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An unbalanced and distributed clustering algorithm – UBDC

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Many in-network aggregation and clustering methods have been proposed for reducing energy consumption in sensor networks. In this paper, we propose an unbalanced and distributed clustering algorithm based on in-network aggregation at nodes within clusters. Cluster heads of the previous round themselves select new cluster heads and determine the number of cluster head considering energy, location and density. This algorithm determines the range of cluster according to the distance between a base station and cluster beads to equalize energy consumption

1. Introduction

Recent advances in wireless communication and MEMS(MicroElectroMechanical System) have enabled the development of sensor nodes with sensing, communicating, and processing capacity[1]. A sensor networks composed of a large number of sensor nodes densely deployed to gather information of a physical environment. Because a size of the sensor nodes is really small, sensor nodes are severely constrained by some resources such as battery power, memory and computing capability available. These constrained resources limit the lifetime and quality of the network.

In order to maximize the lifetime of sensor networks, many researchers have proposed a lot of protocols and algorithms. Some of them are hierarchical architecture and in-network processing among the proposed architectures. Hierarchical techniques can aid in reducing energy consumption and ensure scalability of the large sensor networks[2~5]. Since wireless communications consume significant amounts of battery power a method of in-network aggregation has been proposed to reduce transmitting and receiving the amount of data.

When cluster heads send data to the base station, each cluster head needs different amounts of energy according to the distance between a cluster head and the base station. We consider that it is possible to compensate for the difference of energy required for transmitting and receiving data between each cluster head and the base station by varying members in each cluster according to the distance between its cluster head and the base station. Also we think it is feasible to form a

cluster by employing in-network query processing.

In this paper, we propose an unbalanced and distributed clustering algorithm based on in-network aggregation at nodes within each cluster.

The rest of the paper is constructed as follows. Section 2 discusses related work, and Section 3 describes our sensor networks. In Section 4 the proposed algorithm is presented in detail. Finally, we conclude in Section 5.

2. Related work

Many protocols have been proposed and designed in order to extend the lifetime of sensor networks with constrained resources. For example, Directed Diffusion selects the optimal paths to forward and reply on data to a requesting node as data routing protocols for energy efficiency[7]. TAG aggregation has been introduced to SQL query systems in database. TAG saves energy by using in-network aggregation[8].

As a representative clustering protocol LEACH protocol was proposed. It was a solution using the hierarchical architecture and data aggregation at cluster heads. In LEACH, a pre-determined percentage of senor nodes become cluster heads per round. After forming clusters, the cluster heads gather sensor data from other nodes in their vicinity and transfer the aggregated data to the base station. Since a cluster head consumes more energy than other nodes, LEACH rotates the role of the cluster head among sensor nodes, which leads to balanced energy consumption of nodes. However LEACH does not guarantee to make a good cluster head distribution.

3. Sensor networks

In this paper, we present a mechanism for clustering and data gathering in sensor networks. We assume that the battery capacity of each sensor node differs from anther's among sensor nodes and the sensor nodes are aware of their location and their neighbors and can check the residual energy.

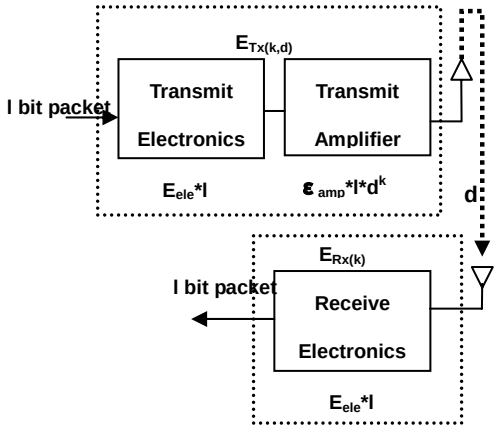

Fig1. Radio energy dissipation model

We use the same radio energy dissipation model as LEACH.

To transmit an l bit message a distance d, the radio expends

$$E_{Tx}(l,d) = E_{Tx\text{-}elec}+E_{Tx\text{-}amp}(l,d)$$
$$= l*E_{elec}+l * E_{amp} * d^k$$

and to receive this message, the radio expends: $E_{Rx}(l) = E_{Rx\text{-}elec}(l) = l*E_{elec}$

In this model, there are some communication energy parameters : the electronics energy(Eelec), the amplifier energy(ε_{amp}) and the energy for data aggregation. Eeach parameter is set as : Eelec=50nJ/bit, ε_{amp}= 100pJ/bit/m^2. And the energy for data aggregation(E_{DA}) is set as

E_{DA}=5nJ/bit/signal.

4. The algorithm-UBDC

We propose a novel data gathering algorithm using the unbalanced clustering based data aggregation at nodes. In this section, we describe our algorithm in detail. First we define the parameters used in clustering and transmitting data e.g. cluster head selection parameters and data tree construction parameters.

4.1 Protocol outline

In order to reduce energy consumption and guarantee scalability in sensor networks, we employ clustering and in-network processing.

We have views on conception of the TAG algorithm and introduce in-network processing in the UBDC.

A round of data gathering is composed of two processes: (1) cluster formation and the data aggregation tree construction, (2) cluster head selection and data transmission. The phase of cluster formation and the data aggregation tree construction is triggered at the same time. The data aggregation is carried out between child nodes and parent nodes. Child nodes sending data to their upper level nodes and parent nodes receiving data from their lower level will be set during the data aggregation tree construction. The phase of cluster formation is carried out by using local multi-hop communication. In other words, each node broadcasts a cluster formation message to its neighbors. In the phase of data transmission and cluster head selection, each node aggregates sensed and collected data from its child nodes. Our cluster head selection algorithm is carried out at each the upper level node in data aggregation tree. Preferentially, the temporary cluster heads are selected by each level parent node. And the final cluster head decision is done by at the present cluster head. The present cluster head select the new cluster head.

4.2 Protocol parameters

The first parameter in the process of cluster formation, the data aggregation tree construction and cluster head selection is the residual energy of each node i (Ei). Further in order to pick out the optimal cluster head and the optimal parent node the secondary parameters are considered such as a distance(D) between neighbors j and the number of nodes that a node can hold as child nodes among its neighbors, called probability(P).

In the phase of cluster formation and the data aggregation tree construction, we use a function of the residual energy, the distance and probability as threshold for estimating the optimal parent node. The threshold function is defined as follows

$$F(e, d_{ij}, p) = \beta * \frac{Ei}{d_{ij}^{\ 2} * p}$$

β is an invariable for regulating the function. Ei is the residual energy of each node i, and d_{ij} is the distance between node i and each neighbor j, and p is the probability. Each node that receives data from several nodes selects a node which holds the highest value returned by the function.

We consider the unbalanced cluster which has the different number of members in each cluster. It compensates for the disparity of energy to vary members in each cluster according to the distance D_{CH-BS} between the base station and each cluster head. The used parameter is the distance D_{CH-BS} . In order to differ from the number of members in each cluster we vary each cluster range or radius CR. The cluster range is in inverse proportion to D_{CH-BS} .

In the phase of cluster head selection, we consider the residual energy, density and location of the cluster head as the cluster head selection parameters. The cluster head selects the new cluster head holding more the residual energy among the present round cluster members. We deal with the coverage problem by varying the number of new cluster head and by broadcasting to the larger cluster range.

4.3 Protocol operation

We previously divide the sensing field into several parts (Pn) like Fig 2 and calculate and set up the cluster range before deploying sensor nodes.

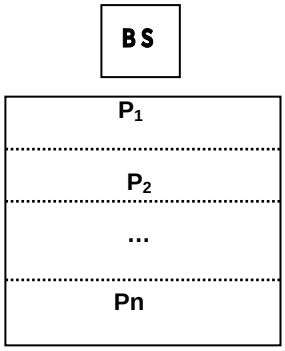

Fig 2 . The partition of a sensor field

The newly selected cluster heads CH_i are aware of their part by calculating the distance between each cluster head and the base station. Each cluster head adjusts and determines their cluster range by multiplexing the coefficient to the previously calculated cluster range according to their part.

The phase of cluster formation and the data aggregation tree construction is carried out as follows like Fig3

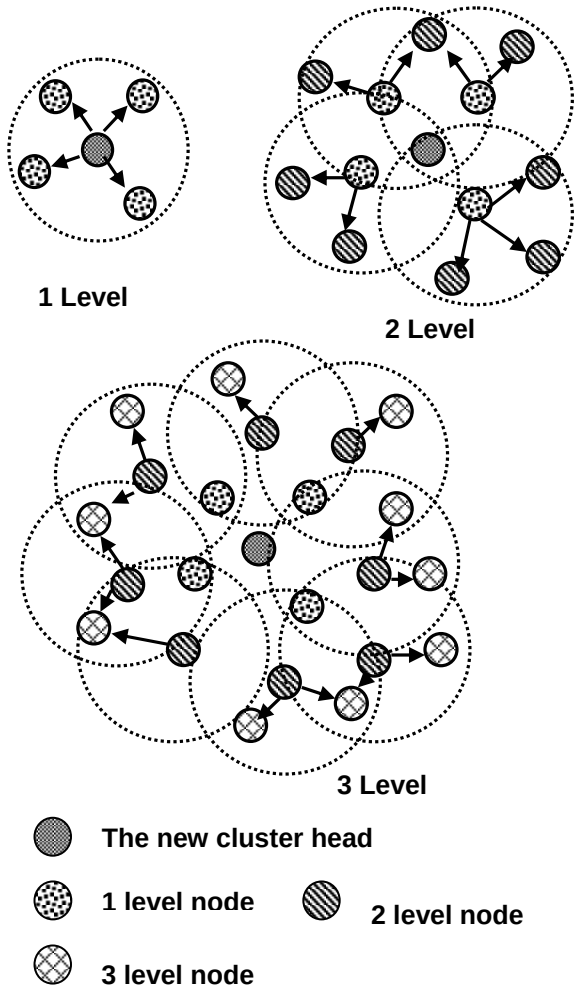

Fig3. Forming cluster and constructing the data aggregation tree

(1) Each cluster head CH_i whose level is set to 0 broadcasts its cluster formation query message, which

include is location data (CH(x,y)) and the cluster range(CR).

(2) The first level nodes which receive data from their cluster head set their cluster head to their parent value and Ls+1 to level value (Lf). They create a message with information of location, the residual energy (Ei) and probability (Pi) and broadcast the message to their neighbors.

(3) Each node receiving a message from upper level nodes sets its level value to the value added one to the upper level one, selects a parent node with high-power energy, the short distance from it, and the low probability, and broadcast the message to its neighbors.

(4) Step (3) is repeated until the message reaches the cluster range.

Our algorithm employs cluster rotation of LEACH, and selects new cluster heads per rounds, although it uses cluster heads selection. The phase of the cluster head selection and data transmission launches as follows after finishing the phase of cluster formation and data aggregation tree construction.

(1) Each child node transfers messages to its parent node according to the data aggregation tree constructed in the data aggregation tree construction phase. The message consists of sensing data and information to related the cluster head selection such as the residual energy and location

(2) Each parent node aggregates the collected sensing data from their child nodes and carries out the process of cluster head selection. Each parent node selects the highest-power node as the tentative cluster head among child nodes and itself

(3) Each parent node transmits a message with aggregated sensing data and data of the tentative cluster head such as location and the residual energy to their upper tree level parents.

(4) Step (2) and (3) are repeated until each cluster head receives the message.

(5) Each cluster head sends the aggregated sensing data to the base station, selects new cluster head and notice to start cluster formation to it.

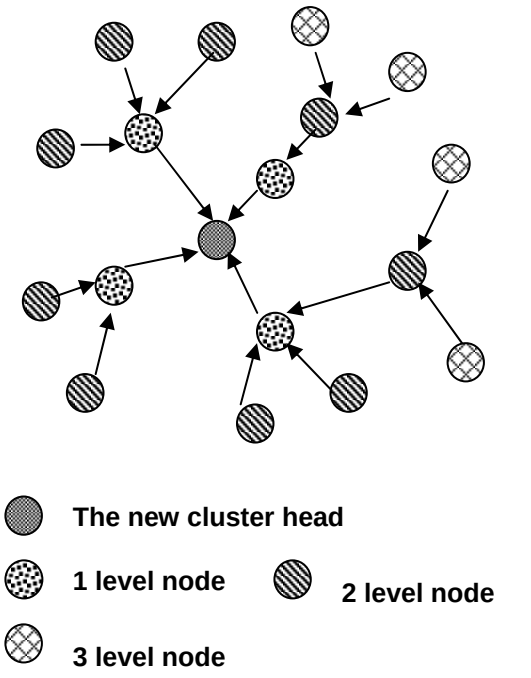

Fig4. Data transmission and cluster head selection

5. Conclusion

In this paper, we presented an unbalanced and distributed clustering algorithm based on in-network aggregation at nodes within clusters. Varying members in each cluster according to the distance between each cluster head and the base station compensates for the disparity of energy for sending data to the base station. By using local communication techniques and in-network processing energy for a cluster head is distributed at each member in their cluster.

We are preparing to conduct experiments for evaluating this algorithm.

Reference

[1] Ian F. Akyidiz, Weilian Su, Yogesh Sankarasubramniam , ,A survey on sensor network,IEEE Communication Magazine, Vol.40, No.8, pp.102-114 ,Aug 2002

[2] S. Bandyopadhyay, E.Coyle, An energy efficient hierarchical clustering algorithm for wireless sensor networks, IEEE Infocom, San Francisco, CA, 2003

[3] Mohamed Younis, Moustafa Youssef, Khaled Arisha, Energy-Aware routing in Cluster-based sensor networks, Proceedings of the 10th IEEE/ACM International Symposium on Modeling, Analysis, simulation of Computer and Telecommunication Systems (MASCOTS'02), Fort Worth, Texas, October2002

[4] W.Heinzelman, A.Chandrakasan, H.Balakrishnan, Application-specific protocol architecture for wireless microsensor sensor networks, IEEE transactions on Wireless Comunication 1(4) ,660-670.2002

[5] Stemphanie Lindsey, and Cauligi S. Raghavendrea, PEGASIS: Power-Efficient Gathering in Sensor Information Systems, Submitted to ICC 2001

[6] O.Younis and S.Fahmy,, Distributed clustering in ad-hoc sensor networks: A hybrid, Energy-efficient approach ,In Proceedings of IEEE INFOCOM, March 2004

[7] C.Intanagonwiwat, R.Govindan, and D.Estrin, Directed diffusion: A scable and robust communication paradigm for sensor networks, In Proc, 6th Annual International Conference on MobiCom 200, p.p 56-67, Boston, ACM press, August 200

[8] S,Madden, M.Franklin,J.Hellerstein, and W.Hong, TAG:a tiny aggregation service for ad-hoc sensor networks, In Pro.of ACM WSNA'02,2002