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Energy-Efficient Data Gathering Algorithms for Improving Lifetime of WSNs with Heterogeneity and Adjustable Sensing Range

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ABSTRACT
In this paper, the energy-efficient data gathering algorithms for improving lifetime of WSNs with heterogeneity and adjustable sensing range have been reported. Here we have assumed that the sensor nodes and base-station are not mobile. The more over location and initial energy of the sensor nodes is known and number of sensor nodes is randomly distributed over a monitoring region. For the heterogeneity the three types of nodes: a normal, advanced and super node with some fraction in terms of their initial energy has been taken. In this work, we have proposed new distributed energy efficient algorithms AEEDPSH and ADLBPSH, based on the distance from the base station and sensor residual energy as well as scheduling of sensor nodes to alternate between sleep and active mode. The simulation results illustrate that the proposed algorithms AEEDPSH and ADLBPSH balance the energy dissipation over the whole network thus prolonging the network lifetime.

Keywords

Wireless Sensor Networks, Targets coverage, Adjustable Sensing Range, Heterogeneity, maximize lifetime.

1. INTRODUCTION
A wireless sensor network (WSN) is defined as a network of (possibly low-size, low-battery power and low-complex) devices denoted as nodes that can sense the environment and communicate the information gathered from the monitored field (such as an area or volume) through wireless links; the sense data is forwarded, possibly via multiple hops relaying, to a sink (controller or monitor) that can use it locally, or is connected to other networks (e.g., the Internet) through a gateway. A node in sensor network consists of CPU (for data processing), memory (for data storage), battery (for energy) and transceiver (for receiving and sending signals or data one node to another node). The size of each sensor node varies with application [4]. The nodes can be stationary or moving. They can be location-aware or not. They can be homogeneous or heterogeneous. Sensor networks can be classified into different ways. One way is whether the nodes are individually addressable and another is the data in the network are aggregated. Whether addressability is needed depends on the application.
In flat networks, each node normally takes the similar role and sensor nodes work together to perform the sensing task. Due to the huge number of sensor nodes, it is not possible to allocate a overall identifier to each node. This deliberation has led to data centric routing, where the BS sends queries to certain regions and waits for information from the sensors positioned in the selected regions. While data is being requested through queries, attribute-based naming is necessary to identify the properties of data. Some of routing protocols in this kind are: SPIN [5], Directed Diffusion [6].
Hierarchical or cluster-based routing, are recognized techniques with special compensation related to efficient communication, scalability and have been utilized to perform energy-efficient routing in WSNs. In a cluster-based architecture, higher energy nodes can be used to procedure and send the information whereas low energy nodes can be used to perform the sensing in the nearness of the target. Some of routing protocols in this group are: LEACH [1], PEGASIS [8].
In this paper, we propose two energy efficient hierarchical data collecting algorithms for heterogeneous sensor networks. Algorithms include two phases: the cluster head arrangement phase and the routing phase. For the cluster head arrangement, algorithms adopt the head node on the basis of the distance (how far the Base-station is located from the head node) and its energy level. After the cluster head arrangement phase, algorithms constructs a routing tree over the set of head nodes but only the higher residual energy nodes can communicate with the Base-station by single-hop communication.
The remainder of the paper is prepared as follows: In Section 2, some related work is presented. In Section 3, the network radio model for energy calculations and problem statement has been discussed. In Section 4, the details of centralized algorithms for SNLP and its simulation have been provided. We present results and discussion in Section 5. Section 6 concludes the paper.

2. RELATED WORK
Heinzelman et al. [1] propose LEACH, a substitute clustering based algorithm. In order to save energy, LEACH deals with the heterogeneous energy condition is the node with higher energy should have larger probability of becoming the cluster head. Each sensor node must have an approximation of the total energy of all nodes in the network to compute the probability of becoming a cluster head but it can not make decision of becoming a cluster head only by its local information, so the scalability of this scheme will be influenced.
Sh. Lee et al. suggest a new clustering algorithm CODA [8] in order to mitigate the unbalance of energy depletion caused by different distance from the sink. CODA divides the whole network into a small number of groups based on the distance from the base station and the strategy of routing and each group has its own number of cluster members and member nodes. The farther

the distance from the base station, the more clusters are formed in case of single hop with clustering. It shows better performance than applying the same probability to the whole network in terms of the network lifetime and the dissipated energy.

In [7] authors report an algorithm based on chain, which uses greedy algorithm to form data chain. Each node, aggregates data from downstream node and sends it to upstream node along the chain and communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round.

In [9], the authors discuss a HEED clustering algorithm which periodically selects cluster head based on the node residual energy and node degree and a secondary parameter, such as node proximity to its neighbors or node degree. The clustering process terminates in *O*(1) iterations and it also achieves fairly uniform cluster head distribution across the network and selection of the secondary clustering parameter can balance load among cluster heads.

In [10] the authors introduce a cluster head election method using fuzz logic to overcome the defects of LEACH. They inquired that the network lifetime can be prolonged by using fuzz variables in homogeneous network system, which is different from the heterogeneous energy consideration.

In [3] the authors propose an EDGA algorithm to achieve good performance in terms of lifetime by minimizing energy consumption for in-network communications and balancing the energy load. It is based on weighted election probabilities of each node to become a cluster head, which can better handle the heterogeneous energy capacities and adopt a simple but efficient method to solve the area coverage problem in a cluster range.

Recently, in [2,4], authors suggested the impact of heterogeneity of nodes in terms of their energy that are hierarchically clustered in WSNs and initiate an energy efficient heterogeneous clustered method for WSNs based on weighted election probabilities of each node to become a cluster head according to the residual energy in each node. For this they suppose a percentage of the population of sensor nodes is equipped with the additional energy resources.

3. MODEL FOR WIRELESS SENSOR NETWORKS

In this section, we define the network model and wireless radio model which is used during the simulation of the protocols.

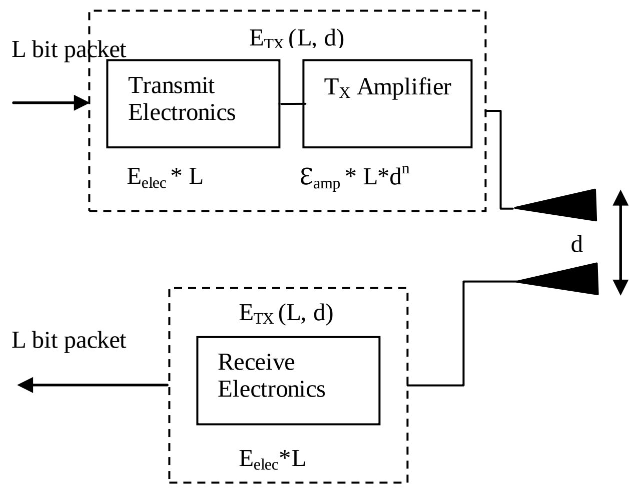
3.1 Network Model

Assume *n* sensor nodes are randomly and uniformly distributed over the sensing field R and the sensor network has the following properties:

1. This network is a static compactly deployed network. It means *n* sensor nodes are compactly deployed in a two dimensional geographic space, forming a network and those nodes do not move any more after deployment.
2. All nodes should be approximately time coordinated on the order of seconds.
3. There is one base station, which is deployed at (50, 50) position.
4. Nodes are location-aware, i.e. not equipped with GPS-capable antennae.
5. There are three types of nodes normal, advance and super nodes. Advance and super nodes are equipped with more battery energy than normal node.
6. These nodes are uniformly distributed over the region R and they are not mobile.

3.2 Wireless Radio Model

We have used similar wireless radio dissipation model as proposed in [1] and illustrated in figure. 3.1 According to the radio dissipation model, The Signal-to-Noise Ratio (SNR) in transmitting an *L* bit message over a distance *d*, energy expanded by the radio is given by (1) and to receive this message, the radio expends energy as (2):



Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. By equating the two expressions at $d = d_0$, we have $d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$. To receive an *L* bit message the radio expends $E_{Rx} = L * E_{elec}$ (2)

Table 3.1 Communication energy parameter values of the radio model.

Description	Symbol	Value
Energy consumed by the amplifier to transmit at a shorter distance	ϵ_{fs}	*10nJ/bit/m²*
Energy consumed by the amplifier to transmit at a longer distance	ϵ_{mp}	*0.0013pJ/bit/m⁴*
Energy consumed in the electronics circuit to transmit or receive the signal	E_{elec}	*50nJ/bit*
Energy for data aggregation	E_{DA}	*5nJ/bit/signal*
Message Size	*L*	*4000*

4. CENTRALIZED ALGORITHMS FOR SNLP AND ITS SIMULATION

4.1 Explanation of Proposed Algorithms

In this algorithm, decision of sensor head and states depends on both the energy level of each sensor and distance (between sensor to neighbor's sensor and sensors to base station). The algorithm has the following steps:

Step:-1.The location of base station fixed at (50, 50) and sensors are read from the input file. It contains the information of sensors x, y position, sensors id and set the initial energy value for each sensor node.

Step:-2.Sensor nodes networks are divided into three categories of the sensor such as advance nodes, super nodes and normal nodes. These sensor nodes used through a heterogeneity model that directly impact on the battery power of sensor nodes.

Step:-3. At any consequence, each sensor stays in one state out of the three states.

a. **Active State:** the sensor monitors the area, collect the information from the monitoring field and send to the base station.

b. **Idle State:** idle and sleep modes, the sensor listen to the other sensors but does not monitor the area.

c. **Deciding State:** the sensors monitor the area but will change there state to either active or idle state soon.

Step:-4. Each sensor knows its neighboring sensor and broadcast its current energy level and sensor id and then stays in deciding state with its maximum sensing range.

Step:-5. When sensor nodes are in a deciding state with range r, then they should change their state into: active and idle.

Step:-6. For each sensor

a. In ADLBPSH, the load balancing algorithm is used to keep as many sensors alive as possible and then let them die simultaneously.
   Active state with sensing range r, if region R which is not covered by another active or deciding sensors.
   Idle state when a sensor is overused compared to its neighbors or when a sensor decreases its range to zero.
   This process stops after all sensors make a decision.

b. In AEEDPSH, attempts are made to minimize the energy consumption for low energy sensors and maximize energy consumption for higher energy sensors. Each sensor decides which sensor is head node of by using the maximal lifetime of all the sensor of its neighbors. After building this conclusion, each sensor decides to become active with range r ($r \leq$ maximum sensing range) or decides to sleep. This process stops after all sensors make a decision.

Step:-7. The decision of all the states to be active or idle state is decided by sensors and each sensor will stay in that state for a specified period of time called, shuffle time, or upto that time when head sensor consumes its energy supply and is going to die. Here wakeup call is used for alerting all sensors and then they change their state back to the deciding state with their maximum sensing range and repeat the process from step 6.

Step:-8. This simulation is repeated until energy level of all sensors reaches zero.

Step:-9. Then, the process finishes and the lifetime of the wireless sensor networks is printed out.

4.2 Simulation Setup

For the simulation purpose, we created a static network of sensors in a 100m x 100m area. The adjustable parameters are:

- S, number of sensor nodes. We vary this from 40 to 200.
- There is one base station at location (50, 50).
- P sensing ranges r_1, r_2,..., r_P. We vary P this from 1 to 6 and each sensor P = 6 sensing ranges with values 10m,20m,30m,40m,50 and 60m.
- The initial energy of each sensor node is 0.5 J.
- In this paper, the energy model is defined as the networks of all nodes having different initial energy and sensor nodes are equipped with more energy resources than the normal sensor nodes. Let m be the fraction of the total number of nodes n, and m_o is the percentage of the total number of nodes m which are equipped with β times more energy than the normal nodes, we call these nodes as super nodes. The rest $n * m * (1 - m_0)$ nodes are equipped with α times more energy than the normal nodes; we refer to these nodes as advanced nodes and remaining $n * (1 - m)$ as normal nodes. We suppose that all nodes are distributed uniformly over the sensor region R. Suppose E_0 is the initial energy of each normal node. The energy of each super node is then $E_0(1 + \beta)$ and each advanced node is then $E_0(1 + \alpha)$. The total initial Energy is

$$E = n * (1 - m) * E_0 + n * m * (1 - m_0) * E_0 * (1 + \alpha) + n * m * m_0 * E_0 * (1 + \beta) \quad (3)$$

$$E = n * E_0 * \left(1 + m * (\alpha + m_0 * \beta)\right) \quad (4)$$

is the total initial energy of the new heterogeneous network [2,3,4**]**.

5. RESULTS AND DISCUSSIONS

In this section, we evaluate the performance of AEEDPSH and ADLBPSH algorithms. We simulate random deployed network located in a 100m×100m area. We implement a new model in the algorithms in heterogeneous form and all nodes initially have the same energy. The figures indicate the lifetime for sensor nodes (Advance, Super, Normal nodes) in case of adjustable sensing ranges. We have considered a base station at the position (50, 50) and the number of sensors have been varied between 40 and 200 with an increment of 20. The largest sensing of range 60 *meters* has been taken in all cases. We have compared the network lifetime for six adjustable sensing ranges which are 10, 20, 30, 40, 50 and 60 *meters*.

5.1 Energy Efficient Data gathering Protocol for Adjustable Range Sensing with Heterogeneity (AEEDPSH)

The following paragraphs discuss the simulation results for AEEDPSH and their lifetime comparisons with different adjustable sensing ranges have been reported.

Case I: α =2, β =1, m=0.2, m_0=0.5

Figure 5.1 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable sensing ranges. It has been observed that when the sensing range is varied from 1 to 4 there is significant increment in lifetime of the network while for other sensing ranges the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of AEEDPSH is [18.50, 28.22, 34.51, 38.79, 41.41, and 42.06] respectively in case of sensing ranges of 1 to 6.

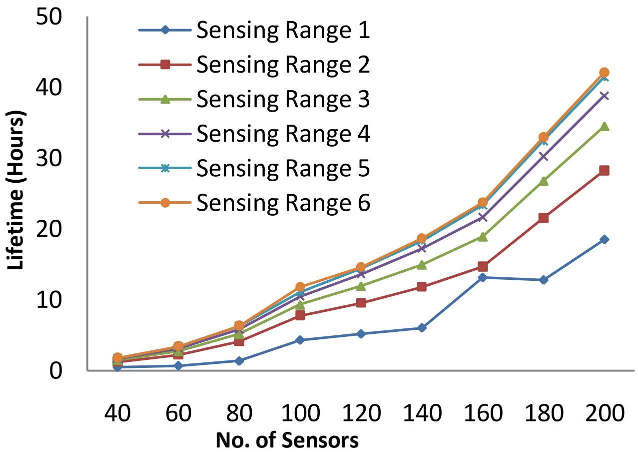


Figure 5.1 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

Case II: α =1, β =2, m=0.2, m_0=0.5

Figure 5.2 points out the lifetime the of sensor networks in case of heterogeneous nodes and different adjustable sensing ranges. It has been concluded that when the sensing range is varied from 1 to 4 there is significant improvement in lifetime of the network while for other sensing range the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of AEEDPSH is [17.14, 26.15, 31.98, 35.94, 38.38, and 38.97] respectively in case of sensing ranges of 1 to 6.

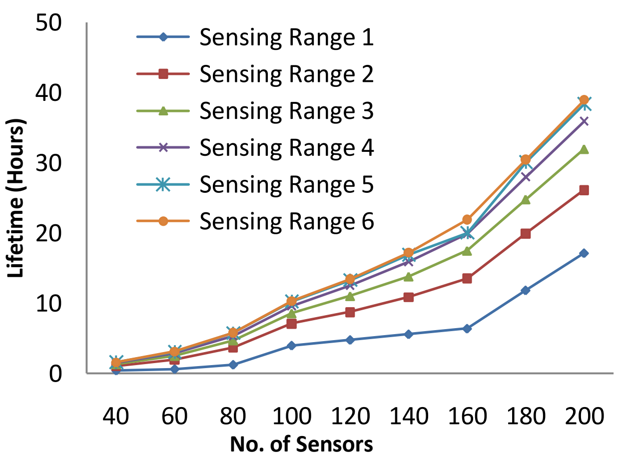


Figure 5.2 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

Case III α =1, β =3, m=0.2, m_0=0.7

Figure 5.3 shows the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable sensing ranges. It has been seen that when the sensing range is varied from 1 to 4 there is significant improvement in lifetime of the network while for other sensing range the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of AEEDPSH is [19.98, 30.48, 37.27, 41.89, 44.72, and 45.42] respectively in case of sensing ranges of 1 to 6.

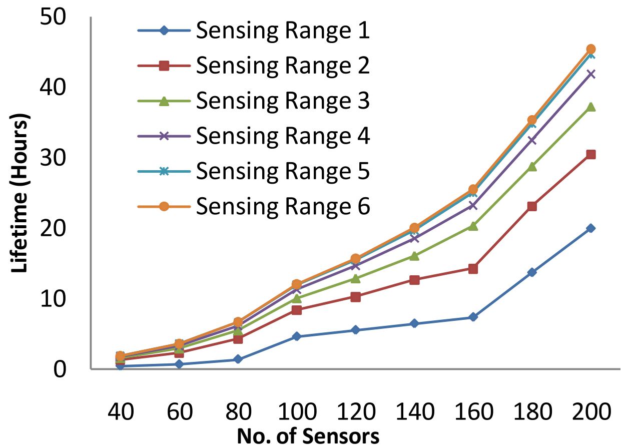


Figure 5.3 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

5.2 Data gathering Load Balancing Protocol for Adjustable Range Sensing with Heterogeneity (ADLBPSH)

The following paragraphs discuss the simulation results for ADLBPSH and their lifetime comparisons with different adjustable sensing ranges have been reported.

Case I: α =2, β =1, m=0.2, m_0=0.5

Figure 5.4 reports the lifetime of sensor networks in case of heterogeneous sensor nodes and different adjustable sensing ranges. It has been observed that when the sensing range is varied from 1 to 4 there is significant improvement in lifetime of the wireless network while for other sensing range the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of ADLBPSH is [19.86, 29.03, 35.35, 39.65, 42.13, and 42.90] respectively in case of sensing ranges of 1 to 6.

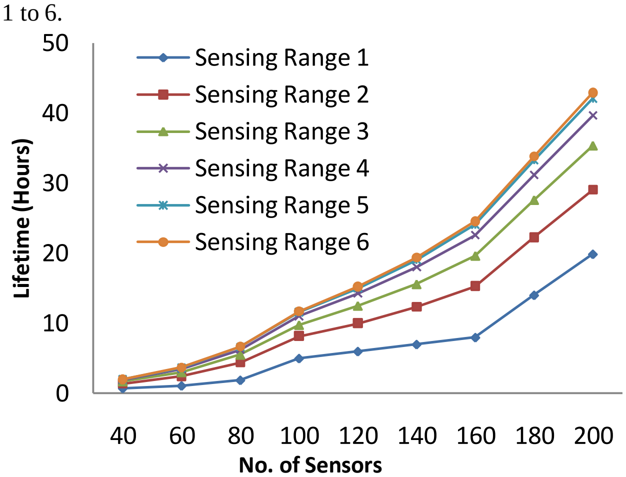


Figure 5.4 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

Case II: α =1, β =2, m=0.2, m_0=0.5

Figure 5.5 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable sensing ranges.

It has been concluded that when the sensing range is varied from 1 to 4 there is significant increment in lifetime of the network while for other sensing range the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of ADLBPSH is [18.40, 26.90, 32.76, 36.75, 39.04, and 39.75] respectively in case of sensing ranges of 1 to 6.

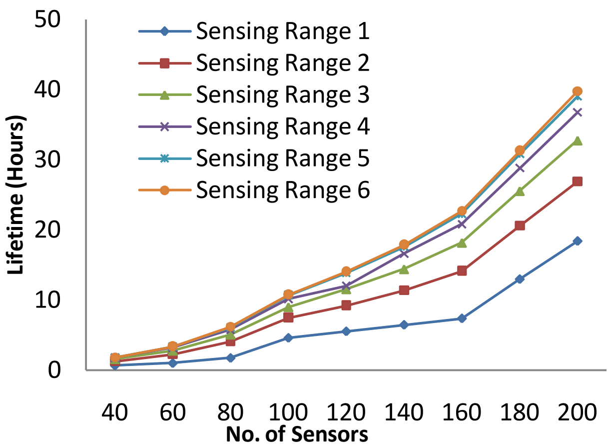


Figure 5.5 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

Case III: α =1, β =3, m=0.2, m_0=0.7

Figure 5.6 points out the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable sensing ranges. It has been observed that when the sensing range is varied from 1 to 4 there is significant increment in lifetime of the network while for other sensing range the change is very small. It has been shown that for 200 numbers of sensors the lifetime obtained in case of ADLBPSH is [21.45, 31.35, 38.18, 42.83, 45.58, and 46.33] respectively in case of sensing ranges of 1 to 6.

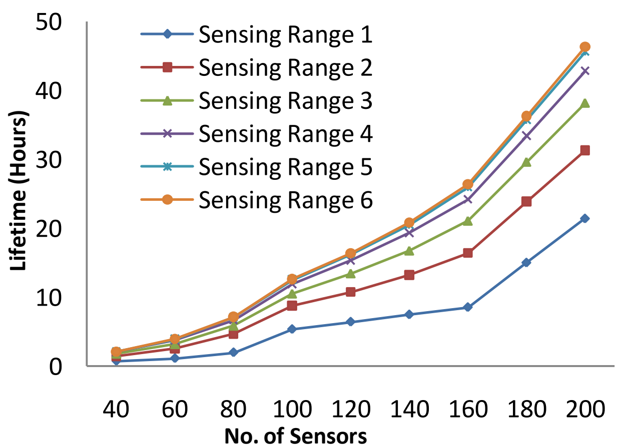


Figure 5.6 indicates the lifetime for sensor nodes in case of heterogeneous nodes and different adjustable range

6. CONCLUSIONS

In this chapter, we have proposed two energy-efficient centralized algorithms for increasing the lifetime of wireless sensor networks with adjustable sensing ranges. Our approach is schedule and energy based: Scheduling sensor nodes to alternate between sleep and active mode is an important method to conserve energy resources and head node are randomly selected based on there residual energy and distance form the base-station. Such mechanisms efficiently organize or schedule the sensor activity and have a direct impact on prolonging the network lifetime. The proposed algorithms AEEDPSH and ADLBPSH work well in increasing the network lifetime and decreasing the energy consumption to transit data in simulation. In all the Cases for AEEDPSH and ADLBPSH protocols, the lifetime of sensor networks shows an increment from [18 to 42; 17 to 38; 19 to 45] and [19 to 45; 18 to 39; 21 to 46] hours for sensing range 1-6 respectively.

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