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An Energy-Efficient Congestion 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 congestion problem at the base station and inter- cluster communication in wireless sensor network. The proposed protocol deals the minimum energy consumption and congestion less transmission between the multihop clustering because one cluster head is sending data to base station and the remaining cluster heads perform intra-cluster communication during this time for receiving data packets from its nodes in finite duration time.The proposed protocol minimizes the congestion at the base station and improved throughput by using Round Robin scheduling at inter- cluster communication. The proposed approach is more scalable than the existing solution.

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

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 [1]. The nodes are used for sensing and monitoring physical or environmental conditions such as temperature, pressure, vibration, humidity, sound etc. [2]. The information sensing node is known as source node The nodes are working together to monitor region. The sensor node has resource constraints due to its physical size and capabilities. Each node consists of limited resources such as battery, memory, 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 .Multihop communication between a data source and a data sink is usually more energy efficient than direct transmission. However, the hot-spots 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.

The sensor network consisting of N sensor nodes uniformly deployed over a vast field to continuously monitor the environment, into levels. The cluster heads are elected by localized competition, and rotation is performed only when the residual energy of current cluster head goes below threshold. The proposed Protocol based on congestion and multihop routing technique for inter-cluster communication with Round Robin scheduling technique. The cluster head with higher level of residual energy and distance are considered for data transmission.

The rest of the paper organized as follows: first we discuss the related work then proposed protocol, validation of the proposed protocol and finally conclusion and references.

RELATED WORK

Many clustering algorithms have been proposed for wireless sensor network in recent years. We review some of the most relevant papers [4][5][6][7]. In LEACH [4], 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 [5], further improvement on energy-conservation 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 [6]. 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 [5][6] In the implementation of HEED [7], 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

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hot spots problem when multihop forwarding model is adopted during cluster heads transmitting their data to the base station. In [8], 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. A similar problem of unbalanced energy consumption among cluster heads also exists in single hop wireless sensor networks. 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 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 can not 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.

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. Figure 1 shows the region division with path formation in levels from L_1, $L_{2\ldots\ldots}L_M$.

A.Algorithms

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 $r_{i=1\ldots\ldots M}$ = 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, $C_T = C_{L1} + C_{L2} + \ldots + C_{LN}$

Cluster head selection algorithm

1. $\forall$ C_T select competitive cluster heads
   $E_R\_N_{i=1\ldots n} > Th_{qual}$
   where E_R 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, $CH_{2\ldots}CH_{T-1}$
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])^ (d_r[i])]
6. Sum of position_count$\forall$route[i] =$\forall$(position_count $\forall$ route[i]) $\forall$ (R_E[i] ^ d_r[i]))
7. Select_Path(CH_i) =min[$\forall$(Sum of position_count)]

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B. Region division with path formation in levels

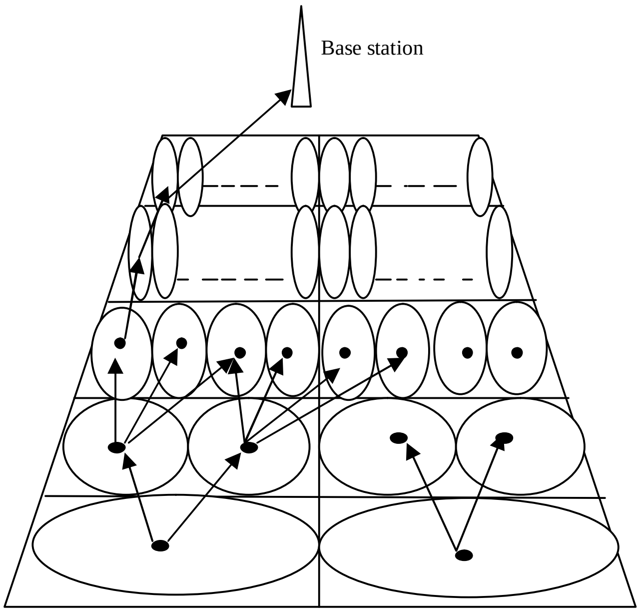

Figure 1. Region division with path formation in levels from L_1, L_2 .. L_M

C. Data Transmission

Inter-cluster communication / transmission of data packet to the base station is done by using Round Robin scheduling technique with fixed quantum time. The clusters are fixed because of its level size and cluster head (CH) may change due to level of residual energy. Initially, all the cluster heads in a region perform route discovery algorithm and synchronize with base station.

The proposed algorithm for the transmission of data packet, each cluster head is scheduled using Round Robin scheduling with fixed time quantum i.e. T_s.

The fixed time quantum T_s,

$$T_s = T_r + T_m$$

Where,

T_r = Route setup time

T_m = Time taken for the transmission of data packet

At time T_r cluster head will perform route setup it activates the route to send the data packet and it also includes the new the route discovery procedure if any of the cluster head on that route have residual energy reaches to below the threshold. At time T_m the transmission of data packet is performed to the selected route. The cluster head continue transmit data packet using selected route in time slots until the residual energy of the cluster head at level L_{i-1}, L_{i-2}….. L_M reaches below the threshold. As the residual energy reaches below threshold the cluster head informs all of its neighbors.

$$T_s = T_r + T_m$$

When there is no route discovery,

$$T_r \leftarrow 0$$

Then,

$$T_s \rightarrow T_m$$

The remaining cluster heads perform intra-cluster communication during this time, data packets are received by cluster head CH in finite duration (C_{LN}-1) and kept all the collected data in its local buffer. So the congestion at the base station is minimum and throughput is improved.

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.

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.

Step 2

Performing Cluster head selection in Cluster C_1 at level L_3 any node can become competitive cluster head with if its energy is greater than qualifying threshold Figure 2 shows the cluster head selection at level L_3.

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

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,

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

Final Cluster Head,

$$CH_1 = CH_{12}$$

If maximum residual energy (R_{E_max}) of two or more cluster heads in a set is equal then find among these cluster heads that is reachable from all remaining nodes.

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For this, calculate distance from these cluster heads to remaining nodes.
Suppose, No. of nodes with equal energy, j = 2

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

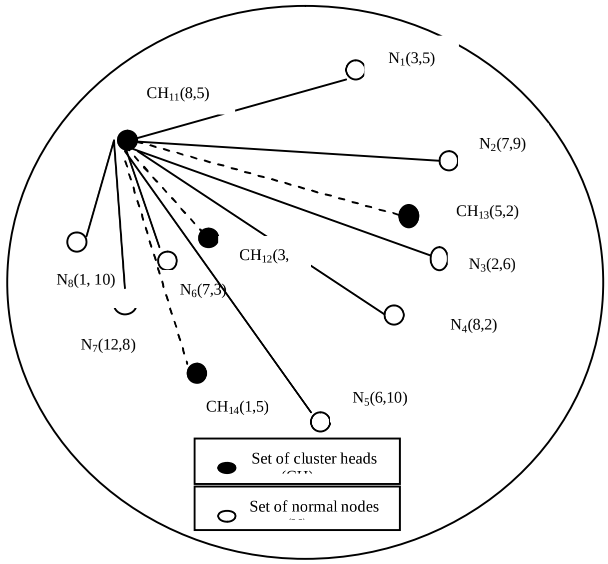

Figure 2. Cluster head selection at level L_3

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

Table 1. 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
$d_{CH11-N2}$	$[(8-7)^2+(5-9)^2]^{½}$	4.1
$d_{CH11-N3}$	$[(8-2)^2+(5-6)^2]^{½}$	6.0
$d_{CH11-N4}$	$[(8-8)^2+(5-2)^2]^{½}$	3.0
$d_{CH11-N5}$	$[(8-6)^2+(5-10)^2]^{½}$	5.3
$d_{CH11-N6}$	$[(8-7)^2+(5-3)^2]^{½}$	2.2
$d_{CH11-N7}$	$[(8-12)^2+(5-8)^2]^{½}$	4.4
$d_{CH11-N8}$	$[(8-1)^2+(5-10)^2]^{½}$	8.6
$d_{CH11-CH12}$	$[(8-3)^2+(5-6)^2]^{½}$	5.0
$d_{CH11-CH13}$	$[8-5)^2+(5-2)^2]^{½}$	4.2
Average Distance across the cluster head		4.61

Table 2. 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
$d_{CH14-N2}$	$[(1-7)^2+(5-9)^2]^{½}$	7.2
$d_{CH14-N3}$	$[(1-2)^2+(5-6)^2]^{½}$	1.4
$d_{CH14-N4}$	$[(1-8)^2+(5-2)^2]^{½}$	7.6
$d_{CH14-N5}$	$[(1-6)^2+(5-10)^2]^{½}$	7.0
$d_{CH14-N6}$	$[(1-7)^2+(5-3)^2]^{½}$	6.3
$d_{CH14-N7}$	$[(1-12)^2+(5-8)^2]^{½}$	11.4
$d_{CH14-CH8}$	$[(1-1)^2+(5-10)^2]^{½}$	5.0
$d_{CH14-CH12}$	$[(1-3)^2+(5-6)^2]^{½}$	2.2
$d_{CH14-CH13}$	$[(1-5)^2+(5-2)^2]^{½}$	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, $C_2 \ldots C_{14}$ 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 certain threshold TH_{ACT}.

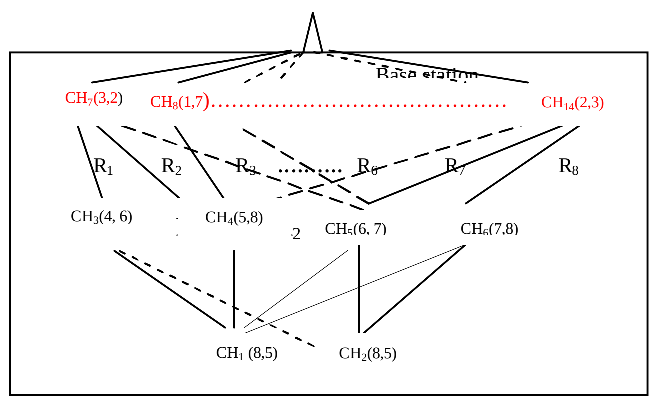

Figure 3. Tree representation of cluster head nodes

Step 3.

The scheduling of inter-cluster communication is followed by time quantum size

CH_1	CH_2	CH_3	CH_4	CH_5	..	CH_{14}

0 1 2…………… 14 15

The quantum value to start the process for $CH_1 = T_0$

At T_{0r}

Route selection for cluster head CH_1 performed

Residual energy of higher level cluster heads,

$E_R\_CH_3 = 25$

$E_R\_CH_4 = 20$

$E_R\_CH_5 = 30$

$E_R\_CH_6 = 35$

Distance from CH1 to higher level cluster heads,

$d_{CH1-CH3} = 4.1$

$d_{CH1-CH4} = 4.2$

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$d_{CH1-CH5} = 2.8$
$d_{CH1-CH6} = 3.6$
Sorting of residual energies of higher level cluster heads in descending order and their distance from CH_1 in ascending order shown in table 3.

Table 3.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	$E_R\_CH_6$ (35)	$d_{CH1-CH5}$ (2.8)
2	R_2	$E_R\_CH_5$ (30)	$d_{CH1-CH6}$ (3.6)
3	R_3	$E_R\_CH_3$ (25)	$d_{CH1-CH3}$ (4.1)
4	R_4	$E_R\_CH_4$(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
Same calculation will be performed upto L_{i-1}, L_{i-2}..... L_M levels.
Select_Route (CH_1) = R_3 - R_5 - R_{10}
CH_1 will not perform route selection in its next time quantum unless the residual energy of any of the cluster head in the following route goes below threshold.
At T_{0m}
All the data packets stored in buffer transmitted to the selected route. Network is congestion free and it selects the transmission rate of the system.

Table 4 For CH_1 after its schedule at T_{0m}

clusters Heads	Data in Buffer	Route
CH_1	12	R_3 - R_5 - R_{10}

CH_5, CH_{11} follow the same route discovered by CH_1 in their time slot.

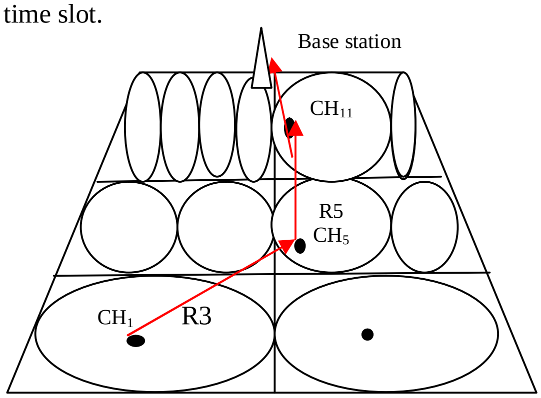

Figure 4. Selected path for CH_1 to CH_{11}

For the cluster heads CH_5, CH_{11} ,

$$T_r \leftarrow 0$$

CH_5, CH_{11} follow the same route discovered by CH_1 in their time slot. Figure 4 shows the final selected route for data transmission.

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 congestion at base station. The proposed protocol deals the minimum energy consumption and congestion less transmission between the multihop clustering because the remaining cluster heads perform intra-cluster communication during this time for receiving of data packets from its nodes in finite duration (C_{LN}-1) time. So the congestion at the base station is minimum and throughput is improved. The overall energy utilization of network is improved and it is more scalable.

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