100nodes in 100m*100m Field

Minimizing the number of selected cluster heads is very important to prolonging the network lifetime as CHs consume more energy. CHs are high energy using sensor nodes as they receive data signals from all their cluster members, aggregate all data and thereafter transmitting the aggregated data to the BS.

Figure 6 below shows the numbers of CHs per round in each of the different protocols. With RB-LEACH (V8) having the lowest average CHs per round, the average amount of energy utilized per round has significantly reduced resulting in an extended lifetime over the LEACH and RB-LEACH.

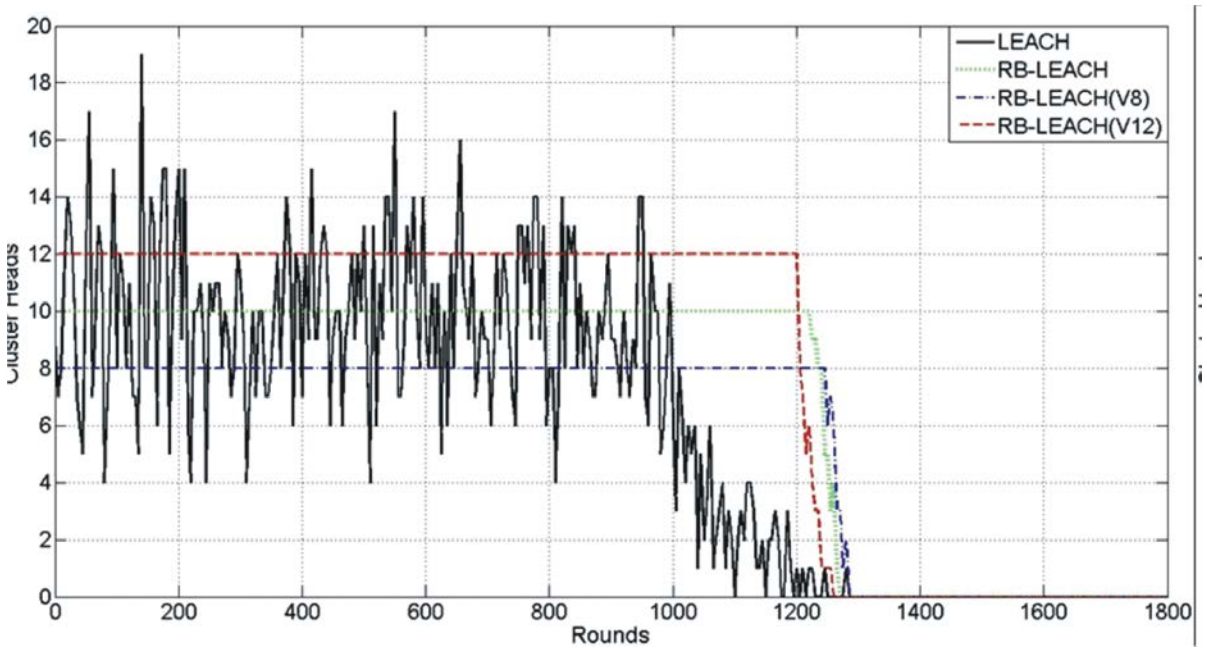

Figure 6: Cluster Heads per Round for 100 Sensors in a 100m*100m Field

CONCLUSION

Development of energy efficient routing protocols for wireless sensor networks is a priority in ensuring longer network lifetime and efficient throughput. This research has been able to simulate and analyze the performance of the RB-LEACH protocol with different parameters. The result of the simulation shows considerable improvement in the stability period of the network with a decrease in the number of sub-regions and vice versa.

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