An Energy-Efficient Position Based Clustering Protocol for Wireless Sensor Network Using Round Robin Scheduling Technique

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***Abstract* - A wireless sensor networks consists of spatially distributed autonomous sensors nodes called motes. Clustering is an effective way for prolonging the lifetime of a wireless sensor network. Current clustering algorithms consumes much time in setup phase and they hardly consider the hot spot problem in wireless sensor network. The cluster heads are co-operatively carry data to forward to base station. The ability to perform task totally depends on the available residual energy at the node. We propose an efficient clustering algorithm with position based multihop approach to partition the network region into levels with increasing number of cluster heads at each level. The cluster head closer to base station have smaller in size because it forwards the data to base station using Round Robin Technique to make the network more efficient. The proposed protocol improves the performance in delay and energy consumption. The proposed approach is more scalable than the existing solution.**

Keywords-Clustering, Position based, Residual energy, Round Robin, Wireless Sensor Network.

I. INTRODUCTION

A wireless sensor networks (WSNs) consists of spatially distributed autonomous sensors nodes called motes. The Sensor Nodes are low power device equipped with one or more sensors, a processor, memory, a power supply, a radio and an actuator [2]. The nodes are used for sensing and monitoring physical or environmental conditions such as temperature, pressure, vibration, humidity, sound etc. The information sensing node is known as source node and information gathering node is considered as sink node. The nodes are working together to monitor region. The sensed information moves from the source node to sink node with the help of intermediate nodes. The sensor node has resource constraints due to its physical size and capabilities. Each node consists of limited resources such as battery, memory and processing capability. So the careful resource utilization is required to prolong the network efficiency. In order to achieve high energy efficiency and increase the network scalability, sensor nodes can be organized into clusters. Within a clustering organization, intra-cluster communication can be single hop or multihop, as well as inter-cluster communication. Multihop communication between a data source and a data sink is usually more energy efficient than direct transmission. However, the hot-spot zone problem arises when using the multihop forwarding model in inter-cluster communication, because the cluster heads closer to the data sink are burdened with heavy relay traffic, they will die much faster than the other cluster heads, reducing sensing coverage and causing network partitioning. Although many protocols proposed in the literature reduce energy consumption on forwarding paths to increase energy efficiency, they do not necessarily extend network lifetime due to the continuous many-to-one traffic pattern.

In this paper, we proposed An Energy-Efficient Position Based Clustering Protocol for WSNs using Round Robin Scheduling Technique. It organizes the network by dividing sensor network consisting of N sensor nodes uniformly deployed over a vast field to continuously monitor the environment, into levels. Proposed technique is a competitive algorithm, where cluster heads are elected by localized competition, and rotation is performed only when the residual energy of current cluster head goes below threshold. The cluster coverage range decreases as its distance to the base station decreasing but the number of clusters increases as moving towards to base station. The result is that clusters closer to the base station are expected to have smaller cluster sizes, thus they will consume lower energy during the intra-cluster data processing, and can preserve some more energy for the inter-cluster relay traffic. The protocol also proposes a position based multihop routing technique for inter-cluster communication, a cluster head chooses a relay cluster head from higher level clusters according to the cluster heads residual energy and its distance to lower level cluster heads.

The rest of the paper organized as follows: Section II covers the related work in this area; Section III describes the proposed protocol with algorithm; Section IV validation of the proposed protocol; Section V concludes this paper.

II. RELATED WORK

Many clustering algorithms have been proposed for wireless sensor network in recent years. We review some of the most relevant papers. In LEACH [3], each node has a certain probability of becoming a cluster head per round, and the task of being a cluster head is rotated between nodes. In the data transmission phase, each cluster head sends an aggregated packet to the base station by single hop. In PEGASIS [4], further improvement on energy-conservation

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is suggested by connecting the sensors into a chain. To reduce the workload of cluster heads, a two-phase clustering (TPC) scheme for delay-adaptive data gathering is proposed in [5]. Each cluster member searches for a neighbor closer than the cluster head within the cluster to set up an energy-saving and delay-adaptive data relay link. HEED [4][5] extends LEACH by incorporating communication range limits and intra-cluster communication cost information. The initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the cost. In the implementation of HEED multihop routing is used when cluster heads deliver the data to the data sink. All these methods require re-clustering after a period of time because of cluster heads' higher workload. However, few works has considered the hot spots problem when multihop forwarding model is adopted during cluster heads transmitting their data to the base station. In [1] An Energy-Efficient Unequal Clustering (EEUC) mechanism for periodical data gathering applications in wireless sensor networks. It wisely organizes the network via unequal clustering and multihop routing. In [6], an unequal clustering model is first investigated to balance the energy consumption of cluster heads in multihop wireless sensor networks. The work focuses on a heterogeneous network where cluster heads (super nodes) are deterministically deployed at some precomputed locations, thus it's easy to control the actual sizes of clusters. Through both theoretical and experimental analyses, the authors show that unequal clustering could be beneficial, especially for heavy traffic applications. Cluster heads farther away from the base station have to transmit packets over longer distances than those of heads closer to the base station. As a result, they will consume more energy. In EECS [9], a distance-based cluster formation method is proposed to produce clusters of unequal size in single hop networks. A weighted function is introduced to let clusters farther away from the base station have smaller sizes, thus some energy could be preserved for long-distance data transmission to the base station. Many energy-aware multihop routing protocols have also been proposed for wireless sensor networks. According to different application requirements, those protocols have different goals and characteristics. However, these multihop routing protocols may not be applied to applications that require continuous data delivery to the data sink. In [10] the optimization problem of transmission range distribution of network is not balanced. The nodes can vary their transmission range as a function of their distance to the data sink and optimally distribute their traffic so that network lifetime is maximized. There simulation results show that energy balance cannot be achieved by expense of using the energy resources of some nodes inefficiently. The work reveals the upper bound of the lifetime of a flat sensor network and gives some valuable guidelines for designing multihop routing protocols for wireless sensor networks.

III. PROPOSED PROTOCOL

Consider a wireless sensor network consisting of N sensor nodes, distribution of nodes is uniform in a particular region R_c. Each sensor node contains the value of its residual energy with node ID i.e. randomly generated coordinate value (x, y). Assuming that the node ID of all nodes known by each other after deployment.

A. Algorithm:

Region division algorithm

1. Select region R_c with n number of nodes

   Each Node n $\longleftarrow$ (Node ID, R_E)

2. Region R_c divides in equal sized levels.

   $R_c = L_1, L_2 \ldots\ldots\ldots L_M$

   $L_1 = r_1 + \Delta r = L_2 = r_2 + \Delta r \ldots\ldots\ldots = L_M = r_M + \Delta r = r$

   where $r_{i=1\ldots.M}$ = area of level

   Δr is the error in area

3. Set level L_1 = Hotspot zone

4. The number of clusters at each level upto M level

   No. of cluster/level$_i$ = 2^j

   where M+1>i>0 and 0<j<M+1

   Total no. of clusters in R_c, $C_T = C_{L1} + C_{L2} + .. + C_{LN}$

Cluster head selection algorithm

1. $\forall$ C_T select competitive cluster heads

   $R_E\_N_{i=1\ldots n} > Th_{qual}$

   where R_E is residual energy of nodes in region R_c

2. Set of 'x' competitive cluster head S = ($N_{i=1\ldots x}$)

3. Implement bubble sort on S in descending order and store result in sort[i], where i =1….x

4. REPEAT IF (sort[i] = = sort[i + 1])

   THEN j $\longleftarrow$ i+1

   ELSE Exit

   $CH_i \longleftarrow$ sort [1]

5. IF (j>1)

   THEN

   m=n-j , m = Remaining nodes

   Calculate Distance

   CH_i= **min** [$\sum$ **[d** (sort[i], N_m)]]

   where 0<i<j+1

Path selection algorithm

1. Select data forwarding routes for CH_1, CH_2……CH_{T-1}
2. Calculate distance for cluster head at level (L_i) to higher level (L_{i+1})], where i=M……1
3. Implement Bubble sort on calculated distances in ascending order,
   $d_r[i]$ = Sorted[distance from cluster head at level (L_i) to higher level (L_{i-1})], where i=M……1
4. Implement Bubble sort to sort Residual energy in descending order,
   $R_E[i]$ =Sorted[Residual energy of cluster heads at L_{i-1}]
5. Assign position_count $\forall$ route[i] $\forall$ [(R_E [i]) $\wedge$ (d_r[i])]
6. Sum of position_count$\forall$route[i] = $\forall$(position_count $\vee$ route[i]) $\forall$ (R_E [i] $\wedge$ d_r[i]))
7. Select_Path(CH_i) = min[$\forall$ (Sum_of_position _count)]

B. Region division with path formation in levels

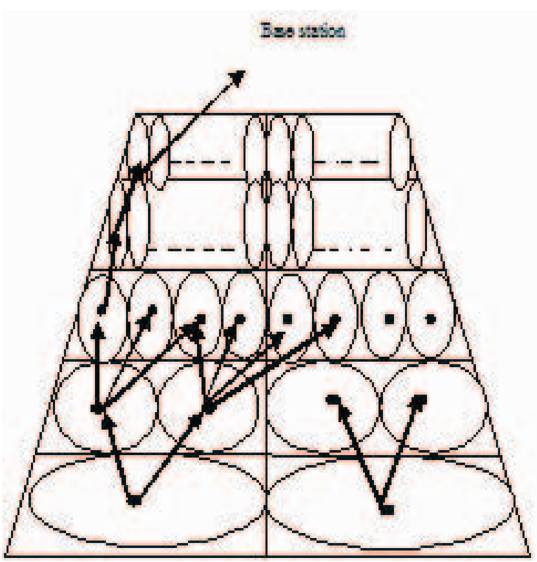

Figure 1. Region division in levels from L_1, L_2 ...L_M with clusters

IV. VALIDATION

Consider a wireless sensor network consisting of N sensor nodes, distribution of nodes is uniform in a particular region R_c. Each sensor node contains the value of its residual energy with node ID.

A. Step 1

Consider a region R_C = 300x300m with total number of nodes 10,000, divide R_C into levels i.e.

Area of level = $L_1 = L_2 = L_3 \approx 100$m
No. of cluster/level$_i$ = 2^j, N<i<1 and 1<j<N

N=3
No. of cluster at L_1, $C_{L1} = 8$
No. of cluster at L_2, $C_{L2} = 4$
No. of cluster at L_3, $C_{L3} = 2$
Total No. of clusters $C_T = C_{L1} + C_{L2} + C_{L3} = 8 + 4 + 2 = 14$

Suppose total number of nodes at level L_3 = 25, and dividing the level into two clusters
Nodes in cluster $C_1 = \lfloor 25/2 \rfloor = 12$
Nodes in cluster C_2= 13
The area of clusters at same level is approximately equal.

B. Step 2

This step performs cluster head selection at Cluster C_1 of level L_3 as shown in figure 2 any node can become competitive cluster head with if its energy is greater than qualifying threshold.

$$TH_{qual} < R_E\_CH_{11}, R_E\_CH_{12}, R_E\_CH_{13}, R_E\_CH_{14}$$

Set of competitive cluster head S= { CH_{11}, CH_{12}, CH_{13}, CH_{14}}

Residual energy of cluster heads in a set
$R_E\_CH_{11} = 30$
$R_E\_CH_{12} = 35$
$R_E\_CH_{13} = 20$
$R_E\_CH_{14} = 25$

Sort in descending order,
$R_E\_CH_{12} = 35$
$R_E\_CH_{11} = 30$
$R_E\_CH_{14} = 25$
$R_E\_CH_{13} = 20$

Cluster Head with maximum energy is selected as final Cluster Head,

$$R_{E\_max} = R_E\_CH_{12}$$

Final Cluster Head,

$$CH_1 \leftarrow CH_{12}$$

If maximum residual energy (R_{E_max}) of two or more competitive cluster heads in a set is equal then find among these cluster heads that has minimum distance across the cluster.
For this, calculate distance from these cluster heads to remaining nodes.

Suppose, No. of nodes with equal energy, j = 2

$$R_E\_CH_{11} = R_E\_CH_{14}$$

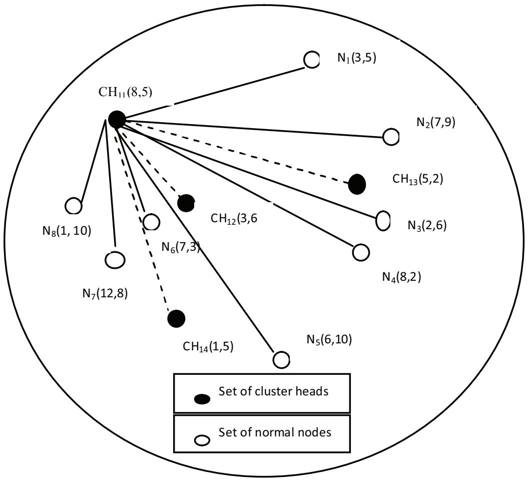

Figure 2. Cluster head selection at level L_3

Then calculate distance from CH_{11} and to all nodes in a cluster CH_{14}

TABLE I. DISTANCE FROM CH_{11} TO ALL NODES IN A CLUSTER

Distance from CH_1	Distance Calculation	Final Distance
$d_{CH11-N1}$	$[(8-3)^2+(5-5)^2]^{1/2}$	5.0
$d_{CH11-N2}$	$[(8-7)^2+(5-9)^2]^{1/2}$	4.1
$d_{CH11-N3}$	$[(8-2)^2+(5-6)^2]^{1/2}$	6.0
$d_{CH11-N4}$	$[(8-8)^2+(5-2)^2]^{1/2}$	3.0
$d_{CH11-N5}$	$[(8-6)^2+(5-10)^2]^{1/2}$	5.3
$d_{CH11-N6}$	$[(8-7)^2+(5-3)^2]^{1/2}$	2.2
$d_{CH11-N7}$	$[(8-12)^2+(5-8)^2]^{1/2}$	4.4
$d_{CH11-N8}$	$[(8-1)^2+(5-10)^2]^{1/2}$	8.6
$d_{CH11-CH12}$	$[(8-3)^2+(5-6)^2]^{1/2}$	5.0
$d_{CH11-CH13}$	$[8-5)^2+(5-2)^2]^{1/2}$	4.2
Average Distance across the cluster head		4.61

TABLE II. DISTANCE FROM CH_{14} TO ALL NODES IN A CLUSTER

Distance from CH_4	Distance Calculation	Final Distance
$d_{CH14-N1}$	$[(1-3)^2+(5-5)^2]^{1/2}$	2.0
$d_{CH14-N2}$	$[(1-7)^2+(5-9)^2]^{1/2}$	7.2
$d_{CH14-N3}$	$[(1-2)^2+(5-6)^2]^{1/2}$	1.4
$d_{CH14-N4}$	$[(1-8)^2+(5-2)^2]^{1/2}$	7.6
$d_{CH14-N5}$	$[(1-6)^2+(5-10)^2]^{1/2}$	7.0
$d_{CH14-N6}$	$[(1-7)^2+(5-3)^2]^{1/2}$	6.3
$d_{CH14-N7}$	$[(1-12)^2+(5-8)^2]^{1/2}$	11.4
$d_{CH14-CH8}$	$[(1-1)^2+(5-10)^2]^{1/2}$	5.0
$d_{CH14-CH12}$	$[(1-3)^2+(5-6)^2]^{1/2}$	2.2
$d_{CH14-CH13}$	$[(1-5)^2+(5-2)^2]^{1/2}$	5.0
Average Distance across the cluster head		5.51

The average distance across the cluster head CH_{11} is lower than CH_{14}, so it will be selected for routing data packet to level 2.

Cluster Head = MIN [Average Distance among Set of competitive cluster heads]

Final cluster head for the given problem,

$$CH_1 \leftarrow CH_{11}$$

This procedure is performed for all the clusters $C_1, C_2 ... C_{14}$ to select cluster head. Figure 3 shows the tree representation of cluster head nodes.

In each cluster, rotation is performed only when the residual energy of current cluster head goes below threshold.

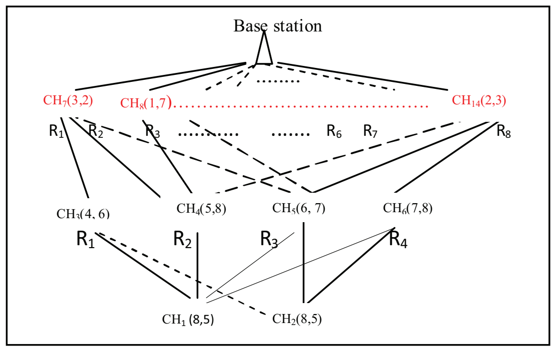

Figure 3. Tree representation of cluster head nodes

C. Step 3

Route selection for cluster head CH_1

Residual energy of higher level cluster heads,

$R_E\_CH_3 = 25$

$R_E\_CH_4 = 20$

$R_E\_CH_5 = 30$

$R_E\_CH_6 = 35$

Distance from CH_1 to higher level cluster heads,

$d_{CH1-CH3} = 4.1$

$d_{CH1-CH4} = 4.2$

$d_{CH1-CH5} = 2.8$

$d_{CH1-CH6} = 3.6$

Sorting of residual energies of higher level cluster heads in descending order and their distance from CH_1 in ascending order shown in TABLE III.

TABLE III. PATH SELECTION TABLE

Position count	Path for CH_{11} to next higher level	Residual energy of higher level cluster heads	distance from CH_{11}
1	R_1	$R_E\_CH_6$ (35)	$d_{CH1-CH5}$ (2.8)
2	R_2	$R_E\_CH_5$ (30)	$d_{CH1-CH6}$ (3.6)
3	R_3	$R_E\_CH_3$ (25)	$d_{CH1-CH3}$ (4.1)
4	R_4	$R_E\_CH_4$(20)	$d_{CH1-CH4}$ (4.2)

Sum of Position count,
R_1 = 3+3=6
R_2 =4+4=8
R_3 =2+1=3
R_4 =1+2=3
Minimum position count route will be selected for the data forwarding,
Select_Route (CH_1) = R_3
Selected route for cluster head to next higher level is calculated in same manner.
Select_ Route (CH_5) = R_5
Now, Final data transmission path is shown in Figure 4.

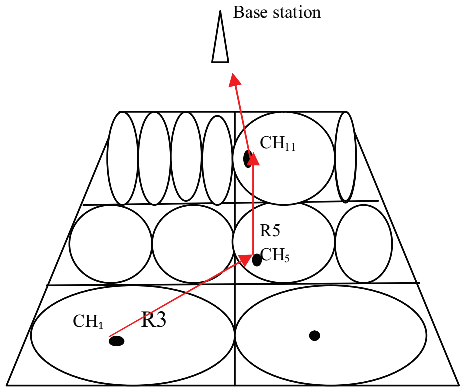

Figure 4. Selected path for CH_1 to CH_{11}

Step 4.

In this step the message/ data reached in the hotspot zone. The transmission of data from the clusters of this level to base station is transmitted by using Round Robin Scheduling Algorithm with quantum size as,

- Time interval
- Packet size.

Based on above example Hot spot zone cluster heads,
L_1 = CH_7, CH_8, CH_9, CH_{10}, CH_{11}, CH_{12}, CH_{13}, CH_{14}
The transmission of data packet from hotspot zone to base station is shown in TABLE IV and TABLE V with quantum size as

1) Time interval is taken as quantum size with equal transmission rate, considering for validation Time Quantum Size = 3

TABLE IV. DATA TRANSMISSION BY USING TIME INTERVAL

Hot spot zone cluster	No of Packets	No of rounds	Packet Transmission Sequence							
CH_7	10	4	3	3	3	1				
CH_8	15	5	3	3	3	3	3			
CH_9	5	2	3	2						
CH_{10}	20	7	3	3	3	3	3	3	2	
CH_{11}	15	5	3	3	3	3	3			
CH_{12}	24	9	3	3	3	3	3	3	3	3
CH_{13}	12	4	3	3	3	3				
CH_{14}	8	3	3	3	2					

2) Number of Packets is taken as quantum size, considering for validation Packets Quantum Size = 5

TABLE V. DATA TRANSMISSION BY USING PACKET INTERVAL

Hot spot zone cluster	No. of Packets	No of rounds	Packet Transmission Sequence				
CH_7	10	2	5	5			
CH_8	15	3	5	5	5		
CH_9	5	1	5				
CH_{10}	20	4	5	5	5	5	
CH_{11}	15	3	5	5	5		
CH_{12}	24	5	5	5	5	5	4
CH_{13}	12	3	5	5	2		
CH_{14}	8	2	5	3			

V. CONCLUSION

The proposed protocol An Energy-Efficient Position Based Clustering Protocol for Wireless Sensor Network Using Round Robin Scheduling Technique provides an effective algorithm to deal with the problem of hot spot zone generation and transmission of data to base station. The proposed protocol also deals with the minimum energy consumption due to multihop approach and improves the overall energy utilization of network. This approach is more scalable than the existing protocols for different solutions.

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