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ENERGY EFFICIENT UNEQUAL CLUSTERING ALGORITHM FOR CLUSTERED WIRELESS SENSOR NETWORK

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Abstract: Clustering provides an effective method for extending the lifetime of a wireless sensor network. Current clustering methods selecting cluster heads with more residual energy, and rotating cluster heads periodically to distribute the energy consumption among nodes in each cluster. However, they rarely consider the hot spot problem in multi hop sensor networks. When cluster heads forward their data to the base station, the cluster heads closer to the base station are heavily burdened with traffic and tend to die much faster. To mitigate the hot spot problem, we propose a Novel Energy Efficient Unequal Clustering Routing (NEEUC) protocol. It uses residual energy and groups the nodes into clusters of unequal layers.

Keywords Wireless sensor networks, Unequal clustering, Routing, Network lifetime, Hot spot problem.

I. INTRODUCTION

A. *Detail Problem Definition*

Wireless sensor networks are of tiny, battery powered sensor nodes with limited processing power and capabilities. To overcome this problem and to achieve higher energy efficiency, sensor nodes are grouped into clusters, where each cluster heads collects all the data and process them before being sent to the base station. To achieve network scalability, clustering[1] is the best solution. The potential applications of sensor networks are highly varied, such as environmental monitoring, tar- get tracking, and battlefield surveillance. Sensors in such a network are equipped with sensing, data processing and wireless communication capabilities. Distinguished from traditional wireless networks, sensor networks are characterized by severe power, computation, and memory constraints. Due to limited and non-rechargeable energy provision, the energy resource of sensor networks should be managed wisely to extend the lifetime[2] of sensors. We consider a network of energy-constrained sensors that are deployed over a geographic area for monitoring the environment. Each sensor periodically produces information as it monitors its vicinity. The basic operation in such a network is the systematic gathering and transmission of sensed data to a base station for further processing. In order to achieve high energy efficiency and increase the network scalability, sensor nodes can be organized into clusters. Data collected from sensors are sent to the cluster head first, and then forwarded to the base station.

B. *Need of Proposed System*

In this paper, we propose and evaluate an Novel Energy Efficient Unequal Clustering Routing (NEEUC) protocol for mitigating the hot spot problem in wireless sensor networks. It is designed for long lived, source driven sensor network applications, such as periodical environmental information reporting. NEEUC consists of two parts, one is an Unequal Clustering algorithm for topology management, and the other is a greedy geographic and energy aware routing protocol for inter cluster communication. The main contribution of the paper is that we provide the first unequal cluster based routing protocol to mitigate the hot spot problem and thus prolong the network lifetime. NEEUC is a self-organized competition- based algorithm, where cluster heads are selected based on local information (i.e., the residual energy of neighboring nodes).

II. RELATED WORK

There has been substantial research in the area of routing in wireless sensor networks. Many energy efficient clustering algorithms have been proposed to prolong the network lifetime [3]. We review some of the most relevant papers. Heinzelman et al. [4] first propose a clustering protocol called LEACH for periodical data gathering applications. LEACH uses randomized rotation of cluster heads to distribute energy consumption over all nodes in the network. In the data transmission phase, each cluster head forwards an aggregated packet to the base station directly. An energy-aware variant of LEACH is proposed in [5][6], in which the nodes with higher energy are more likely to become cluster heads. However, the underlying routing protocol is assumed to be able to propagate node residual energy through the network. The authors analytically determine the optimum number of cluster heads. HEED [8][9] introduces a variable known as cluster radius which defines the transmission power to be used for intra-cluster broadcast. 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 intra-cluster communication cost. HEED terminates within a constant number of iterations, and achieves fairly uniform distribution of cluster heads across the network. EECS [10] introduces a cluster head competitive algorithm without message exchange iterations. It extends LEACH and HEED by choosing cluster heads with more residual energy. It also achieves a decent distribution of cluster heads. While the clustering problem has been extensively explored, researchers have only recently started to study the strategies for balancing the workload among cluster heads while considering the inter-cluster traffic. In single hop sensor networks, cluster heads use direct Communication to reach the base station, and the problem of unbalanced energy consumption among cluster heads arises. Cluster heads farther away from the base station have heavier energy burden due to the long-haul communication links.

Consequently, they will die earlier. In EECS [11][12], a distance based cluster formation method is proposed to produce clusters of unequal sizes. Clusters farther away from the base station have smaller sizes, thus some energy could be preserved for long-haul data transmission to the base station. On the other hand, the hot spot problem arises when multi hop routing is adopted when cluster heads deliver their data to the base station. Heinzelman first investigate an unequal clustering model for balancing the energy consumption of cluster heads in multi hop sensor networks. The work focuses on a Heterogeneous network where cluster heads (super nodes) are deterministically deployed at pre-computed locations. Through both theoretical and experimental analyses, the authors show that unequal clustering could be beneficial, especially for heavy traffic applications.

The hot spot problem addressed in this paper is due to the many-to-one multi hop data forwarding pattern on the cluster head backbones. Researchers have proposed several methods to mitigate this kind of hot spot problem. Perillo et al. [15] analyse two such strategies. Although the network lifetime can be improved by using a more intelligent transmission power control policy that balances the energy consumption of each node, they conclude that it cannot solve the hot spot problem on its own.

They also investigate the effectiveness and cost efficiency of using a heterogeneous clustering hierarchy to mitigate the hot spot problem.

In some works, special assumptions about the sensor network are made to facilitate solving the hot spot problem. For example, in homogenous sensor networks, additional sensor nodes can be deployed in the area near the base station as reservoirs of energy [16][17].In [18], multiple sink nodes are deployed to alleviate the hot spot problem in large-scale sensor networks. It also reduces the energy dissipation at each node. Recent research begins to exploit the mobility of some nodes to facilitate the delivery of the sensed data to the base station. Gandham et al. [19] investigate the idea of employing multiple mobile sink nodes to increase the lifetime of sensor networks. Location-based geographic routing is also attractive in wireless sensor networks due to its efficiency and scalability, and it is more energy-efficient for data forwarding on the cluster head backbone compared to traditional hop based methods. Geographic routing algorithms have been studied in the context of wireless networks. In this paper, we study the hot spot problem existing in the hierarchical (cluster-based) wireless sensor networks. In our study there is no need for pre-deployment which greatly simplifies system deployment. Besides that we also present a novel inter-cluster routing strategy considering the metrics of both transmitting distance and residual energy.

III. NETWORK MODEL

The network consists of a set of sensors which are uniformly deployed over a field to continuously monitor the environment. We make some assumptions about the sensor nodes and the network model.

- All the nodes are alike and each node is assigned with a unique identifier (ID).
- Base station is located at the center of the monitor field. Sensors and the base station are all stationary after deployment.
- A node can compute the approximate distance to another node based on the received signal strength.
- Node can transmit in different power levels to achieve different communication range.

We use a simplified model presented in [1]. Either the free space (d2 power loss) or the multi-path (d4 power loss) channel is used based on the distance between the transmitter and the receiver. The energy spent for transmitting h-bit packet over distance d is:

$$ETX(h,d) = \begin{cases} hE_{elec} + h\varepsilon_{fs}\, d^2 \ldots\ldots d \le d_0 \\ hE_{elec} + h\varepsilon_{mp}\, d^4 \ldots\ldots d > d_0 \end{cases} \quad (1)$$

Where d0 is the critical distance beyond which multi-path channel mode is used. Energy spent for receiving h-bit packet is

$$ERX(h,d) = hEelec \quad (2)$$

All the cluster head can always aggregate the data coming from its member into a single length-fixed packet.

IV. NEEUC Routing Algorithm:

A. Assumption

1. Sensors uniformly deploy over a sensor field
2. Sensors and a BS are all stationary
3. Sensors can use power control
4. A node can compute the
5. Approximate distance to another node based on the received signal strength

The key idea of NEEUC is to mitigate the Hotspot problem.

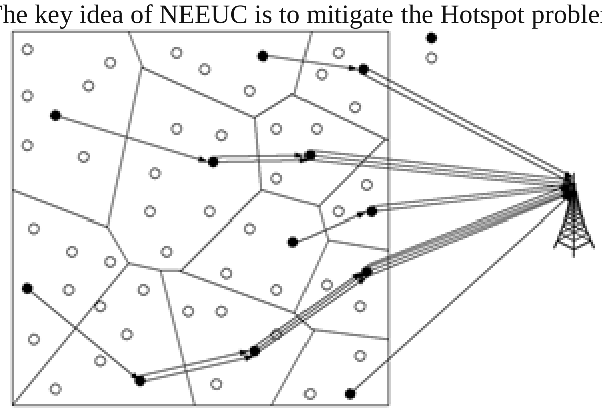

Fig.1 Unequal clustering mechanism

We introduce a novel energy efficient unequal clustering protocol for hierarchical routing, called NEEUC. It organizes the network into clusters of unequal sizes. By decreasing the number of nodes in clusters with higher relay load near the base station, we can maintain more uniform energy consumption among cluster heads in the long run.

B. Novel Unequal clustering algorithm

The Algorithm includes the following phases
a). Design of network structure
b) Determine communication radius
c) Clustering mechanisms
d) Multi hops transmission.

Clustering a wireless sensor network means partitioning its nodes into clusters, each one with a cluster head and some ordinary nodes as its members. Similar to LEACH, the operation of this algorithm is divided into rounds. The task of being a cluster head is rotated among sensors in each round to distribute the energy consumption across the network. NEEUC is a distributed cluster head competitive algorithm, where the cluster head selection is primarily based on the residual energy and distance to the base station. The algorithm for determine scope of each layer is follows.

a) Design Network Structure
The BS broadcasts a “hello” message to all nodes.
1. Each node computes the distance to the BS based on signal strength and determine layer using following formula.
Upper = dmin + i *dmin/m , i=1,2,-----n (3)
Lower = dmin +(i-1)*dmax-dmin/m , i=1,2,----n
Where dmin & dmax –shortest and longest distance between node and base station.
Assume distance between node and base station is greater than lower boundary & less than upper boundary then node belongs to layer i.

b) Determine cluster Radius
In this phase cluster radius of each node computed based on distance to the base station and residual energy.
Radius= [ε_1 (1-c* dmax −d (S_i,BS)/ dmax-dmin) + ε2* E_{Th}/Einit]*Ro (4)
Where dmin & d_{max} –shortest and longest distance between node and base station.
d (S_i,BS) - distance from node I to base station.
C, ε_1, ε2 - constant between 0-1
Ro- system setting of cluster radius.
Radius varies as residual energy & distance between node to BS varies.

c) Clustering algorithm
Step-1 node generate random number between 0-1
If Random-no< T then node becomes candidate node.
Step-2 Candidate node send message to its radius calculated in above formula.
Step-3 if node i can receive a message(id,Ri,RE) from node j & distance between both nodes is less than any competition radius of each other, then node i store node j in $S_{ct..}$ Each tentative CH maintains a set S_{CH} of its “adjacent” tentative CH.
Where Ri- radius RE-residual energy
Step-4 Node i compare its own energy with the energy of each node in $S_{ct...}$If the energy of node i > any node satored in $S_{ct..}$ then node becomes CH and release a message Finish _Elect_Meassage within its cluster radius.
Step-5 According to information within Compate_Head_Meassage non CH node join with CH.If non CH received more message then use larger signal strength.

d). Multi Hop communications
C. Algorithm of multipath routing

***if**(network created)*
***if**(SourceNode != DestNode)*
int Size = datasize;
Send(data)
ACK = data received size;
***if**(ACK == datasize)*
Data received successfully;
Flag = true;
else
Data is lost in path;
Flag = false;
***if**(Flag == false)*
***For** all paths;*
Calculate average of energy and trust value.
***if**(average==maximum value)*
shortest path = current path;
Send(data);

Multipath Routing is a routing procedure, which chooses various ways to convey information in the middle of source and destination nodes. As the essential significance of routing means, selecting best way in the system, multipath routing strategies are utilized to choose the best path in the network.

C) Data-Aggregated Unequal Layer Inter-Cluster Routing
There is a large number of redundant data among different clusters in practical application. In this paper, Data-aggregated Unequal Layer Inter–cluster routing protocol is proposed to solve this problem. Cluster heads from outer layer forward to the next inner layer and finally reach the base station. We will select the MCH (Main Cluster Head) in layer 0 whose distance are smaller to base station as less than TD_MAX. The algorithm is as follows.
1)Suppose there are many cluster heads CH_1,CH_2….CH_n, whose distances are less than threshold TD_MAX, each cluster head sends their residual energy E_1,E_2,…..E_n and values of data size K_1,K_2,….K_n.to base station.
2) Base station calculates the total size of data packet as
Ksum=K1+K2+……..+Kn (5)
3)In order to transmit a K-bit message, the radio expends

ETX(k,d)=Eelec*k+εamp*k*d^2 (6)

where E_{elec} and ε_{amp} are the fixed values. In order to send the data packets from CH_1 and CH_2, the base station expends:

$E_{T1} = E_{elec} * K_{sum} + \epsilon_{amp} * k_{sum} * d_1^2$ (7)
And

ET2 =Eelec *Ksum +ϵamp *ksum *$d2^2$ *(13)*
Where d_1 and d_2 are distances from CH_1 and CH_2 to base station.
4) Base station calculates the difference value between cluster head CH1 and CH2 as
ΔET=εamp*Ksum*(d11- d22) (8)
And the difference value between the residual energy of cluster head CH1 and CH2 is: ΔE=E–E2 (9)
5) Compare ΔE with ΔE_T,
if ΔE is greater than ΔE_T
CH1 chosen as the preliminary main cluster head (PMCH). Final PMCH will become the main cluster head (MCH). MCH will collect all the data and it will check for redundancy, before being sent to the base station. Thus it efficiently balances the energy consumption and increases the network lifetime.

V. RESULTS AND DISCUSSION

A. Energy Efficiency
We observe that the energy consumed by CH’s and normal nodes in EEUC is greater than NEEUC.

VI. CONCLUSION

In this paper, we have introduced a novel unequal clustering routing protocol for wireless sensor networks. The hot spot problem arises when employing the multi hop routing in a clustered sensor network. To address the hotspot problem, we first introduce an unequal clustering algorithm. Cluster heads closer to the base station have smaller cluster sizes than those farther from the base station, thus they can preserve some energy for the purpose of inter-cluster data forwarding. As well as we introduced aggregated unequal layer inter clustering.

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