A CLUSTERING PROTOCOL BASED ON TREE ROUTING ALGORITHM IN WIRELESS SENSOR NETWORKS (WSNs)

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***Abstract*— In today's world Wireless Sensor Networks (WSNs) are an emerging technology for monitoring physical environment. WSNs consist of small nodes with sensing, computation and wireless communications capabilities. These sensor nodes are constrained in energy supply, processing and storage. Such constraints combined with a typical deployment of large number of sensor nodes have posed many challenges to the design and management of sensor networks. The main drawback of WSNs is their very limited battery energy which has great influence on the lifetime of the network. The design is affected by several constraints that call for new paradigms. In this paper, we propose routing algorithm called Chain-Tree based Routing Algorithm (CTRA), which makes full use of the advantages of LEACH and PEGASIS, and provides improved performance. It divides WSNs into a few chains and runs in two stages. In first stage, sensor nodes makes network into group of clusters with chain routing inside the cluster. Sensor nodes in each chain transmit data to their own chain leader node in a cluster, using an improved chain routing protocol. In the second stage, all chain leader nodes form a tree routing in a self organized manner. Experimental results demonstrate that our CTRA algorithm out performs LEACH in terms of energy consumption, throughput and network delay.**

Keywords- Wireless sensor networks, LEACH Protocol, Cluster mechanism, Chain based routing, Binary tree

1. INTRODUCTION

The flexibility, self-organization, low-cost and rapid deployment of wireless sensor networks (WSN) are ideal characteristics to many new and exciting ubiquitous application areas such as data gathering, military, environment monitoring, intelligent control, traffic management, medical treatment, manufacture industry, antiterrorism. WSNs will be the essential infrastructure for intelligent ubiquitous services by sensing and collecting the information of various scattered objects. Therefore, recent years have witnessed the rapid development of WSNs.

A wireless sensor network is a kind of ad-hoc networks and it is composed of numerous sensor nodes. Each sensor node can sense its periphery to collect specific data and deliver these data to the other sensor nodes or to the external base station. In general, sensor nodes have some limitations such as a restricted computing ability, memory size and battery. The largest part of a node's energy is consumed while transmitting and receiving. In a clustering network, nodes are grouped into clusters and there are special nodes called cluster head. They are responsible for an efficient way to lower energy consumption within a cluster by performing data aggregation. In a heterogeneous sensor network, two or more different types of nodes with different battery energy and functionality are used. On the other hand, in homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity. As a result, network performance decreases since the cluster head nodes goes down before other nodes do. Thus dynamic, energy efficient and adaptive cluster head selection algorithm is very important. Therefore, we have to consider these limitations to design routing protocols. The current routing protocols in the wireless sensor networks can be divided into the flat-based, hierarchical-based and location-based routing protocol. Most of the hierarchical-based routing protocols assume that sensor node can communicate with the external base station by one-hop routing regardless of the distance between them. However, considering limitations of sensor nodes, this assumption is unrealistic when the hierarchical-based routing protocol is applied to large-scale sensor networks.

The remainder of this paper is organized as follows. In section II, we give an overview of the related works. Then communication model of our proposal are discussed in section III. A detail description of our approach CTRA is presented in section IV. We present our simulation results compared with other algorithm in section V. Finally, section VI presents a conclusion.

II. RELATED WORK

In general, three strategies are considered for the design of data aggregation techniques in WSNs. They are clustering based, tree-based , and chain-based.

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular clustering algorithms for WSNs (W. Heinzelman et al., 2000) [1]. LEACH guarantees that the energy load is well distributed by dynamically created clusters, using cluster heads elected dynamically according to predetermined optimal probability variable. The rotation is performed by getting each node to choose a random number between 0 and 1. A node becomes a CH for the current rotation round if the number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)}, \text{if } n\epsilon G \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

where p is desired percentage of cluster head nodes in the sensor network, r is current round number, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

Energy-LEACH protocol improves the CH selection procedure. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. Same as LEACH, E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy [2]. A new version of LEACH called Two-level Leach was proposed. In this protocol; CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station [3]. In V-LEACH protocol, besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies because the reasons we mentioned above. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies. This will extend the overall network life time [4]. PEGASIS which proposed a fixed chain topology to avoid the periodic head voting. Its long chain topology, however, increases the delay of data transmission [5]. Chain Oriented Sensor Network (COSEN) for collecting information efficiently is proposed which is a hierarchical chain based protocol. Sensors are grouped into one higher level chain and several lower level chains. In every chain one sensor is elected as a chain-leader based on the residual energy and this node remains as a chain leader for an optimal number of rounds. One higher level leader is selected among all lower level leaders based on some measures at every round. All nodes in a lower level chain send messages to the lower level leader. Besides, all lower level leaders send the information to the higher level leader. The higher level is the node that transmits the information to the BS [6].

III. COMMUNICATION MODEL

In this paper, we have the following assumptions for such WSNs.

• Nodes are static in nature.
• All nodes know their position information.
• All sensor nodes can directly communicate with the sink.
• All sensor nodes are homogeneous and have the same initial energy supply
• Radio channel is symmetric, i.e., the energy consumption for transmitting a message from one node to another is the same as on the reverse direction.
• Energy consumption for a data transmission only depends on (1) the distance between a sender and a receiver. (2) the size of the data packet. For the simplicity of energy analysis, we adopt a first order radio model used in LEACH (Heinzelman et al. 2000) [1].Energy consumptions in circuitry for running the transmitter or receiver and in radio amplifier for wireless communication are E_{elec}=50nJ/bit, ε_{fs}= 10pJ/bit/m^2 and ε_{mp}=0.0013pJ/bit/m^{4}respectively. The value of ε_{fs} is directly proportional to the square of transmission distance. Therefore, we have the following formula, where k is the size of transmitted packets, and d is the distance between a transmitter and a receiver.

The energy for transmitting a packet is:

$$E_{TX}(k,d) = kE_{elec} + k\varepsilon_{fs}\, d^2 \qquad d < d_0 \quad (2)$$

$$E_{TX}(k,d) = kE_{elec} + k\varepsilon_{mp}\, d^4 \qquad d \geq d_0 \quad (3)$$

For receiver,

$$E_{RX}(k) = kE_{elec}$$
(4)

$$E_{RX}(k,d) = kE_{elec} \quad (5)$$

Given a threshold transmission distance of d_o, the free space is employed when d ≤ do, and the two-ray model is applied for the cases where d > do. The threshold distance, d_o can be determined by:

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (6)$$

Here, ε_{fs} and ε_{mp} denote transmit amplifier parameters corresponding to the free space and the two-ray models, respectively.

IV. CTRA PROTOCOL

We proposed a scheme to combine clustering strategy with chain and tree routing algorithm in order to satisfy energy and delay constraints in WSNs. Clustering strategy is useful for low latency while chain and tree routing algorithm is beneficial to energy efficiency.

A .SCHEME

Clustering strategy + Chain routing inside cluster + Tree routing among chain-leaders.

First, all nodes make clustering. Then chain routing is made among all the nodes in each cluster and tree construction is made among the chain leaders. When data transmission begins, sensor nodes in each chain transmit their own data to their own chain leaders. Then each chain leader from each cluster fuses and transmits the data along the tree among the chain leaders. With the clustering strategy, chain and tree routing among all nodes, we can achieve more energy efficiency and reduced delay. Our motivation is to improve the routing performance in terms of energy and delay metrics that is important in many time-critical applications. Our CTRA works in two phases: chain based routing and tree based routing, which are discussed in details as follows.

B. CONSTRUCTION OF CHAIN

The proposed scheme constructs a chain among the nodes in each cluster so that each node will receive from and transmit to an adjacent node. It is supposed that there are N nodes in the network. Each node contains the following information which is required in constructing a chain:

1) Node ID-i;
2) Node position-Pi (xi, yj);
3) Distance between the node and the base station d_{iB};
4) Distance set between this node and the other nodes
dij = {j= 1,2,.........N ≠ i}.

The nodes are joined to construct a chain with the following method.

1) Start with the node which is farther away in the cluster from Base Station say node i.
2) The minimal value from the distance set between node i and the other nodes j in the cluster is chosen as k, ie. Min dij=k.
3) Corresponding node j with k as distance is included in the chain as next hop node.The next hop node for node j is selected in the same procedure as mentioned above.The above process continues until all the nodes are included in the chain for each cluster. Each node records the IDs of its pre-hop node and next-hop node.In constructing the chain, it is possible that some nodes may have relatively distant neighbors along the chain. Such nodes will dissipate more energy in each round compared to other sensor. We can improve the performance by not allowing such nodes to become leaders. This can be done by setting a threshold on neighbor distance to be leaders.

C. SELECTION OF CHAIN LEADER NODE

In this paper, the chain leader selection algorithm is modified based on the LEACH to further reduce and balance the total energy dissipation of sensors.

When choosing which nodes to be acted as the chain leader, the remaining energy of the nodes must be considered.We considered the inclusion of the remaining energy level in each node and distance between nodes.Therefore, the threshold is multiplied with a factor representing the remaining energy level of a node.

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)}\left(\frac{E_c}{E_m}\right) + \min d_{ij}, \text{if } n \epsilon G \\ 0, \text{ otherwise} \end{cases} \quad (7)$$

where, E_c is the current residual or remaining energy of the node, E_m is the initial energy of the node, d_{ij} is the distance between nodes and the other variables have the same meanings as in Eq. (1).

Each node broadcasts the node residual energy within radio range r, which contains residual energy of node. Each node receives the node residual energy from all neighbors in its radio range and updates the neighborhood table.

The steps involved in selecting a chain leader of a cluster are as follows.

1) Every node broadcasts its own residual energy to all nodes.
2) Node receiving residual energy from all neighbor nodes, update its neighborhood table.
3) Node compute the threshold value T(n).
4) N ode having less T(n) is selected as chain leader
5) Otherwise cluster node.

D. DATA TRANSMISSION IN A CHAIN

In a given round, the CTRA schedules the data transmission through an improved token mechanism. At the beginning of each round, chain leader node n3 generates two tokens and then transmits them to two ends nodes i.e., n5 and n1along the chain. Node n5 transmits the message which includes aggregated data and node information to node n4 after node n5 receiving the token. Node n4 aggregates both the local data and the receiving data, sends them to node n3 with the token. Node n1 repeats the work done by node n5 and send data to node n2. After node n2 processes the receiving data and local data, it passes a token and the data to node n3.Finally, the chain leader n3 fuses all the data and destroys the two tokens. If the link to the next node is broken or when a node dies, the chain is reconstructed in the same manner to bypass the dead node. Each node keeps track of its first neighbour.

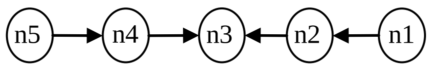

Fig.1. Data transmission in the chain

E. TREE BASED ROUTING CONSTRUCTION

The entire network is divided into many clusters and each cluster has a chain leader node. To design a binary tree structured WSN, the base station (sink node) acts as a root node. The entire network is divided into many levels. The level of the root node is assigned to zero. The sink node (root node) sends its ID, position and node type to its two neighbour, chain leader nodes which are in the next level (Level-1). The neighbor, chain leader nodes who receive the message send their node id, position and level as the acknowledgement to the root node. Now these two nodes become the children for the level-1.

The distance between the left chain leader node and right chain leader node are at the range of distance (d). Like that the level-i nodes send the message to its two neighbor's chain leaders to receive the ACK from level-i+1 and then they become the children of the previous level. The above steps are continued until there are no more sensor nodes without the level labels. After constructing the binary-tree structured WSN, the sink node (root node) sends a message to its immediate chain leader nodes to collect the sensed data from all the chain leader nodes. Each chain leader maintains a routing table using the obtained information from the sensor nodes. Now the chain leaders in the level-i send this information to its child chain leader in the level-i+1. So the chain leaders node in the level-i+1 transmit the sensed data in their own time slot and forward it to the chain leader in level-i.This process is continued until the forwarded data reached chain leader in level- 1.Finally the chain leader node in Level-1 forwarded all the fused data to sink node (base station).The collected data will be processed in the base station. In general each nodes in the cluster need not to be active except chain leader. The chain leader is always active so whenever there is an information exchange the chain leader loses more energy compared with other sensor nodes in the cluster. When each round of data transmission is completed the chain leader is to be updated.

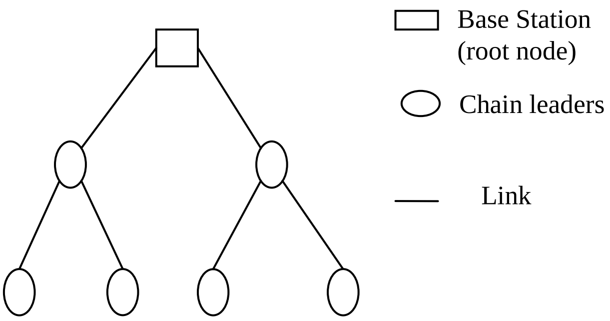

Fig.2. Structure of routing tree

F. ENERGY DISSIPATION

When the data packets are forwarded to the chain leader then each sensor node calculates the consumed energy by applying the following formulae.

$$\text{Normalised Energy} = \frac{n\Pi d^2}{1000} \quad (8)$$

Where n is the number of nodes and d is the distance between nodes. The unit of normalized energy is measured in terms of Joules (J). The energy dissipation of sensor nodes is low when sensor nodes are located in small distance.

V. SIMULATION RESULTS

The experiments described in this section have been conducted with the aid of the well known tool of simulation NS-2. For the experiments described in this work, both the free- space model and the multi-path fading model were used depending on the distance between the transmitter and receiver, as defined by the channel propagation model in NS2. We ran wireless micro-sensor networks simulations using NS-2 to determine the benefits of CTRA in comparison to LEACH in terms of energy consumption, delay and throughput. The parameters considered in our simulation for both CTRA and LEACH with different node densities are listed in Table 1.

Table 1. Simulation Parameters

Parameter	Value
Simulation time	10 sec
Routing Protocol	CTRA
Propagation Model	Free space/Two ray Propagation
Mac type	802.11
Link layer type	LL
Interface type	Queue/Droptail
Number of nodes	20,40,60,80,100
Traffic type	Constant bit rate
Packet Size	500 bytes
Time interval	0.01 sec
Bandwidth	1 Mbps
Optimized number of clusters	5
Initial Energy	2J

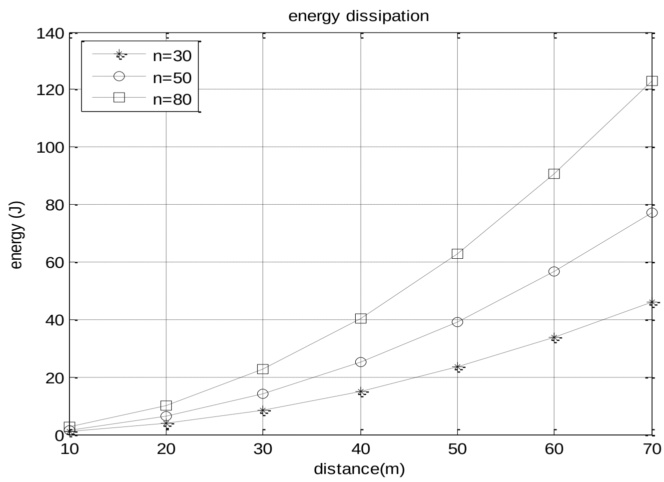

Fig.3.energy dissipation as a function of distance

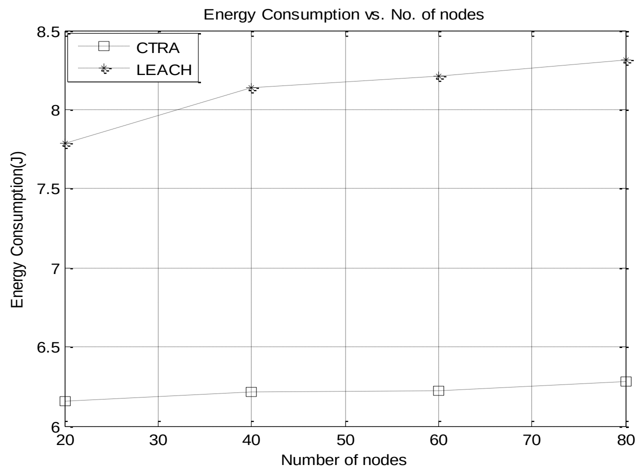

Fig.4. Energy Consumption as function of number of nodes

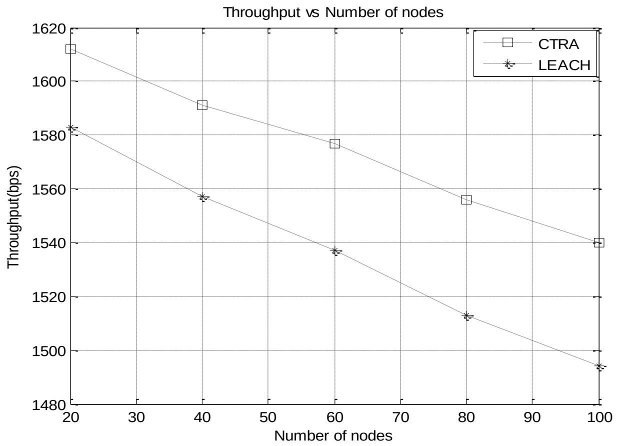

Fig. 5 Throughput as a function of number of nodes

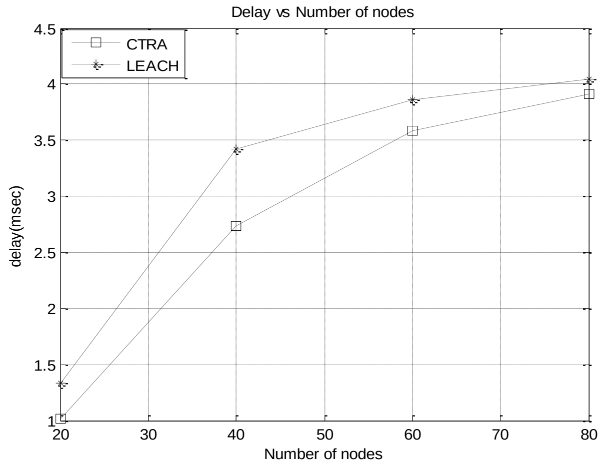

Fig.6 Delay as a function of number of nodes

In fig.3 shows the energy dissipation of all the sensor nodes in respect to the distance between the two sensor nodes. It is found that when the distance of a sensor node increases then the energy dissipation also increases for different nodes density.

In fig.4, CTRA shows a more reduce energetic consumption that at the end it will bring to an increase of the lifetime of the network. This could be brought back to the fact that while in the LEACH there is only a level before sending to the base station, in the CTRA architecture two levels can be exploited for decreasing the distances of transmission.

In fig. 5, the amount of data for a chain leader to receive is at most two messages instead of 16 nodes (16 nodes per cluster in LEACH for 80 node network). As can be noticed, CTRA sends much more data to the base station than original LEACH and it also has less transmission distance for the data packet to reach the sink node from the source node using TDMA scheduling that has allowed the increase of frequency of data transmission.

In fig. 6, CTRA establishes a less transmission distance to route the data to its neighbors. As the number of nodes in the network increases, the number of hops between nodes gets increased for data to reach the sink node from the source nodes. This improvement is achieved by the binary tree hierarchical routing structure in the CTRA instead of direct transmission strategy in LEACH Protocol.

VI. CONCLUSION

This paper exploits the full advantages of LEACH and PEGASIS and to some extent alleviates their weakness, i.e., direct communication between cluster heads and the base station which consume much energy if cluster heads are far away from the base station in LEACH, and long transmission delay in PEGASIS. The experiments show our CTRA is much better than LEACH in terms of energy, throughput and delay metrics. This CTRA will enhance effective life time of the network and quality of service for packet transmission in WSNs technologies.

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