International Journal of Advanced Science and Technology
Vol.121 (2018), pp.31-42
http://dx.doi.org/10.14257/ijast.2018.121.03

SNRP: Sub-Netting Based Routing Protocol for Improved Network Performance in WSN

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Abstract

Wireless Sensor Networks (WSNs) experiences various technical challenges such as power, transmission range, and computation imposed on the sensor nodes. As energy conservation is one of the key issues in the applications of WSN, we describe an energy efficient network with traditional routing method that divides the whole network into smaller regions based on sensor locations. The proposed sub-netting technique consists of a base station (BS) located at a distant place and a Sub-BS is placed inside the network for direct communications from nodes nearer to it. The nodes far away from BS and Sub-BS adopt conventional method communication. Low energy adaptive clustering hierarchy (LEACH) is the most famous hierarchical routing protocol implemented in the proposed network scenario. The network performance considering parameters like stability period, throughput and energy consumption is compared and found that the proposed network shows enhanced performance.

***Keywords**: WSN, Sub-netting, energy utilization, throughput, lifetime*

1. Introduction

WSN consists of spatially distributed sensor nodes or motes to monitor different environmental or physical condition [1] and communicates their sensed information to the end user. The important components of any WSN is a sensing unit (consists of sensors and ADC), processing unit (manages the collaboration of sensor nodes to carry sensing tasks), transceiver (connects the node to the network) and a power unit (typically <0.5 Ah, 1.2 V) [1]. With the gradual increase in application due to its diverse nature, WSN has emerged as one of the most researched communication infrastructures. Yet there are some typical issues including limited battery power, limited computational capability, environmental challenges that hamper the network performance.

One of the important design challenges that WSN has to face is to conserve energy by reducing power consumption at different levels of communication. Further, utilization of energy-efficient routing protocols (especially cluster-based algorithms) has been proved to be the best solution to reduce energy effectively [2]. Clustering [3] is a method used by network designer to group the nodes for communication to the base station (BS). The nodes cannot send data directly to BS instead they send it to cluster head (CH) who takes the responsibility to aggregate and group the data before sending to BS.

LEACH [4] is the primitive clustering protocol that distributes energy dissipation evenly amid all nodes within the network. The network field is grouped into small clusters, each having its own CH. The CH allocates TDMA [5] time slots for its non-CH nodes that can transmit its sensed data only during its defined time. The node turns off its radio during idle condition. This TDMA scheduling saves energy and extends the network

Received (May 10, 2018), Review Result (July 23, 2018), Accepted (October 13, 2018)

ISSN: 2005-4238 IJAST

lifetime. Further, the cluster head also performs data fusion on the collected data to filter out any redundant information and then transmits to the BS. In this way, the transmission energy also reduces to a considerable amount.

In this paper, a method called sub-netting based routing protocol (SNRP) is recommended to improve network performance. The network is subdivided into various regions based on the distance of BS from each sensor node. A sub-base station is placed within the network that can be recharged from time to time. The sensor nodes placed nearer to the BS or sub-BS can transmit its data directly to them instead of forming clusters and CHs. The LEACH protocol can be used on some of the regions instead of the whole network to conserve energy in the unnecessary transmission of data.

The rest paper organization is as follows. Section 2 reviews the related published work on LEACH protocol and other modifications of LEACH. Section 3 presents the proposed network model description. Section 4 illustrates the pros and cons of the network performances in comparison to conventional one. And finally, Section 5 indicates the future research followed by the conclusive remark.

2. Related Works

Research has been done over the past decade to enhance network performance in terms of energy utilization, throughput and lifetime [6]. The design of the sink node [7] that is responsible for transmission of aggregated data to the end user has also been investigated by researchers. A lot of advancement has been done with LEACH protocol to modify the algorithm and achieve better performance [8] [9], either in terms of low power consumption, no of alive nodes with higher rounds or computational complexity.

A distributed PSO algorithm for cluster formation in WSN was proposed in order to give low communication overheads with better performance [10]. A two-level clustering scheme called TL-LEACH [11] has been proposed in which there are two CHs on two different levels. The CHs in one level collects information from member nodes like in LEACH, whereas the CHs in the second tier have CHs of the first tier as member node. As the network load is well balanced, the hence longevity of network increases.

Another multi-hop routing protocol called MR-LEACH [12] has been proposed to conserve energy by partitioning the field into various layers of clusters. CH of each layer cooperates with adjacent layers for transmission of data to BS.

Energy Efficient Unequal Clustering (EEUC) [13] algorithm tends to divide the network into unequally sized clusters. The clusters nearer to BS are smaller in comparison to those that are far away. Hence the protocol actively preserves energy in the inter-cluster communication of data. An energy-balanced clustering scheme [14] was discussed that effectively increases the network lifetime where each node elected as a cluster head for a particular round calculates its lifetime in a distributed manner.

Arranging the size of clusters and their transmission ranges [15] for WSN aims to maintain uniform energy consumption for all the CHs by reducing the size of cluster near to BS (that relays more data). Simulation-based results have shown prolonged network lifetime over LEACH protocol. Chen et.al in [13] presented a power saving technique called Span without hampering the capacity or connectivity of the multi-hop ad-hoc network. The nodes present in the region of the shared channel take decision individually whether to participate as a coordinator for data transmission or go to sleep mode. Span is a randomized algorithm that also increases capacity a latency of the network.

M-GEAR [16] is another multi-hop routing protocol uses a gateway node is placed between the sensing areas. The nodes nearer to gateway node can directly send data to it instead of sink node. The technique provides improved distribution of CHs within the sensing field.

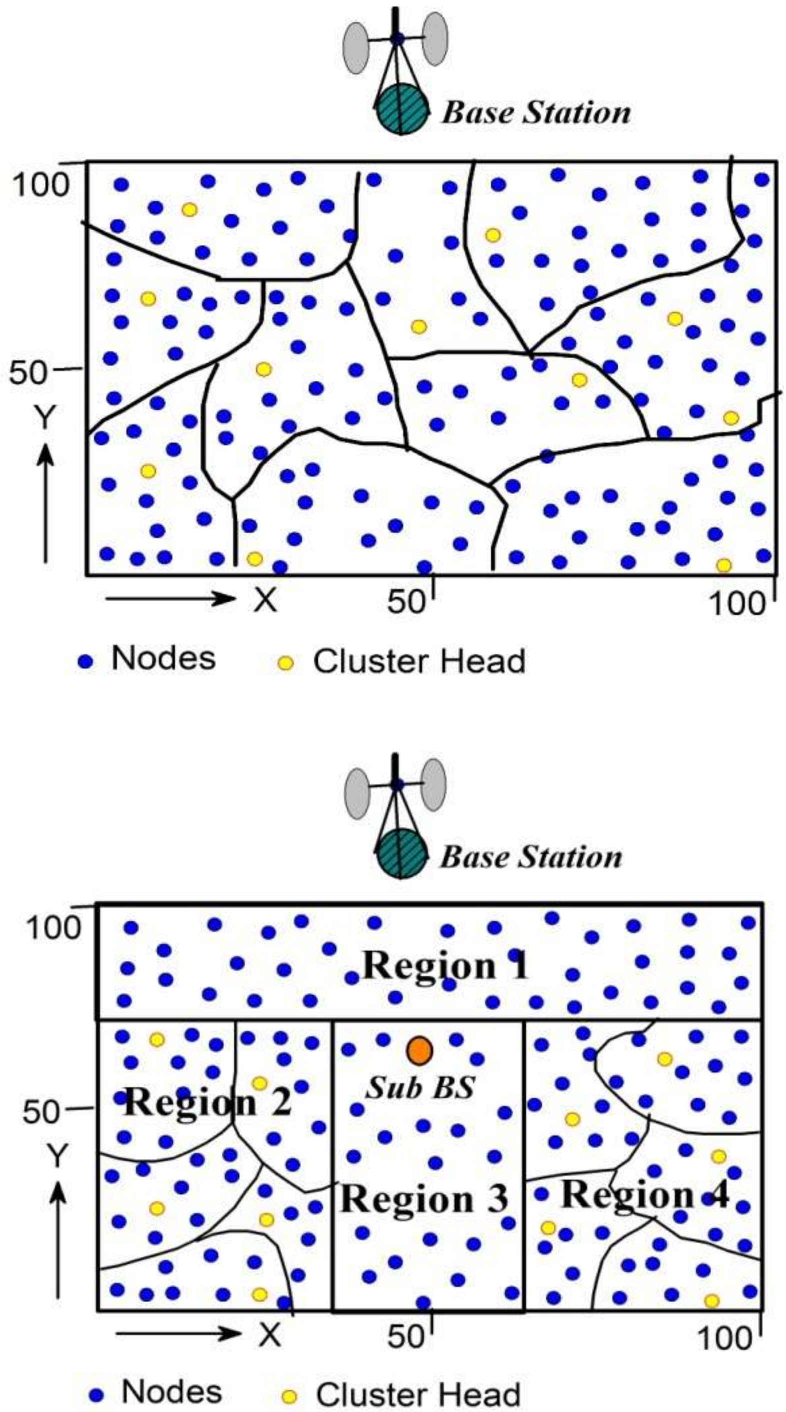
For any clustering protocol, the CH is overloaded with functions like data aggregation and then accelerating the fused data to the BS again takes a lot of power consumption. Moreover, when the BS is situated at a distant place from the network, then the energy of the CHs farther from BS will deplete at a faster rate than that of comparatively nearer ones. The dead CHs have to be replaced with new elected CHs and corresponding new clusters which increases unnecessary power consumption. As per our knowledge and literature survey of related articles, we did not find any article that divides the network and implement two different kinds of routing to improve network performances. In this article, the design of the network is modified by placing a sub-BS within the network when the main BS is situated in a farther place to save network energy with extension in network lifetime

3. Proposed Work

A cluster-based network deals with three modes of data transmission [17]. The cluster members transmit data to the corresponding CHs following a TDMA schedule called as intra-cluster Transmission. Data is exchanged between neighboring CHs under inter-cluster Transmission. And finally, the cluster heads transmits the fused data to the sink or BS under long-haul transmission [18].

The power required for these modes of operation can never be uniform, in case the BS is placed at a farther location (outside the network). Intra-cluster requires a low level of energy as compared to other modes of transmission which reduces a considerable amount of energy resulting in minimal packet drop ratio [18].

The network model shown in Figure 1 describes one such scenario where BS is located in a distant region. The model in Figure 1(a) shows the existing network model where the LEACH protocol is implemented in the entire network to form clusters and CHs to transmit data from a source node to BS. Figure 1(b) shows the proposed network model where the sensing field is divided into four small regions (Region 1, 2, 3 and 4) depending on the type of communication required to send the data in order to reduce average transmission distance. Moreover, we use another rechargeable sub-BS within the network. Nodes nearer to the BS in region 1 can send the data directly to the BS. Nodes in region 3 are nearer to sub-BS, hence they can send data directly to sub-BS. Region 2 and 4 are clustered regions and clusters and CHs are formed using the LEACH protocol. The sub-BS allots TDMA slots to CHs of region 2 and 4 to send their aggregated data to sub-BS. The sub-BS collects all data from Region 2, 3 and 4 and performs data aggregation to remove redundancy and then transmits to BS. Increasing the clustering level in either of the regions increases the epidemic threshold [19] and decreases the total epidemic size of the whole network.



(a)

(b)

Figure 1. (a) Existing Network Model (b) Proposed Network Model

Let us consider 'n' number of sensor nodes deployed randomly in the network. The first order radio model shown in figure 2 can be either a free space model or multi-path fading model [20] depending on the distance from sensing to the receiving node.

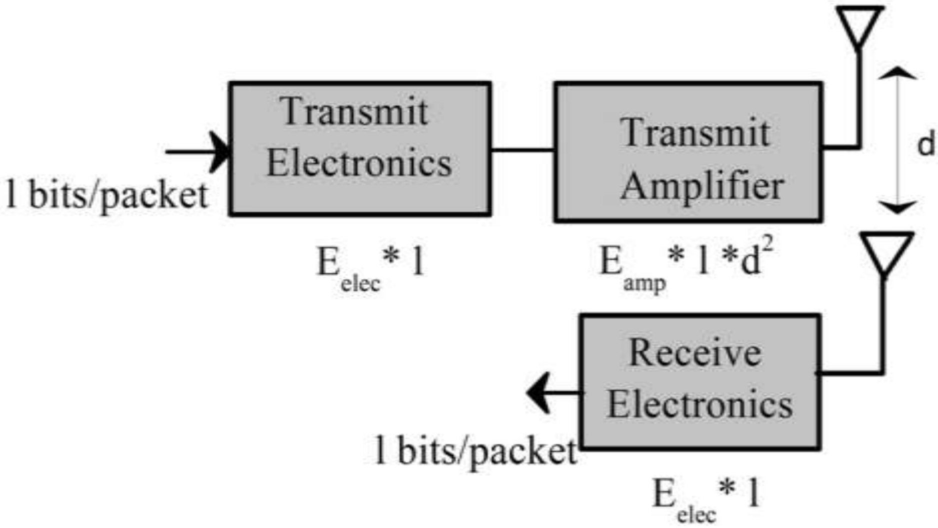


Figure 2. Radio Energy Model

Assuming symmetrical communication channel, the energy consumed by a sensing node in transmitting *l* bits/packet to another node *d* meters away can be given as [21]:

$$E_{Tx} = E_{Tx\_elec}(l) + E_{Tx\_amp}(l,d) \tag{1}$$

$$E_{Tx}(l,d) = \begin{cases} E_{elec} \times l + \in_{fs} \times l \times d^2, d \le d_0 \\ E_{elec} \times l + \in_{amp} \times l \times d^4, d > d_0 \end{cases} \tag{2}$$

E_{elec} is the energy consumption per bit by receiver or transmitter. $\in_{fs}$ and $\in_{amp}$ are the parameters of amplification related to the free-space model and the multi-path fading model respectively.

d_0 represents threshold distance given as the ratio between $\in_{fs}$ and $\in_{amp}$ as given by equation (3)

$$d_0 = \sqrt{\frac{\in_{fs}}{\in_{amp}}} \tag{3}$$

The energy consumed in receiving a '*l*' bits packet is given as:

$$E_{Rx}(l) = E_{elec} \times l \tag{4}$$

Energy consumed to directly transmit 'l' bits to sub-BS located at distance d_G from a particular node in Region 3 can be given as:

$$E_{Tx\_G} = \begin{cases} E_{elec} \times l + \in_{fs} \times l \times d_G^{\ 2}, d_G \le d_0 \\ E_{elec} \times l + \in_{amp} \times l \times d_G^{\ 4}, d_G > d_0 \end{cases} \tag{5}$$

Where d_G represents the Euclidean distance between any node in Region 3 and the sub-BS.

Let ‘r’ be the number of rounds taken by a node to be elected as CH, i.e. after every $r = \frac{1}{p}$ round, the node can elect itself as a CH.

When first-round initiates, all the nodes in Region 2 and 4 have equal probability to be elected as CH. The cluster head is selected by calculating the residual energy of each node and with the probability P.

Let the sensor nodes that are non-CH nodes in the current round be represented as set ‘S’. At the beginning of each round, any node belonging to ‘S’ randomly chooses a number between 0 and 1. If the number is less than a predefined threshold value *T(n)*, then that node is declared as a cluster head for the particular round

$$T(n) = \left\{ \frac{p}{1 - p(r \bmod \frac{1}{p})} \right\}; n \in S \quad (6)$$

$$T(n) = 0; Otherwise$$

Once a CH is elected in each region, it transmits a control packet using a CSMA protocol [22] to the nodes. The nodes in return send ACK message and join to the nearest CH. The CH then assigns TDMA slots for the member nodes to transmit their sensed data. The node transfers data only during the allotted time period and switches to sleep mode by turning off the radio in idle condition. Hence, the energy dissipated by the nodes decreases substantially.

4. Simulation and Result Analysis

To study the behavior network performance for proposed, we consider 100 nodes deployed over an area of 100×100 m^2 as shown in Figure 3. The BS (red color) is placed at a distant place which is 20m far away from the sensing network. The sub-BS (green color) is situated within the network. The number of bits in a packet is set to 4000 bits.

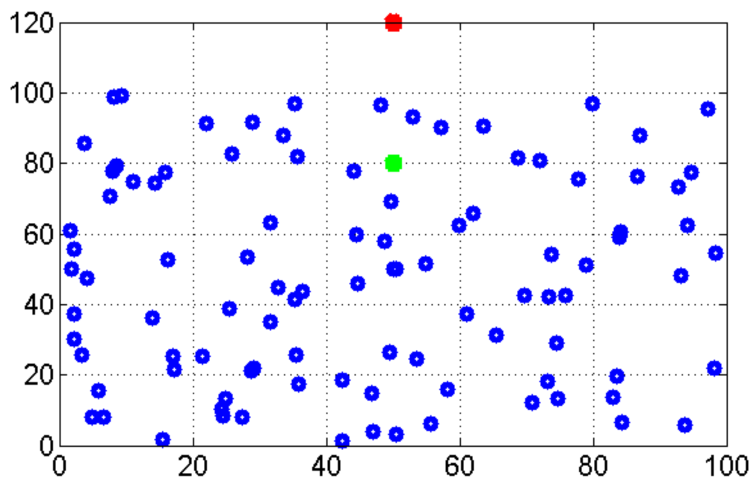


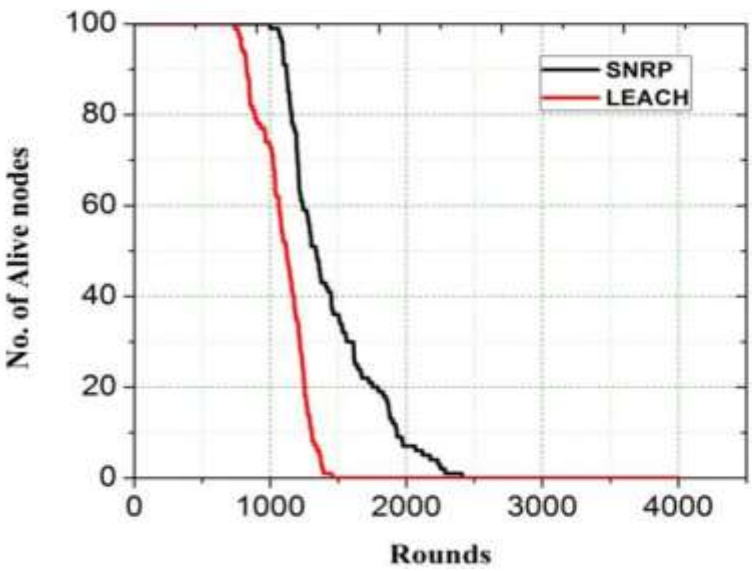
Figure 3. Deployment of Sensor Nodes

The system parameters used to simulate different metrics using MATLAB is given below in Table 1:

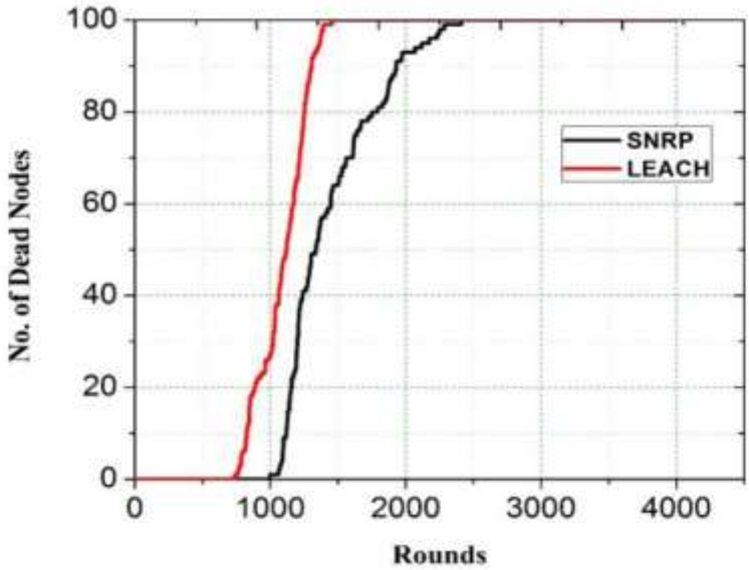
Table 1. System Parameters

SYMBOL	DESCRIPTION	VALUE
E_0	The total energy of the network	0.5J
ϵ_{amp}	Energy dissipation: receiving	$0.0013/pJ/bit/m^4$
ϵ_{fs}	Energy dissipation: free space model	$10/pJ/bit/m^2$
E_{da}	Energy dissipation: aggregation	5pJ/bit
E_{elec}	Energy consumed per bit	5nJ/bit

We compare SNRP with that of LEACH protocol to evaluate the network behavior for metrics such as network lifetime, residual energy and throughput.



(a)



(b)

Figure 4. (a) Percentage of Alive Nodes (b) Percentage of Dead Nodes

The lifespan of any network can be evaluated by estimating the number of rounds taken by all the sensor nodes to die out completely. Stability period of any network is the time elapsed from functioning of the network to the death of the first node. These two parameters help to decide the efficiency of any routing algorithm. Figure 4(a) and 4(b) shows the percentage of nodes alive and dead respectively with respect to a number of rounds. For LEACH, the first node dies out at after 800 rounds whereas for SNRP it is 1000 rounds. This clearly indicates the stability period for the proposed concept is improved to a great extent as compared to conventional LEACH algorithm. The SNRP ensures extending the lifespan of the network to almost 2500 rounds when the last node stops operating as compared 1500 rounds for LEACH. This is because of well-distributed energy among all sensor nodes. In LEACH, the nodes located at a longer distance consume more energy than those placed nearer to the BS. As a result, these nodes and CH deplete energy at a faster rate resulting in a breakage of the network. SNRP balances the energy consumption by placing a sub-BS within the network for direct transmission of data to the BS through it.

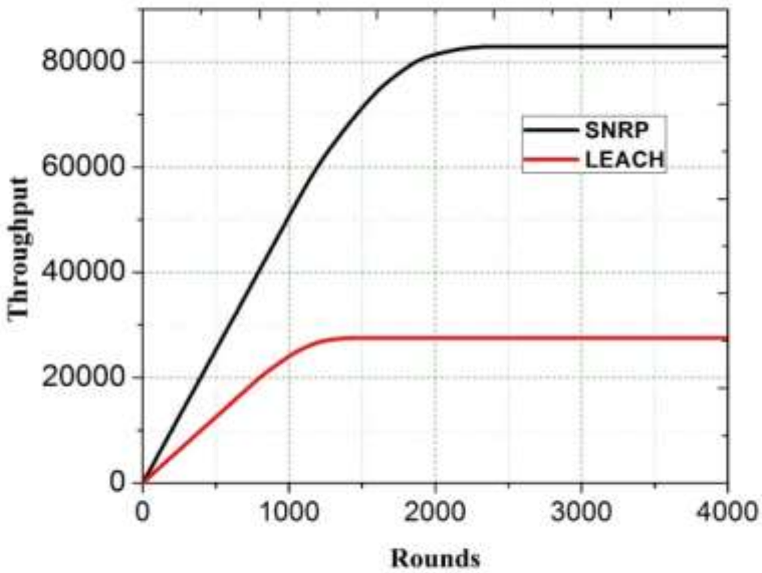


Figure 5. Throughput

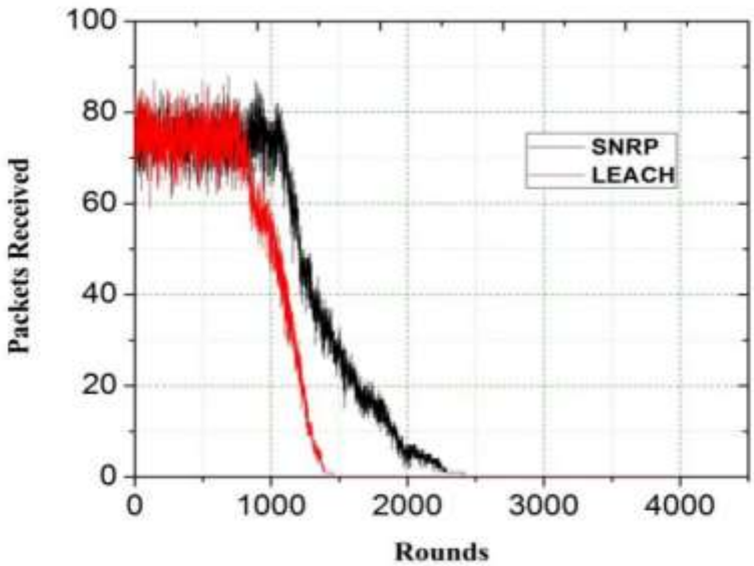


Figure 6. Data Packets Received

The effectiveness of any routing protocol is influenced by the number of data packet received by the BS with minimal packet drop ratio. Achieving a large data collection rate is a challenging task for WSN where the energy and communication resources are limited [23]. Figure 5 clearly shows the rise in throughput for SNRP which is almost 4 times as that of LEACH protocol. This is due to the direct transmission of data from the nodes nearer to BS and sub-BS. Sensor nodes in these regions stay alive for a longer time and are able to send more of the sensed data in the form of packets. Figure 6 shows the packets received ratio with respect to rounds. For LEACH, the packets from 70 to 85 nodes have been received for the first 900 rounds wherein SNRP, packets from the same number of nodes continue to be received till 1100 rounds. Thereafter the packets reception ratio decreases gradually with the number of rounds. However, from the graph, we can find that the number of packets is much greater for SNRP as that of LEACH.

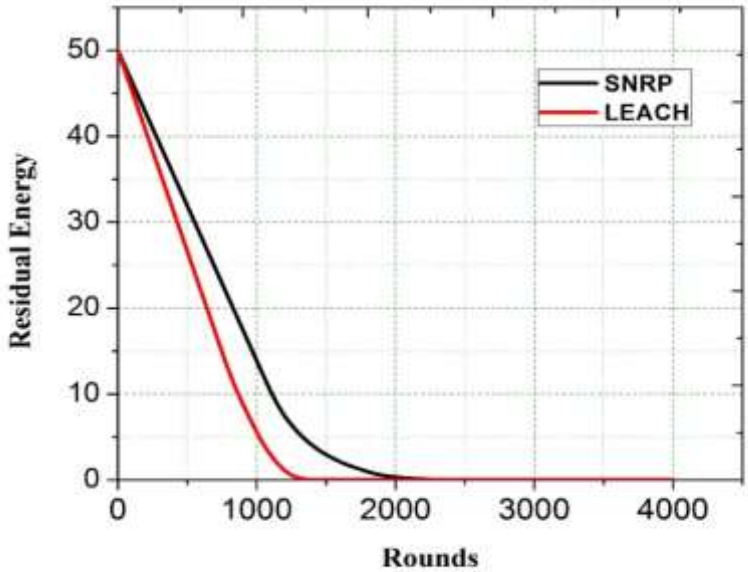


Figure 7. Residual Energy

The most important factor in a WSN is the average residual energy that tells the energy consumed in each round. We have assumed total energy of the network to be 50 Joule that is equally distributed among 100 nodes. Figure 7 shows that SNRP outperforms LEACH in terms of residual energy of the network. The reason behind this is the division of network to equally distribute the power utilization of nodes depending on its location with respect to BS. In addition, the computational complexity of the network also decreases since the LEACH routing protocol is implemented only in some regions and not on the whole network.

5. Conclusions

Features such as ease of deployment, energy constraint of nodes, data aggregation, and application are some of the important parameters to be considered during the design of network architecture for WSN. LEACH with the proposed sub-netting technique protocol improve the network performances by considering these above-mentioned features. SNRP outperforms in terms of network lifetime, throughput and energy consumption as compared to the network that functions entirely with LEACH algorithm. It is observed that the lifetime of the network increases almost 1.5 times and the throughput increases to 1.73 times to that of LEACH protocol. The sub-netting based routing can be best applicable in situations where the BS is located at a distant place from the sensing field for example in battlefields or to track any animal in the forest area. From a future perspective, the work can be extended to a heterogeneous network where sensor nodes are assigned to different power level.

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