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Multiple input and multiple output and energy-aware peering routing protocol for energy consumption in sensor networks

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Summary

Wireless sensor network consumes large number of energy-constrained nodes that are used to monitor the external devices while transferring the information in the sensor networks. At the time of the information transmission process, node contains high energy, and battery of node may be recharged continuously, which leads to reduction of the entire information transmission system performance. This paper introduces the multiple input and multiple output (MIMO) method with energy-efficient protocol for reducing the energy consumption in the network. Initially, the network coverage is determined by applying the shadow fading sensing model, and the clusters are formed with the help of the particle dual clustering process. After the cluster is formed, the information has been transmitted with the help of the energy-aware peering routing protocol (EPR), which reduces the network traffic and also improves the energy efficiency with efficient manner. Then, the efficiency of the system is analyzed with the help of experimental results in terms of coverage fraction, accuracy of the cluster, and energy consumption.

KEYWORDS

multiple input and multiple output (MIMO) method with energy-efficient protocol, particle dual clustering process, shade fading sensing model, the energy-aware peering routing protocol (EPR), wireless sensor network

1 | INTRODUCTION

A wireless sensor network (WSN) consists a spatially independent sensor nodes that are dispensed, which are able to monitor the physical movement in the environmental conditions and capable of communicating the sensed data to the base station around the surface. Microsensor technology has recent innovations, which made it possible for the large number of sensors to be available at affordable cost and compact. However, it is capable to be deployed for military, ecological observation, and real-time applications. The sensor nodes are having limited energy sources; therefore, go to clustering.

Important issue of WSN design is an energy usage, which naturally depends on movable energy sources like batteries for power. WSN is large-scale networks for communication of small industries, which have each embedded devices with sensing and capability for computation. In recent years,[1-3] they have been widely discussed. After that, the development of smart sensors is facilitated, which is known as microelectromechanical system (MEMS) sensor technology. These smart sensor nodes are available in small devices; however, these have limited power, processing, and computation resources. If the smart sensors have one or more sensors, power units and processors, they are known as power constrained devices.[4]

The constraints of WSN are power for processing, bandwidth for communication, and space for storage, which require a very efficient resource utilization of sensor nodes in WSN. Energy optimization is significant of WSN network design in which clustering is observed to achieve considerable energy efficiency. In this paper, sensor nodes are formed into a group and select the cluster heads for each cluster. The data transmission to the base station uses cluster head, which in turn reduces the energy expended. It provides network scalability, sharing of resource, constrained resources, which are use efficiently, and energy-saving attributes. Behind clustering schemes are reduced communication expenses, decreased overall energy utilization, and reduced interference among sensor nodes. A large number of clusters will congest the data transmission in coverage area and the cluster head with large amount of data transmitted from cluster members using very small numbers of cluster.

Particle dual clustering (PDC) process is one such randomized clustering technique that is energy proficient. Dual clustering is where one domain refers to the optimization domain and the other refers to the constraint domain. Attributes on the optimization domain are those involved in the optimization of the objective function, while those on the constraint domain specify the application-dependent constraints. Energy-aware peering routing protocol (EPR) is a hierarchical routing based on clustering and finding the optimal number of clusters in WSNs in order to save energy and enhance network lifetime. This paper presents that initially, the network coverage is determined by applying the shadow fading sensing model (SFSM) and applying PDC process, which help to form a clustering of the nodes. After the cluster is formed, the information has been transmitted with the help of the EPR, which reduces the network traffic and also improves the energy efficiency. Finally, the efficiency of the system is analyzed with the help of experimental results.

The remaining part of the paper is organized as follows. Related work is discussed in Section 2. The proposed PDC is given in Section 3. Section 4 presents the result and discussion, and the conclusions are presented in Section 5.

2 | RELATED WORK

Moussa et al[5] developed grid clustering hierarchy (GCH) for energy-efficient management in WSN to create optimum clusters based on available number of virtual grid for average energy of network. Here, the cluster head has round robin scheduling role in each grid. The GCH distributes the overall energy to all nodes uniformly throughout the network. The simulation result is compared with the traditional low-energy adaptive clustering hierarchy (LEACH) algorithm and produces a better performance than the LEACH. The final data reports achieve long network lifetime and reduce the optimum energy consumption. Zhou et al[6] introduce allocation-based routing protocol to point out the location of each nodes, wherein nodes are prepared with a small low-power GPS receiver, which is available by communicating satellite using GPS. Main aim of the protocol is reducing the energy consumption. When the data transmission is through a long distance, the energy consumption is maximized. Here, the algorithm is minimizing the distance between the two nodes and dividing the many clusters, therefore achieving the minimum energy consumption. The simulation result is compared with LEACH protocol.

Ben Salah and Boulouz[7] proposed an improved particle swarm optimization (PSO) algorithm for extending the network lifetime of WSN. The protocol considers the account of both energy consumption and the data transmission distance. The clustering algorithm considers the parameter like number of nodes, coverage area of network, and position of base station. Improved PSO clustering to minimize the transmission distance therefore obtained the optimum energy consumption, however minimizing the overall energy consumption and balancing energy consumption among nodes throughout the network lifetime. Zain-ul-Abidin et al[8] proposed an algorithm LEACH for homogenous network to enhance the network lifetime, less energy consumption, and more stability of network. Cluster head selection considers the remaining energy of sensor nodes in the network. In future work, the algorithm has to improve and simulate heterogeneous environment. Bettstetter and Hartmann[9] proposed energy-efficient routing protocol for two-tiered WSN. The cluster head selection process is based on residual energy of sensor node periodically. Moreover, greedy algorithm is used to create a routing with the help of genetic algorithm. Relay reselection mechanism balances the energy consumption of the entire sensor nodes.

3 | METHODOLOGY

3.1 | Shadow fading sensing model

The sensing ability of a node is all the directions that are not uniform (Figure 1).[10] This is similar to shadowing in radio wave transmission. The sensing radius of a node is not uniform in all directions since the signal coming from different directions is related to different transmission paths in the shadowed environment. Let x be defined as distance between an arbitrary sensor node and an event of significance. Here, assume P_s is equal to the event for the power emit. Assuming shadowing path loss model, the node received power is due to the event as follows.

$$P(x)[dBm] = P_s[dBm] - PL(s)[dB], \tag{1}$$

where path loss is

$$PL(x) = \overline{PL}(x_0) + 10n\log_{10}\left(\frac{x}{x_0}\right) + x_\sigma. \tag{2}$$

The path loss exponent is known as parameter n, and a zero mean Gaussian-distributed random variable (in dB) with standard variation σ (in dB) is known as X_σ.[11]

Let P_s be the sensitivity of the sensor node. Then, $P(x) \geq P_s$ describes the transmission, which will be successful. Thus, the probability of shadow fading environment is detecting the event as follows:

$$P_{det}(x) = Prob\{P(x) \geq P_{s,th}\} = Q\left(\frac{P_{s,th} - \left(P_s - \overline{PL}(x)\right)}{\sigma}\right), \tag{3}$$

where

$$\overline{PL}(x) = \overline{PL}(x_0) + 10n\log_{10}\left(\frac{x}{x_0}\right). \tag{4}$$

Let r_s be the sensing range of nonshadowed environment for which (5) does hold well.

$$P(r_s) = P_{s,th} = P_s - \overline{PL}(x) - 10n\log_{10}\left(\frac{r_s}{x}\right). \tag{5}$$

Plugging (5) into (3) yields

$$P_{det}(x) = Q\left(\frac{10n\log_{10}(x/r_s)}{\sigma}\right), \tag{6}$$

where

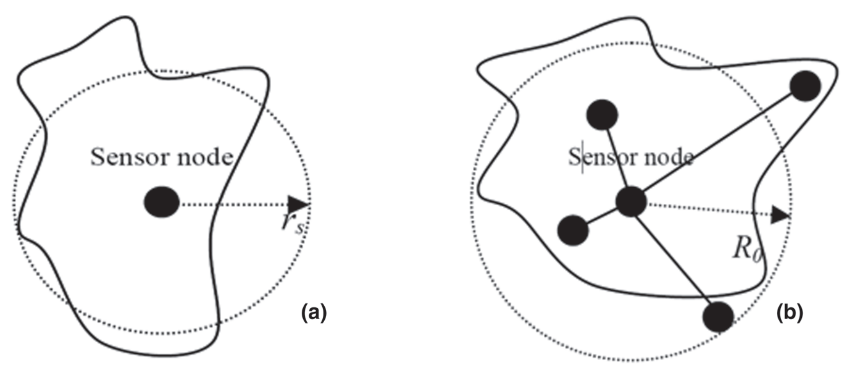

FIGURE 1 A, Shadow fading sensing model. B, Network coverage of shadow model

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-y^2/2} dy. \tag{7}$$

The probability of shadow fading sensing for network coverage is an event, which will be detected.

$$P_{det} = \frac{2\pi}{A} \int_{0}^{\infty} P_{det}(x) x dx = \frac{2\pi}{A} \int_{0}^{\infty} Q\left(\frac{10n\log_{10}(x/r_s)}{\sigma}\right) x dx \tag{8}$$

The network coverage is dependent on sensing model. Its appearance is very simple due to Boolean sensing model (BSM). It is quite complex in the probabilistic sensing model. It reveals from Fall and Varadhan[10] that when the shadowing parameter increases, then the network coverage of shadowing sensing model reduces.

3.2 | Particle dual clustering

The PDC algorithm leads to design of two cluster heads by using the basic PSO. The attribute of the algorithm considers the node energy efficiency and additionally focuses on the second choice of the cluster head in the cluster member. After the clusters are formed, then it carries out the data transmission in intracluster. Behind the algorithm is the selected two cluster heads, which are the primary cluster head (PCH) and secondary cluster head (SCH). The PCH collects the data from its cluster members and forwards it to SCH, whose process is similar to each cluster. The SCH sends collective data to the base station using direct communication, and the PCH is not directly linked with the base station. This methodology is an efficient way to reduce the power utilization and better for the reduction network workloads and extension the network lifetime. Figure 2 shows the cluster representation of PDC.[16]

The selection of PCH and SCH is initiated the same as the PSO. Here, taking fitness function, it can be stated that SCH has more energy and the distance with PCH is much closed. Therefore, we use the suboptimal solution as the SCH. The fitness function of this algorithm is in Equations (1) to (3).

The PDC algorithm steps are as follows:

Step 1. Initialize the node. Randomly initialize position and velocity of every node.
Step 2. Evaluate the fitness of each node using the formulas as follows:

$$f = \varepsilon \times f1 + (1-\varepsilon) f2, \quad f1(i) = \frac{E(i)}{\sum_{j=1,\, j \neq i}^{k} E(j)}, \quad f2(i) = \frac{k-1}{\sum_{j=1,\, j \neq i}^{k} d(i,\ j)}.$$

The cluster head is chosen by $f(i)$ known as maximum value of node. It is the most good decision.

Step 3. Find the personal best for each node. The personal best is the current position of the node.

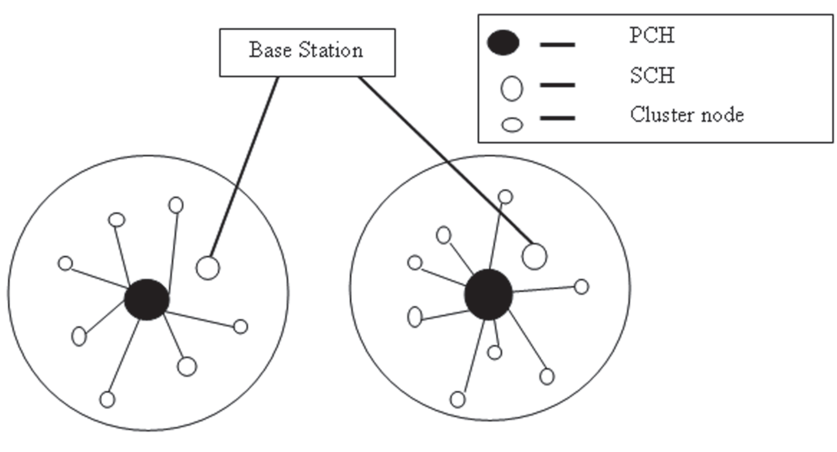

FIGURE 2 Cluster representation of particle dual clustering

The $P_{best,i}$ is calculated by using the formula

$$P_{best,i} = \begin{cases} P_{best,i} \; iff(x_i) > P_{best,i} \\ X_i \quad iff(x_i) \leq P_{best,i} \end{cases}.$$

Step 4. The global best refers to the position of the node that has the maximum fitness. The global best position G_{best} is calculated by using this formula:

$G_{best} = \{\min\{P_{best,i}\}$, where $i \in [1, \ldots, n]$, where it is less than 1.

Step 5. Update each node's position and velocity using formula

$$V_i^{t+1} = WV_i(t) + c_1 r_1[x_1(t) - x_i(t)] + c_2 r_2[g(t) - x_i(t)].$$

Step 6. Repeat steps 2 to 5 until reached the maximum numbers of iterations. Select the global best as PCH and the global best of the previous iterations as SCH. The base station transmits the data, in which data contain PCH ID and SCH ID details to all the nodes.

Step 7. Considering the concept of received signal strength indicator (RSSI), the cluster formation is done.

3.3 | Energy-aware peering routing protocol

The EPR contains neighbor and routing table. Here, we consider the routing table for the data transmission using energy-efficient way. The transfer packet and the neighbor table contain information about the destination ID (ID_{DST}), location of destination (L_{DST}), source's ID (ID_j), distance between source node j and the destination ($D_{j,DST}$), remaining energy (E_j), and device type (T_j).

ID_{DST}	L_{DST}	ID_j	L_j	$D_{j,DST}$	E_j	T_j

The remaining energy (E_j) is the remaining node j energy. The ($D_{j,DST}$) is calculated by using Equation (7). The neighbor table stores the information about the packets transmission from the node j and the receiver node i for further processing. Moreover, the node i adds its own information to the received packet. When the sender has moved away or has broken down, then the next packet is not received within a certain time period. All the entries in the neighbor table associated with the routing table will be updated.

$$D_{(j,Dst)} = \sqrt{(X_j - X_{Dst})^2 + (Y_j - Y_{Dst})^2} \tag{7}$$

$$D_{(i,j)} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2} \tag{8}$$

3.3.1 | Routing table

```
Input: Neighbor table, is neighbor table records NH_{i,Dst}.
For each destination DstDo
If (ID_j(nt) == ID_Dst(nt)) then
```

```
(add a new record for the Dsts information in the routing table)

ID_Dst ← ID_Dst(nt)
L_Dst ← L_Dst(nt)
NH ← ID_Dst(nt)
Else
If (C_j == min_{k∈NH_{i,Dst}} C_k) then
(add a new record for the Dsts information in the routing table)
ID_Dst ← ID_Dst(nt)
L_Dst ← L_Dst(nt)
NH ← ID_Dst(nt)
End if
End if
End if
```

4 | RESULT AND DISCUSSION

The simulation of the PDC is performed using network simulator (*NS*-2).[12,13] Moreover, the graphical evaluation is generated using *MATLAB*.[14] In the simulation, the sensor nodes are deployed randomly under the coverage area of network, which is 500 × 500 m^2. The proposed clustering algorithm forms the clusters in the network for reducing the energy consumption. The simulation parameters in the experimental are shown in Table 1.

4.1 | Coverage fraction of shadow fading sensing model

The sensing range r to the deployment range A is assumed to be 100 m^2, respectively. All the results reported are averages of 50 simulation runs. As shown in Figure 3, under the random deployment, the deviation between the coverage fraction derived from our theoretical analysis and that obtained from the simulation. N number of deployed sensor nodes randomly select N locations in a uniform and independent distribution in C. Observe that if there exist more than 40 nodes in deployment area C, the coverage fraction derived from simulation equals 81 m^2 and when 60 nodes deployed in C area, the coverage fraction derived from simulation equals 85 m^2. Figure 3 shows that coverage fraction of SFSM is compared with two existing model BSM and Elfes sensing model (ESM).

From the analysis of Figure 3, network coverage of SFSM gets reduced, and the shadowing parameter has increased that is why we achieve better coverage fraction compared with existing BSM and SFSM.

TABLE 1 Values of parameter

Parameters	Values
Network dimension	500 × 500 m^2
No. of nodes	100 nodes
Radius of sensor	60 m
Simulation time	100 seconds
Routing protocol	*EPR*
Sampling time	10 s
No. of samples	10 samples
No. of data formats	Three formats
Initial energy	150 J
Power of transmission	15.800 mW
Power of reception	50.250 mW
Data packet	20 bytes

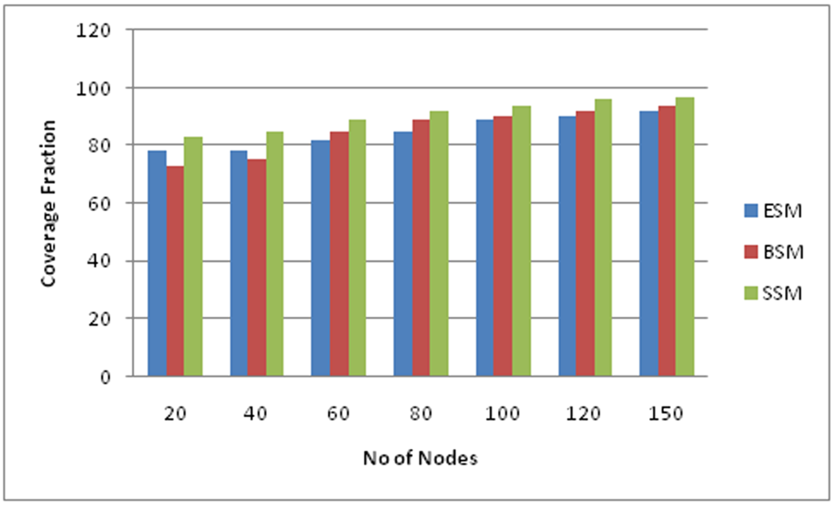

FIGURE 3 Coverage fraction of shadow fading sensing model (SFSM)

4.2 | Accuracy of PDC

The PDC algorithm leads to creation of two cluster heads by using the basic PSO. One is PCH, and another one is SCH. The PCH is not directly communicated with base station. Figure 4 shows the performance analysis of the proposed method with different number of nodes. Figure 5 shows the comparison between PDC and the existing algorithm like PSO and ant colony optimization (ACO).

From the analysis report of Figures 4 and 5, the PDC is giving better network lifetime compared with other existing algorithm. The two cluster heads lead to balanced energy consumption over the wider network, thereby resulting in better performance of PDC over PSO and ACO.

4.3 | Energy consumption of energy-aware peering routing protocol

Energy-aware peering routing protocol is a hierarchical routing based on clustering and finding the optimal number of clusters in WSNs in order to save energy and enhance network lifetime. The cluster head selection contains rounds. Figure 6 shows the percentage of energy saved in EPR with different number of nodes based on rounds.

From the analysis of Figure 6, the proposed method obtained a high energy saving. Figure 7 shows energy consumption analysis of EPR compared with existing LEACH protocol and energy-efficient multihop hierarchical routing (EMHR) protocol.

From the analysis of Figure 7, the proposed method obtained a better energy saving compared with the existing LEACH and EMHR protocols.

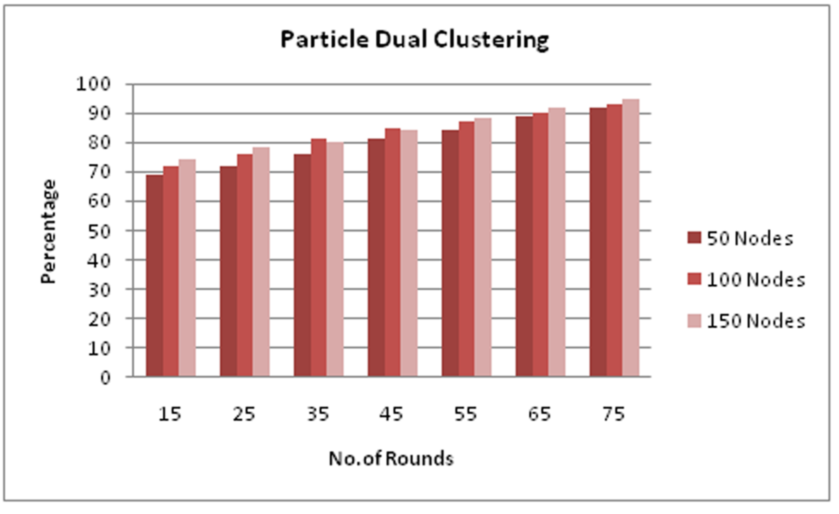

FIGURE 4 Performance analysis based on accuracy

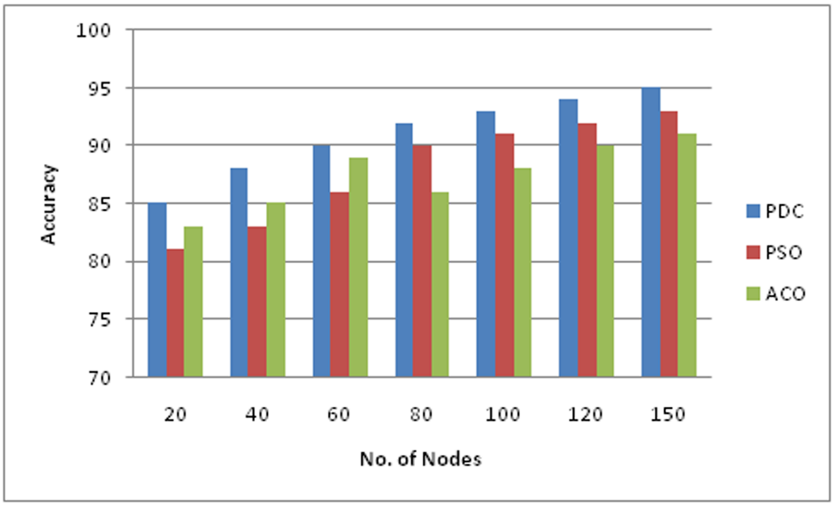

FIGURE 5 Comparison of particle dual clustering (PDC) with particle swarm optimization (PSO) and ant colony optimization (ACO)

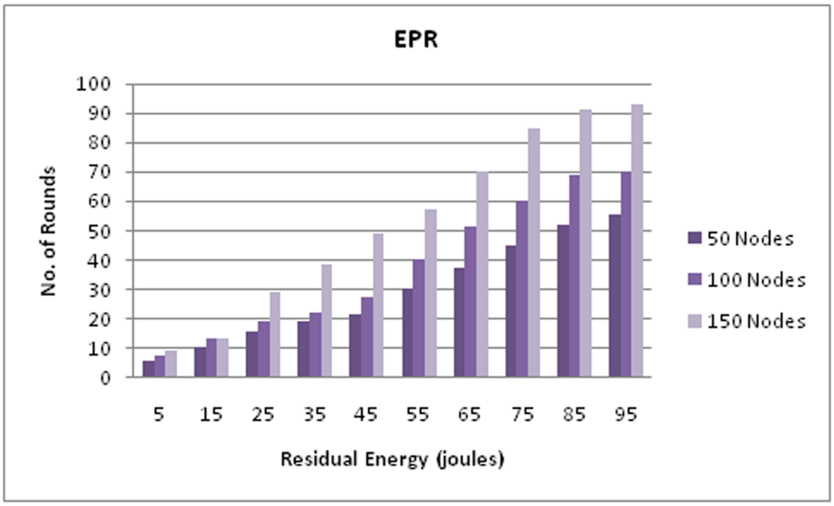

FIGURE 6 Performance analysis based on energy

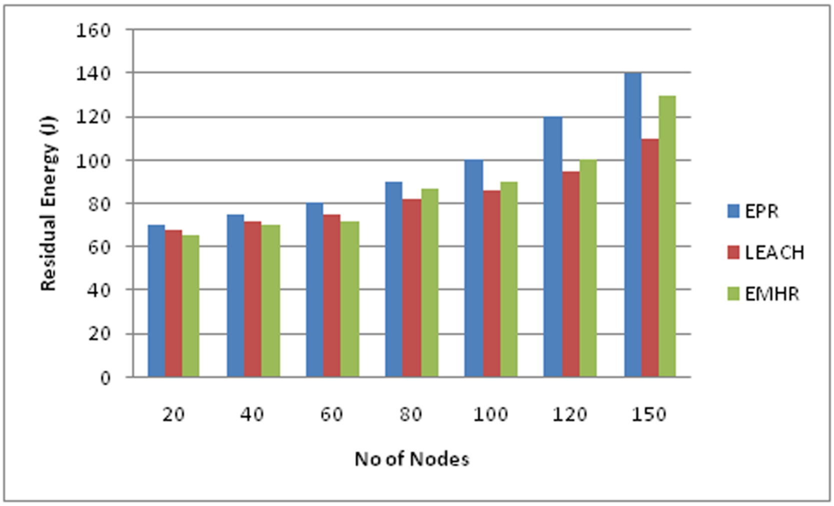

FIGURE 7 Comparison of energy-aware peering routing protocol (EPR) with low-energy adaptive clustering hierarchy (LEACH) and energy-efficient multihop hierarchical routing (EMHR)

5 | CONCLUSION

Wireless sensor network consumes large number of energy constrained. At the time of the information transmission process, node contains high energy, and battery of node may be recharged continuously, which leads to reduction of the entire information transmission system performance. In this paper presents the multiple input and multiple output (MIMO) method with energy-efficient protocol for reducing the energy consumption in the network. Initially, the network coverage is determined by applying the SFSM. The network coverage of the model gets reduced and the shadowing parameter has increased. After the model is applied, the clusters are formed with the help of the PDC process. An algorithm leads to creation of two cluster heads by using the basic PSO. After the cluster is formed, the information has been transmitted with the help of the EPR. The cluster achieves the high accuracy and better lifetime, and EPR protocol obtained the better energy saving compared with existing protocol.

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