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A Survey on Flow Balanced Routing in Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) consists of a large number of sensor nodes which are densely deployed. Energy conservation and coverage preservation are two important performance metrics for a WSN. Routing is important in WSN in order to reduce the energy consumption of the sensor nodes. Multipath routing techniques enable the use of multiple alternative paths and also the energy consumption of each sensor node get balanced. Hence it helps in increasing the network lifetime. In many routing protocols, cluster formation is done at each round. Most of the multipath routing techniques does not consider the full coverage over a longer period. Hence the routing protocol which considers the overlapping degree in choosing a Cluster Head(CH) needs to be developed to provide full coverage for longer time. Event to sink directed clustering scheme form clusters only towards the sink which avoids unnecessary cluster formation. The Backbone network can be constructed by using the Load Balanced Connected Dominating Set(LBCDS) in order to balance the energy consumption of sensor nodes. The energy efficient wake up scheduling can be used to reduce the energy consumption of sensor nodes. Since the CH's at higher level have large amount of data than CH's at lower level, the wake-up time of CH's at higher level is set to be higher than the CH's at lower level, which decrease the delay and also increases the network lifetime.

1. Introduction

A Wireless Sensor Network (WSN) consists of a large number of sensor nodes which are densely deployed. Sensors are used for sensing the environment. Since the coverage area of each sensor is very less, a network of sensors is needed to monitor the large environment. The WSN architecture is shown in Fig.1

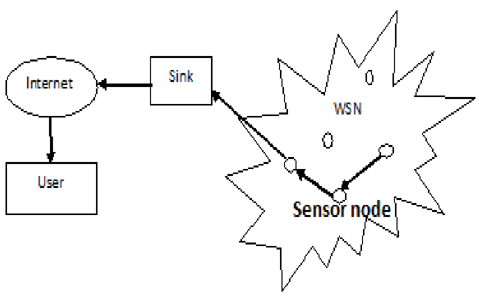

Fig.1 WSN Architecture

The WSNs is widely used in military applications such as battlefield surveillance. It is also used in environment surveillance and security monitoring and in many industrial and consumer applications.

1.1 Routing

Routing is the process of selecting best paths in a network[1].Routing is performed for many kinds of networks, such as telephone network, electronic data networks and transportation networks. Most routing algorithms use only one network path at a time. Multipath routing techniques enable the use of multiple alternative paths and also the energy consumption of each sensor node get balanced. There are several routing techniques in Wireless sensor networks. In Flat routing protocol, each node typically plays the same role and sensor nodes collaborate together to perform the sensing task. In a hierarchical architecture, higher energy nodes are used to process and send the information and lower energy nodes are used in performing sensing of the target. Hierarchical routing is a efficient way to reduce the energy consumption by performing data aggregation and fusion which helps in reducing the number of transmitted messages to the BS. In Location based routing, the distance between neighboring nodes is estimated based on incoming signal strengths. In order to save energy, in some location based schemes nodes are in sleep mode, if there is no task.

2. LITERATURE SURVEY

2.1 Cluster head election techniques for coverage preservation

Existing techniques for the selection of CH nodes base this decision on various criteria, such as maximum residual energy, location of the CH candidate relative to the other nodes, topology information or previous activity of the sensor node as a CH. Most of these cluster head selection approaches are designed with the goal to provide balanced energy consumption among sensor nodes, but at the same time, these approaches does not consider the network's requirement for full coverage over extended periods of time. This coverage aware cost metric considers the node's remaining energy as well as the coverage redundancy of its sensing range, thereby measuring the contribution of this node to the network coverage task. The sensors that are more important to the network coverage task are less likely to be selected as CH nodes. The HEED clustering protocol[8] uses a hybrid criterion for CH selection, which considers the residual energy of the node and the node's proximity to its neighbors or the node's neighbor degree. HEED prolongs the network lifetime by ensuring balanced energy dissipation as well as uniform distribution of cluster head nodes in network that contains uniformly dispersed sensor nodes. Hence the energy dissipation among the nodes are balanced which extends the network lifetime.

2.1.1 Coverage Preserving Clustering Protocol (CPCP)

CPCP spreads CH nodes more uniformly throughout the network by limiting the maximum cluster area[6]. Thus, clusters in sparsely covered areas are formed as well as clusters in densely covered areas, which prevents the high cost nodes from having to perform costly packet transmissions to distant cluster head nodes. Also, nodes from the sparsely covered areas elected to serve as cluster head nodes support clusters with a smaller number of nodes compared to CH nodes in dense areas. The cluster radius Rcluster is defined as a tunable parameter which

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determines the minimum distance between any two CH nodes in the network. By using this parameter, CPCP prevents the appearance of non-uniformly distributed clusters within the network. Rcluster can be easily tuned by changing the transmission power of the CH nodes.

Advantages

- By using Coverage-aware cost metrics, the sensors that are more important to the network coverage task are less likely to be selected as CH nodes.
- The most critical sensors are kept alive , thereby preserving the coverage and extending network lifetime for coverage-based applications.

2.2 An Energy-Aware Backbone Construction

The backbone members are selected based on the remaining energy of nodes. The nodes with high remaining energy will be selected to relay the message to the sink. These nodes are the backbone nodes or CH. Each node checks if it is a backbone member only based on the local information of the node. If the energy used by a WSN is considered, the energy used by transmitting data is higher than the energy used by computing and sensing. Hence in order to prolong the network lifetime, usually a virtual backbone is constructed to transmit data. The virtual backbone is constructed by using the connected dominating set(CDS). In a network, nodes in the CDS are connected and the other nodes in the network have at least one neighbor in the connected dominating set. The CDS will form a routing backbone in the network and every node sends the monitored information to its neighbor in the CDS. Only the nodes in the CDS, the dominators, have to relay the packet to the sink and the other nodes may go into the idle mode, or the sleep mode to save their energy[10]. Therefore, it is better to reduce the number of nodes in CDS.

Advantages

- The nodes with high remaining energy is selected as CDS.
- The nodes in the CDS alone will relay the packet to the sink. Other nodes are put into sleep mode to reduce the energy consumption.

Drawbacks

- Although the number of nodes in CDS is small, the node in CDS will die if the load is unbalanced between the nodes in the CDS.
- The countdown mechanism has a problem that a longer path with more remaining energy will be selected because that the path with more remaining energy has the shorter propagation delay.

2.3 Construction of Load-Balanced Virtual Backbone

A CDS is used as a virtual backbone for efficient routing and broadcasting in WSNs[11]. The nodes in a CDS are called dominators, other nodes are called dominatees. In a WSN, with a CDS as its VB(Virtual Backbone), dominates forward the data only to their connected dominators. Moreover, the CDS with the smallest size (the number of nodes in the CDS) is called a Minimum sized Connected Dominating Set (MCDS). The MCDS[10] is built to reduce the number of nodes and links involved in communication. Minimum rOuting Cost Connected Dominating Set (MOC-CDS) finds a minimum CDS and assures that any routing path through this CDS is the shortest in WSNs. Most of the existing works considers constructing the MCDS and MOC-CDS but does not consider the load-balance factor of the WSNs. If the workload on each dominator in a CDS is not balanced, the dominators with high load (i.e) the dominator with large number of dominatees, deplete their energy quickly. Due to this the whole network might be disconnected. Hence, in addition of constructing a MCDS, it is also necessary to construct a Load-Balanced CDS (LBCDS). In Fig.2,dominators are marked as black nodes, while white nodes represent dominatees. For each dominatee si, VDi is the number of its connected dominators. For each dominator sj , VDj is the number of its allocated dominatees. In Fig.2(b) and Fig.2(c), solid lines represent that the dominatees are allocated to the connected dominators, while the dashed lines represent the communication links in the original graph shown in Fig.2(a).

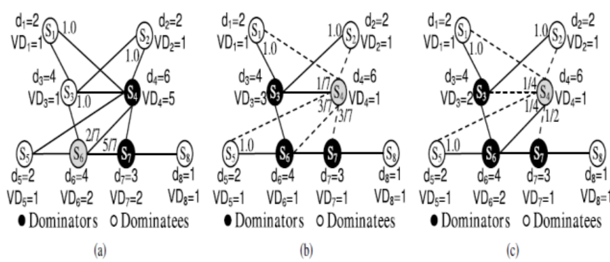

Fig.2 Illustration of Regular CDS and LBCDS

According to the traditional MCDS construction algorithms, a CDS {s4, s7} with size 2 is obtained for the network shown which is shown in Fig.2(a). However, The set of neighboring dominatees of the dominator si is denoted by ND(si). First, ND(s4) = {s1, s2, s1, s5, s6}, which represents that dominator *s*4 connects to 5 different dominatees, and ND(s7) = {s6, s8}. If every dominatee have same amount of data to be transferred through the connected dominator in a fixed data rate, the energy of dominator s4 reduce faster than dominator s7, since dominator s4 has to forward the data collected from 5 connected dominatees. Second, dominatee s6 connects to both dominators. If s6 chooses dominator s4 as its data forwarder, only one dominatee s8 can forward its data to dominator s7. In this situation, the workload imbalance in the CDS occurs. In Fig.2(b), where the constructed CDS is {s3, s6, s7}. According to the topology shown in Fig.5(b), the dominatee sets of each dominator are ND(*s*3) = {s1, s2, s4}, ND(s6) = {s4, s5}, and ND(s7) = {s4, s8}. Compared with the MCDS constructed in Fig.2(a), the numbers of dominatees of all the dominators in Fig.2(b) are very similar. Let A(si) = {sj |sj is a dominatee and sj forward its data to si} is used to represent the dominatees allocated to a dominator si. The two different dominatee allocation schemes are shown in Fig.2(b) and Fig.2(c) respectively. One is: A(s3) = {s1, s2, s4}, A(s6) = {s5} , and A(s7) = {s8}. The other one is: A(*s*3) = {s1, s2}, A(s6) = {s4, s5} , and A(s7) = {s8}. Hence, the workload on each dominator is almost evenly distributed in the CDS

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constructed in Fig.2(c). Hence, the dominate allocation scheme shown in Fig.2(c) will extend the network lifetime.

Advantages

- The workload among each dominator is balanced
- The degree of each dominator is considered as the indicator of potential future workload.

2.4 Energy Equalizing Routing

The nodes of wireless sensor networks have the very limited energy, so the main aim of WSNs routing is to improve the energy efficiency. LEACH protocol is a cluster based routing protocol. In this, the CH's are selected randomly for even energy consumption among all the nodes, so that the overall lifetime of the network is prolonged. However, the randomness in the selection of the CH's may result in some poor clustering schemes. On the other hand, single hop communication is adopted for the communications between the CH's and the nodes inside the cluster as well as the communication between the CHs and the base station. Since CHs are usually far away from the base station and the energy consumption in the communication grows exponentially with the distance, the single hop communication can result in large energy consumptions. Therefore, these protocols cannot use the network energy efficiently. Based on the clustering model, an Energy Equalizing Routing Algorithm[13] is used. In this algorithm, CH's are selected based on the routing utility evaluation function so that the overall network lifetime is prolonged.

Advantages

- Adopting a multi-hop communication, the communication load at the CH's is reduced and the overall energy consumption is reduced.
- The candidate nodes compete for cluster heads according to their residual energy and positions, so that the selected CH's are evenly distributed to balance the network coverage.

2.5 Quality of Service (QoS) Provisions in Wireless Sensor networks

2.5.1 QoS Aware Routing Protocols

2.5.1.1 Sequential Assignment Routing(SAR)

SAR is the one of the routing protocol which provides QoS support in WSN[14]. It is a multi path table driven routing protocol which tries to achieve both energy efficiency and fault tolerance. This protocol creates a tree of sensor nodes having root at the one hop neighbor of the sink node. It takes into account the QoS metrics, energy resource in each path and priority of each packet. Using the created tree, multiple paths are selected based on the energy resource and QoS on each path. SAR ensures failure recovery by enforcing routing table consistency between upstream and downstream node on each path. Although SAR provides fault tolerance and recovery, it suffers from the overhead of maintaining routing tables and states at each sensor node, when the number of sensor nodes deployed is large.

2.5.1.2 Minimum Cost Forwarding

This protocol finds the minimum cost path in a large network. It is simple and scalable protocol. A cost function is used for determining the delay, throughput and energy consumption from any sensor node to sink node in WSN. The protocol is divided into two phases. In the first phase, the cost value in each node is set starting from the sink node and diffuses across the network. Each node calculates its cost by addition of the cost value of the node received from in a message and the cost of the link. Here the forwarding of message is deferred for preset time duration to minimize the cost to arrive. So this algorithm determines the optimal cost of all nodes to the sink nodes by exchanging only one message. The next hop state information is not required after the value of the cost fields is set. In the second phase, the source node starts broadcasting the data to its neighbors. When a node receives this broadcast message, it adds the transmission cost to the sink node to the cost of the packet and checks the remaining cost in the packet. If the remaining cost is sufficient to reach the sink node, the packet is forwarded to its neighbor node, otherwise the packet is discarded. This protocol achieves optimal forwarding with minimum number of advertised messages.

2.6 Lifetime Enhanced Cluster Based Routing in Wireless Sensor Networks

In WSNs, data transmission is constrained by the limited battery energy of the nodes. The densely deployed sensor nodes will detect redundant and correlated data which may cause wastage of energy. In order to save resources and energy and to enhance the network lifetime, clustering technique can be used[15]. In cluster based networks, the CH's performs data aggregation and routing. The cluster based routing method with a power saving mechanism is used for enhancing the lifetime. The overlapping coverage area of the randomly deployed nodes forms the basis of the power saving scheme.

2.6.1 Importance of Clustering

The important issue of the WSN is that, the battery power of each node is very much limited. In most of the applications sensor nodes are deployed in inaccessible areas which makes inconvenient/ impossible in recharging the batteries. Clustering is an effective way to minimize the energy consumption. The Objectives of clustering is to eliminate the redundant data while transmitting and to balance the load among the nodes for prolonging the network lifetime. The sensor nodes can be organized to clusters and each cluster is managed by a special node or leader, called CH. The CH is responsible for coordinating the data transmission activities of all sensors in its cluster. Transmission to the base station is also performed by the CH. The CH node selection is one of the important issues in the clustering technique. Since the CH performs data aggregation by collecting the data from its members and also transmit the data to other CH nodes , it should have sufficient energy. Since the energy of the CH depletes faster than other nodes, there should be some mechanism to replace the exhausted head with a new node.

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Advantages

- The aggregation of data at the CH's reduces the number of data transmissions
- The routing node selection is based on residual energy which makes the routing procedure energy efficient.

2.7 Event-to-Sink Directed Clustering(ESDC)

The clusters are formed only in the direction of sink and the shortest path from the area where the event occurs to the sink is shown in Fig.3.
1) A sensor has a higher chance of being a CH, if it is closer to the sink, because ESDC is designed to reach the sink using the shortest path to reduce energy consumption, delay and overhead.
2) ESDC selects CHs to be as close to the center of the region where the event occurs as possible in order to make use of spatial correlation of data and efficient data aggregation and provides best coverage.

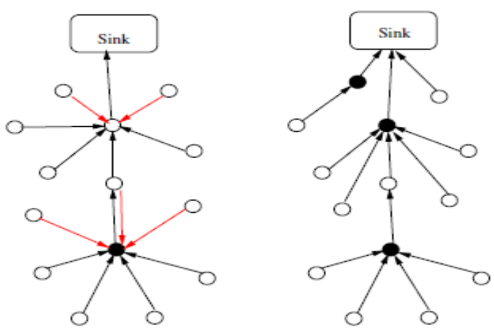

Fig.3 Event-to-sink directed clustering approach

The cluster formation is done only towards the direction of sink which reduces unwanted cluster formation throughout the network. In undirected clustering mechanisms shown in Fig.4(a), increases the route length, since it always send the data to the head although some of nodes are closer to the sink. In directed clustering shown in Fig.4(b), each node forwards the data packet to its neighbor having the smallest distance to the sink.
3) Data aggregation in the region where the event occurs must be efficient in terms of energy, number of clusters and packet overhead. Since there is some correlation between the data related with the same event detected by the sensors in the event region, data collected by the sensors that are spatially close to each other should not create different routing paths in the network. Therefore, a node in the event region has a higher probability of being a CH if it can reach most or all of the sensors that have detected the event.
4) The node that is going to be a CH should have enough energy to aggregate data, to maintain its cluster, and to forward collected data toward the sink. Therefore, the higher the remaining energy (Ei) of the node, the more likely it is to be a CH. The cluster formation is done only towards the direction of sink which reduces unwanted cluster formation throughout the network. In undirected clustering mechanisms shown in Fig.4(a), increases the route length, since it always send the data to the head although some of nodes are closer to the sink. In directed clustering shown in Fig.4(b), each node forwards the data packet to its neighbor having the smallest distance to the sink.

2.8 Energy-Efficient Wake-Up Scheduling MAC Protocol

A key challenging in WSNs is to schedule the activity of the node to reduce energy consumption[17]. Hence the energy-efficient protocols is designed for low-data-rate WSNs, where sensors consume different energy in different radio states (transmitting, receiving, listening, sleeping, and being idle) and also consume energy for state transition. TDMA is used as the MAC layer protocol and scheduling of sensor nodes is done with consecutive time slots at different radio states. Hence the number of state transitions is reduced. In a scheduling period, any sensor node needs to wake up at most twice. Once for continuously receiving all packets from its children nodes and once for sending its own data to its parent node

2.8.1 Centralized Activity Scheduling

The energy cost is reduced by scheduling the activities of a subset of sensors in one bundle[18]. The set of children nodes of node vi in data gathering tree T is represented by CT(vi). Thus CT(vi) will form a virtual cluster Ci. For each cluster Ci, weight Wi is defined. Wi is the total number of time slots that node vi should wake up to receive the data from its children in the data gathering tree T. Thus instead of scheduling the transmitting time slots for each individual child node of node vi, a chunk of consecutive Wi time slots is scheduled to the cluster Ci of these children nodes. So each child vj will be assigned a consecutive wj time slots from this chunk. All the children will send their data in this period and the parent will receive the data at the same time. Thus, the energy consumption due to the state transition is saved since each node need to wake up only twice: once for receiving all data from its children and once for transmitting its data to its own parent. However, two conflicting clusters can still be scheduled together. Two clusters Ci and Cj conflict with each other . If there is any pair of nodes u and v (one from each cluster) such that u and v cannot be scheduled simultaneously. For example, assume that C1={u1,u2} and C2={u3,u4} and each sensor node needs wi time slots for transmitting. Assume pair of nodes u1 and u3 cannot be scheduled simultaneously. Then following schedule is valid: node u1 uses time slots 1, 2, node u2 uses time slots 3, 4, node u3 uses time slots 3, 4 and node u4 uses time slots 1, 2.

Conclusion

Since the data flows in multiple path to the sink, the energy of the CH nodes are balanced thereby increasing the network lifetime. Since the clusters are formed towards the sink unnecessary cluster formation is not required. By scheduling of sensor and the CH nodes, the power used in listening and for switching from sleep to wake up is reduced. The processing time at each level is set based on the amount of data received, which conserve the power used in processing. By using LBCDS the load on dominators are balanced which minimize the death of sensor thereby extending the network lifetime.

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