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Event Driven Hierarchical Cluster based Routing Protocol for Wireless Sensor Network

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Abstract*— The wireless sensor networks (WSNs) is one of the booming field of research in recent era of scientific world. A WSN consists of sensors which are distributed spatially to monitor physical or environmental conditions and to pass their data cooperatively through the network to Base Station (BS). The major fact that sensor nodes dies due to run out of energy quickly because of the small size of the sensor nodes has been a constraint and many energy efficient routing protocols have been developed for solve this problem and to preserve the lifetime of the network. To conserve energy in wireless sensor network we are proposing an Event Driven Hierarchical Cluster based Routing Protocol. In this whenever there is an occurrence of event in the sensor area, then this event information is passed through the selected cluster head which have the highest residual energy and shortest distance to the sink in each communication round of transmission. Simulation results show that routing of event data through different level of hierarchy prolongs the lifetime of the network compared to other clustering scheme and shows significant performance increase.

Keywords*—sensors, routing, hierarchical, event, cluster.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of several autonomous sensor nodes which can range from few to several hundreds or even thousands, where every node is connected to one another. The research perspective of wireless sensor networks (WSNs) is one of the emerging and fast growing fields in this scientific era. This has results into the development of low cost, low-power and multi-functional sensor nodes. But, the important fact that sensor nodes dies fast due to the depletion of energy quickly has been a constraint and many energy efficient routing protocols are being proposed in order to solve this problem and increase the lifetime of the network. This is one of the reasons why routing protocols in wireless sensor network mainly focus on the accomplishment of energy conservation. The Routing protocols are basically divided on the basis of network structure into three main groups which are: Flat routing, Hierarchical routing, Location based routing. The clustering technique is mainly used for the sensor nodes, in which sensors send information to only the cluster heads (CH) and then the CH transmits the aggregated information to the base stations or the sink, it is considered as a good method to minimize energy consumption in WSN. This way of data aggregation by the cluster head nodes results into the reduced energy consumption in the network with the minimizing the total data messages to be sent to BS. When there is less energy consumption, then there is increase in the network life time. The main purpose of developing cluster-based routing protocols is the reduction in the network traffic toward the base station. This method of clustering may sometime introduce overhead because of the cluster configuration and maintenance, but it has been studied that cluster-based protocols are energy efficient when compared to flat network topologies for WSNs [2]. . There are various algorithms that use Cluster formation and CH selection such as LEACH, PEGASIS, and TEEN etc for WSN. In this paper, in our approach, the clusters are formed geographically into different sizes to see how they could affect the network lifetime of WSN whenever there is an occurrence of event. With energy awareness and event driven protocol, our proposed hierarchical technique, uses the smallest transmission energy via the shortest path possible to send event data to the BS proof to offer more reduced energy consumption and also increase in the lifetime of the WSN. Simulation results show that proposed technique is better than the non-hierarchical event driven routing technique. Also it is energy efficient and results into prolonging the lifetime of WSN. The organization of the paper is as follows. Section I introduces the paper in brief, section II explains related work, section III introduces the Sensor Network Model. Section IV gives Proposed Routing Algorithm and corresponding flow chart .Section V gives Simulation and Performance evaluation of hierarchical and non-hierarchical routing algorithms. Section VI concludes the paper.

II. RELATED WORK

There are various methods for minimizing energy consumption in wireless sensor network such as by Heinemann et al. [3] who described the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol which is a hierarchical self organized clustering based approach for monitoring applications for wireless sensor network. The sensor area of the data

is randomly divided into clusters. LEACH makes use of time division multiple access (TDMA), to communicate data from the sensor nodes to the cluster head. Then CH collects the data and then transmits it to the base station or the sink node for processing. One of the important features of LEACH is the coordination and control for the formation and operation of clusters locally. The rotation of cluster head is random. In [4] Lindsey et al. proposes PEGASIS protocol which is an extension of LEACH. It eliminates the overhead of dynamic cluster formation which is an issue in LEACH. In this protocol, the node communicates data to the CH and then transmission of data is performed by the cluster head, which is selected in a random manner, to the BS. PEGASIS protocol is found to be more energy efficient and more robust in node failure when it is compared to LEACH. Muruganathan et al. [5] developed a protocol which creates clusters of the similar sizes and uses multi-hopping between CH and the BS for data transmission. The cluster head which forward the data to the last hop is selected randomly from the given sets of cluster heads to minimize the overhead from cluster head which are located nearest to the sink. In [8], Wei Li proposes protocol which is a geometric programming model in order to extend the network lifetime of the wireless sensor network by cluster formation of the sensor nodes into groups. It is an iterative method which solves the geometric programming by selecting the optimal position of cluster heads. Clustering technique is useful in the monitoring of habitat and environment. This however, requires the use of continuous stream of sensor data. Xinhua Liu et al. [12] propose DDBC (Directed Diffusion Based on Clustering). DDBC is a protocol which an energy-efficient directed diffusion protocol which is based on the reducing the network topology and gives decrement to the redundancy message for plain flooding in order to reduce the energy consumption in wireless sensor network.

Ye, Heidemann and Estrin [13] proposed a contention based medium access protocol, S-MAC, which reduces energy consumption in wireless sensor network by the formation of virtual clusters. They developed a schedule of common sleep for the clusters and have used in-channel signalling. Wei Cheng et al. [14] gave an adaptive, distributed and an energy efficient clustering algorithm, AEEC for wireless sensor network. Their approach chooses cluster heads based on the energy of the node to that of the whole network which can bring performance efficiency in heterogonous networks.

Al-Karaki and Kamal [12] also made a survey of the routing technique in wireless sensor network and mentioned that hierarchical routing technique has the advantages related to scalability and efficient communication.

III. SENSOR NETWORK MODEL

A. Radio Model

We are using the same conditions which were used in LEACH with the simple radio model for hardware energy dissipation, as a shown Fig.1. L is the number of bits per data packet transmission and d is distance between the sender sensor node and the receiver node [11]. Electronics energy consumption is same for the transmission and reception of the data, and is given by,

$$E_{Tx\text{-}elec}(L) = E_{Rx\text{-}elec}(L) = E_{elec} * L \qquad (1)$$

E_{elec} is the energy dissipated per data bit to run the transmitter or the receiver circuit of the sensor node.

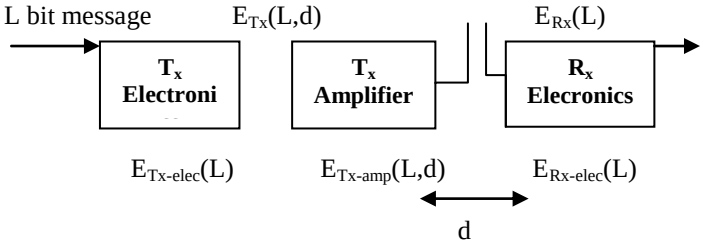

Fig1. Radio energy dissipation model

Transmission cost to transmit L-bit message between any two nodes over distance d is given by the following equation:

$$E_{Tx}(L, d) = E_{Tx\text{-}elec}(L) + E_{Tx\text{-}amp}(L,d) \qquad (2)$$

$E_{Tx\text{-}amp}(L, d)$ is the amplifier energy consumption and it can be further expressed in terms of ε_{fs} or ε_{mp}, depending on the transmitter amplifier mode that applied. They are power loss factors for free space (d^2 loss) when $d < d_0$; and multipath fading (d^4 loss) when $d \geq d_0$, respectively. The threshold d_0 can be determined by equating the two expressions, resulting:

$$d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}} = 87.7\text{m} \qquad (3)$$

Thus, to transmit L-bit message within d distance, a node expends:

$E_{Tx}(L, d) = L*(E_{elec} + \varepsilon_{fs} * d^2)$ if $d < d_0$ or

$E_{Tx}(L, d) = L*(E_{elec} + \varepsilon_{fs} * d^4)$ if $d \geq d_0$

To receive L-bit message within d distance, a node expends:

$$E_{Rx}(L) = E_{Rx\text{-}elec}(L) = E_{elec} * L \quad (4)$$

IV. PROPOSED ROUTING ALGORITHM

A. Assumptions

In this paper we have proposed an event-driven hierarchical cluster based routing scheme for wireless sensor network. Event detection and data collection are the means to identify environmental events by randomly deployed sensors which are working cooperatively. Following are the assumptions of wireless sensor network:

- All nodes are homogeneous in nature
- All nodes start with the similar initial energy
- The base station is located at the origin (0,0) of the area space
- Clusters and nodes are static in nature
- Normal nodes communicate directly to their respective cluster heads within a particular cluster
- Cluster heads use multi-hoping to relay data to the data sink

B. Proposed Algorithm

Our proposed Event Driven Hierarchical Cluster based Routing Protocol is based on the principle of clustering algorithm for event driven sensors. With data transmission at the network layer being the prime area of interest, in this protocol we have used event driven routing integrated with hierarchical data transfer and the employment of energy prediction technique used for the selection of cluster head (CH) via any shortest possible path to the BS. In the proposed routing algorithm, clusters are formed geographically. The geographical formation of the size of the cluster is based on equal division of sensor area space. In this we compared the event driven data routing not only for the one cluster formation or which makes use of the entire sensors area space, other formation such as two clusters formation and three clusters formation involves equal segregation of area space. The two clusters formation and the three clusters formation are otherwise known as first level and second level hierarchy respectively.

The CH election phase proceeds after the cluster formation phase. The selection of CH(s) within each cluster formed is carried out by electing a node that require less transmission energy (to BS or to the next hop CH nearer to the BS) to be the CH for a specific transmission round. Due to draining of energy being constraint on a cluster head during data aggregation and transfer phase, the cluster head is rotated among the sensor nodes of each cluster at every transmission round. A completely new estimation of energy is carried out at the beginning of every transmission round to elect a new CH for the cluster and thereby energy wastage is being reduce to its minimum, and utilization of each nodes energy is being maximized to ensure a prolong network lifetime. Fig. 2 illustrates the proposed hierarchical routing technique and the cluster head selection of the protocol respectively.

The algorithm in Fig. 2 consists of four main stages

i. Geographical formation of cluster.

ii. Finding the node at which event occur at a particular round

iii. Selection of cluster heads in each cluster formed.

iv. Data aggregation phase which involves the gathering of collected event data from the node at which the event occurred by the cluster head from the sensor nodes within its cluster.

v. Data transmission phase which involves the transfer of all data from the nearest cluster head(s) to the BS.

Also, the Fig illustrates the CH selection in the proposed hierarchical routing technique. The CH selection flowchart can be explained also in four main stages:-

i. The initial energy $E_{in}(n)$ of node is measured

ii. Also, the distance $d(n)$ from each node to the base station or to the corresponding higher level cluster head is measured.

iii. Estimation of the energy required by each node for transmission within the cluster not to BS or to higher level CH for two and three cluster formation within a cluster is carried out using the formula: ($E_{amp}*k*d2$) .

iv. The maximum energy after the consecutive transmission round for each node is estimated and selection of CH is done using the formula: max $(E_{in}(n) - E_{amp}*k*d2)$, then after the CH is selected, the next cluster head selection will take place after the current round is completed.

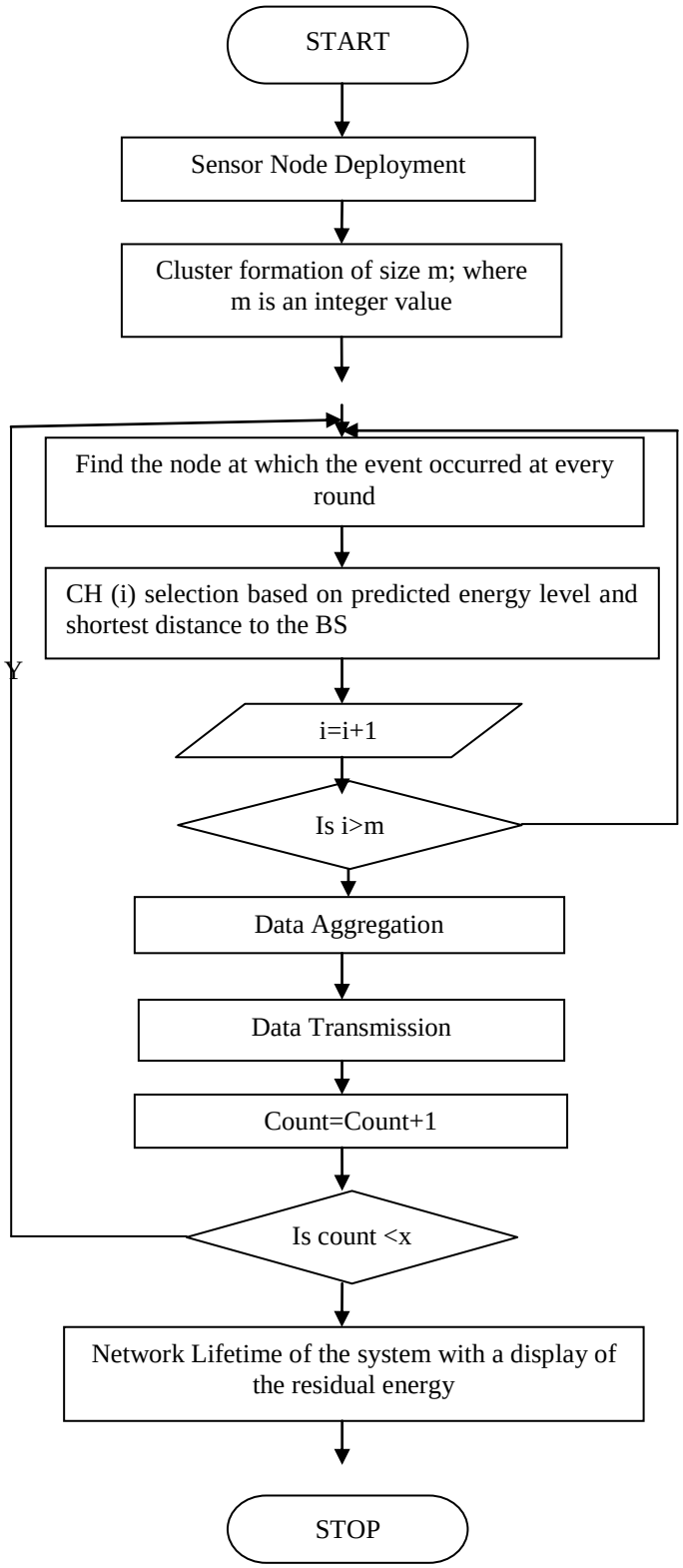

Fig 1. Flowchart of the proposed hierarchical routing technique.

V. SIMULATION AND PERFORMANCE EVALUATION

In this simulation, a total number of 250 nodes were randomly deployed within a space region on 300 m x 300 m .The figure 2, 3, 4. Illustrates the simulated environment of the 250 nodes we deployed for different level of hierarchy. The coordinates of *X* and *Y* are measured in meters. Table I shows the simulation parameters used.

TABLE I
SIMULATION PARAMETERS

Sink Location	(0,0)
Network Size	300*300
Number of nodes	250
Initial node power , E_{in}	200J
Nodes Distribution	Nodes are uniformly distributed
Data Packet size	100 bytes
Energy Dissipated per bit, E_{elec}	50nJ/bit
Constant for amplifier energy consumption. E_{amp}	100pJ/bit/m^2

A.Node Deployment for different level of hierarchical routing

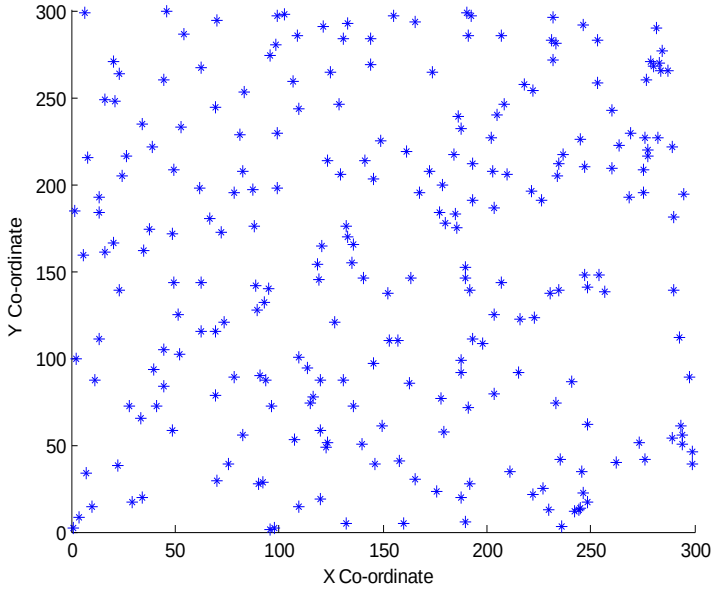

Fig 2. Non Hierarchical node deployment

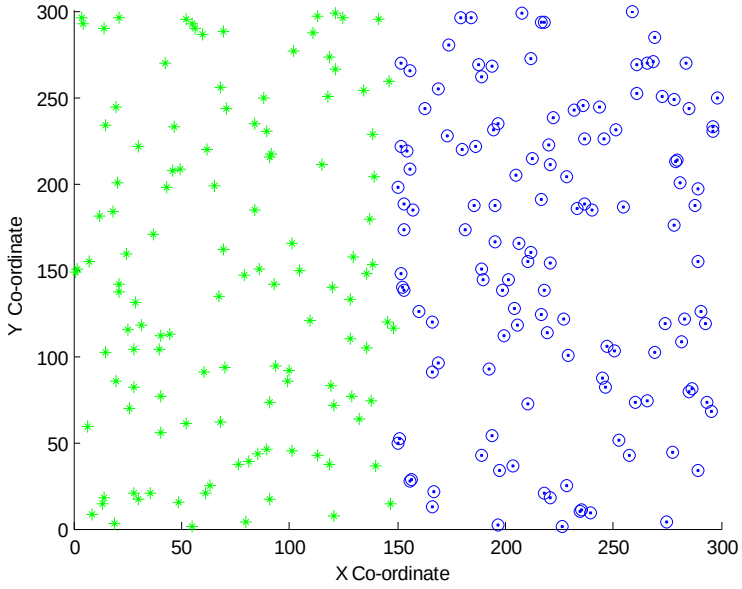

Fig 3. First level Hierarchical node deployment

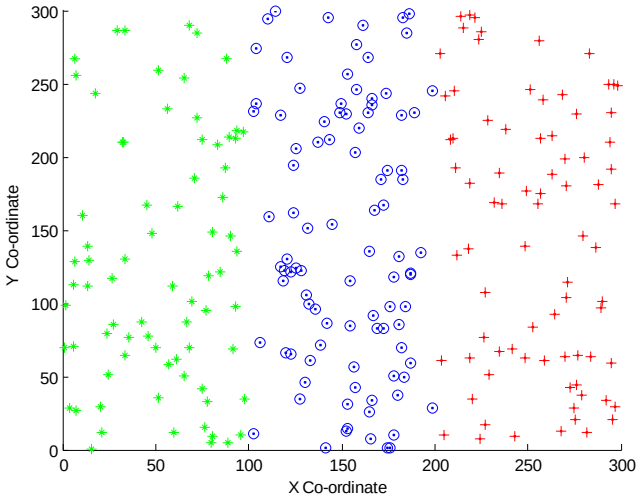

Fig 4. Second level Hierarchical node deployment

B. Network Lifetime with Number of Alive nodes for different level of hierarchy

More alive nodes show the increase in network life time. Table II. Display the number of nodes alive in the network with the increase in number of rounds.

TABLE III

Number of Rounds	Number of Alive node		
	Non-Hierarchical	First Level Hierarchy	Second Level Hierarchy
50	250	250	250
100	38	217	233
150	0	148	189
200	0	0	140
250	0	0	106
300	0	0	74
350	0	0	18
400	0	0	0

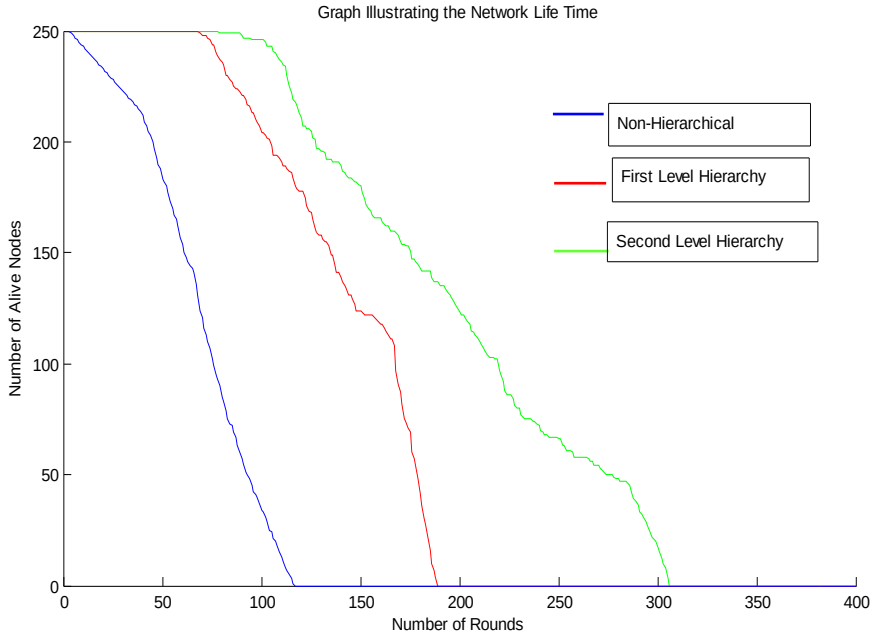

Fig 5. Alive node vs. Number of Rounds

C. Mean Residual energy for Different Level of Hierarchy

The mean value of the residual energy increases in each round of simulation as the hierarchical structure increases .This implies better network performance since the nodes has more energy in the subsequent level of hierarchy.

	Mean residual energy (J)
Non-hierarchical Technique	7.1184
First level hierarchy	13.7242
Second level hierarchy	58.3438

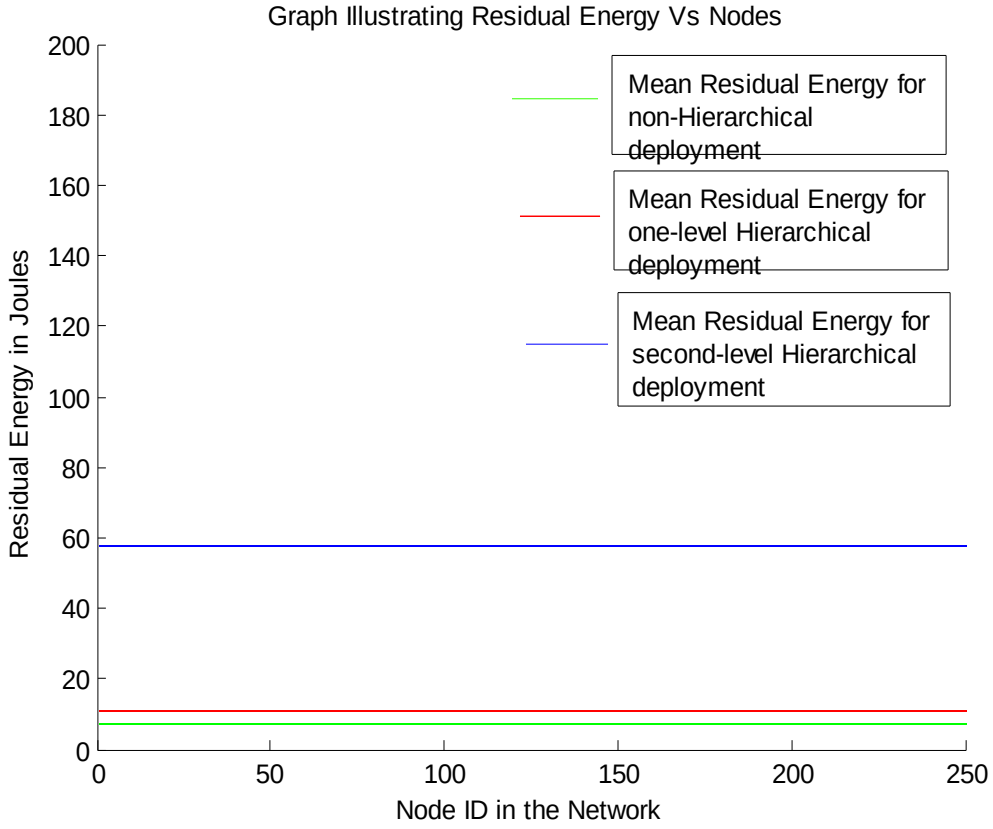

Fig 6. Residual energy for non-Hierarchical node deployment

VI. CONCLUSIONS

In this paper we have proposed an Event Driven Hierarchical Cluster based Routing Protocol for Wireless Sensor Network which is an energy efficient hierarchical routing technique in which cluster heads are selected based on the prediction of transmission energy via shortest possible distance to the base station for transmitting the event driven information. In this we create clusters of the sensor nodes geographically, rotate the role of CH, and optimize the CH selection by the help of prediction of energy used for transmission in every rounds of simulation, and when event occur CH aggregates event data before transmitting it to the BS. The important features which includes cluster formation and rotation, cluster head election and rotation, and cluster optimization of our proposed event driven hierarchical routing technique in transmitting event driven data to the base station is analysed. Our analysis shows that energy efficiency of WSNs can be further improved by using the event driven hierarchical routing technique. The concept of hierarchical routing technique can be effectively used along with event driven routing to designed energy efficient routing protocol in WSN. In our algorithm, the clusters are geographically formed into different sizes to see how it could affect the network lifetime of WSN. With energy awareness and event driven protocol being our core interest in this work, our proposed protocol, which uses the prediction of smallest transmission energy via the shortest path possible to send data to the BS proves that it offers more reduced energy consumption and also increases the lifetime of the WSN. From the analysis of our simulation results, we found out that our proposed protocol shows better performance for second level of hierarchy than first level hierarchical routing protocol and non hierarchical technique and also results into improved network lifetime which indicates better energy efficiency in the WSN.

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