A STUDY OF VARIOUS HIERARCHICAL ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

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ABSTRACT

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and the sensor's proximity to the cluster head.

The physical layer addresses the needs of modulation, transmission, and receiving techniques. Since the environment is usually noisy (for example, disaster areas) and sensor nodes can be mobile, though in many case they are not, the MAC protocol must be power-aware and able to minimize collision with neighbour nodes' broadcasts. The network layer takes care of routing the data supplied by the transport layer. The transport layer helps to maintain the flow of data if the sensor networks applications require. Depending on the sensing tasks, different types of application software can be built and used on the application layer. In addition, the power management plane, the mobility management plane and the task management plane monitor the power, movement, and task distribution among the sensor nodes respectively. These planes help the sensor nodes coordinate the sensing task and lower overall power consumption. Protocols for routing in sensor networks are classified into two major categories: data centric routing and hierarchical routing.

Keywords: Protocol, Routing, MAC and WSN.

1. LEACH

LEACH [1] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This saves energy since the transmissions are only done by cluster heads rather than by all sensor nodes.A cost function is defined between any two nodes in terms of energy consumption, delay optimization, and other performance metrics. Using this cost function as the link cost, a least-cost path is found between sensor nodes and the gateway. The gateway will continuously monitor the available energy level at every sensor that is active in data processing, sensing, or in forwarding data packets, known as relaying. Rerouting is triggered by an application-related event requiring a different set of sensors to probe the environment or the depletion of the battery of an active node.

There are many protocols derived from LEACH by using the same scheme to randomly pick CHs. The main idea of LEACH is that sensor nodes can be randomly selected as CH based on their previous experiences of being a CH. In the cluster formation phase, each sensor node generates a random number between O and 1. Each sensor node has its threshold *Th*(LEACH) which is related to the predefined percentage of CHs in a network. If the generated random number is less than *Th*(LEACH), then the node becomes the CH; otherwise, it joins a cluster to be a cluster member. CHs change randomly in order to balance the energy dissipation of nodes. Once the CHs are decided, other nodes choose one of them to join by comparing the Received Signal Strength (RSS) of the advertisements from CHs.

After clusters are set up, the CH broadcasts a transmission schedule within the cluster and asks its member nodes to send data based on a TDMA approach. In the steady phase, CHs are responsible to aggregate and send data to the sink. All data processing is local to the cluster. After a certain period of time spent in the steady phase, the network goes to formation phase to redo the clustering. One thing must be noted: the formation phase is much shorter than the steady phase therefore, LEACH has light overhead.

LEACH is completely distributed and requires no global knowledge of the network. LEACH achieves a factor of 7 or more reduction in energy dissipation compared to direct communication and a factor of 4 to 8 compared to the minimum transmission energy routing protocol [2]. LEACH clustering terminates within a constant number of iterations but it does not guarantee good cluster head distribution and assumes uniform energy consumption for cluster heads. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. head changes and advertisements, which may diminish the gain in energy consumption.

A variant of this routing approach has been discussed in [3]. The algorithm constrains the minimum transmission range in order to limit the delay. Simulation results have demonstrated that such an approach consistently performs well with respect to both energy-based metrics (e.g., network lifetime), as well as contemporary metrics, throughput and end-to-end delay. The results also have indicated that combining the routing approach with the time-based medium arbitration can further increase the life of the network by an order of magnitude.However, such an approach assumes a simple propagation model, which might require the deployment of many gateways to ensure high sensor coverage.

The approach is further extended in [4] to overcome ambiguity in signal propagation by introducing an additional tier to the network. Basically nodes that are not reachable are assigned an agent sensor to convey commands from the gateway and to pass nodes status back to the gateway.

2. HEED

Hybrid Energy-Efficient Distributed clustering (HEED) [5] protocol is an energy aware hierarchical approach improved from LEACH. To avoid the problem of selecting a low energy node as a CH, HEED is presented to set up well-distributed clusters. In LEACH, with the strategy that every node has an equal chance to be CH, the network may choose a "bad CH" which leads to higher energy consumption and higher probability of a crashed cluster. HEED initializes a probability for each node to be a tentative CH depending on its residua' energy and makes the decision according to the energy cost based on the connectivity degree of the node. Also, HEED adopts multi-hop communication to further reduce energy consumption.

HEED uses residual energy as the primary clustering parameter to select a number of tentative CHs. Those tentative CHs inform their neighbors of their intentions to become CHs. These advertisement messages include a secondary cost measure that is a function of neighbor proximity or node degree. This secondary cost is used to avoid elected CHs being within range of each other, and to guide the regular nodes in choosing the best cluster to join. If a CH is far from the sink, it tries to send the aggregate data to another CH instead of sending to the sink directly. Simulation results show that HEED prolongs network lifetime, and the clusters it produces exhibit several appealing characteristics. By adjusting the parameters, HEED can be tuned to optimize resource usage according to network density and application requirements. As the number of nodes increases, HEED has been shown to outperform LEACH by about 100% to 300% regarding when the first node dies. Compared to LEACH, HEED dissipates only 30% as much energy during clustering [6].

3. ERA

Energy Residue Aware (ERA) [7] clustering algorithm is another energy-aware hierarchical approach. It is improved from LEACH by including the communication cost into the clustering. The communication cost includes residual energy, communication energy from the CH to the sink and communication energy from the cluster members to the CH. There is a difference from HEED: ERA uses the same CH selection scheme as LEACH but provides an improved scheme to help non-CH nodes choose a "better" CH to join. After CHs are selected, ERA adds the three factors to help non-CH nodes choose an appropriate CH.

As a result, the non-CH nodes can join the cluster where the CH is closest to it and the sink. With the improved traffic pattern of data aggregated to the sink, this protocol manages the communication cost both inter-cluster and intra-cluster. ERA has 300 rounds more network lifetime than LEACH does [8].

4. PEGASIS and Hierarchical PEGASIS

Power Efficient GAthering in Sensor Information Systems (PEGASIS) [9] is based on LEACH and uses the greedy algorithm to organize all sensor nodes into a chain and then periodically promote the first node on the chain to be the CH. Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node communicates only with its close neighbors, and allows only one designated node to send to the sink in each round. To locate the closest neighbor node, each node uses the RSS to estimate the distance to all neighboring nodes and then adjusts the signal strength so that it only communicates with its closest neighbor.With the focus on how to reduce transmission energy consumption, nodes take turns transmitting to the sink. Building a chain to minimize the total length is similar to the traveling salesman problem, which is known to be intractable. However, with the radio communication energy parameters, a simple chain built with a greedy approach performs quite well.

PEGASIS provides performance gain through decreasing the amount of transmission and reception by aggregating data and eliminating the overhead caused by cluster formation in LEACH. The PEGASIS protocol outperforms LEACH by about 100% to 200%, regarding when 1%, 25%, 50%, and 100% of the nodes die, with different network sizes and topologies [10]. However, PEGASIS introduces an excessive delay for distant nodes in the chain, and since only one node can connect to the sink, the delay is even worse. Dynamic topology adjustment is required in PEGASIS since a sensor node needs to know the energy status of its neighbors in order to calculate where to route its data. Such topology adjustment can introduce significant overhead, especially for heavy traffic networks.To decrease the delay incurred for packets, hierarchical PEGASIS was introduced in [11]. It presents a solution to the data gathering problem by considering energy x metric delay. Hierarchical PEGASIS has two improvements, using CDMA for signal coding, and spatially separating nodes. The chain-based protocol with CDMA-capable nodes constructs a chain of nodes that forms a tree-like hierarchy, and each selected node at a particular level transmits data to a node in the upper level of the hierarchy. This method ensures data transmitting in parallel and reduces the delay significantly. Since the tree is balanced, the delay will be in O(lgN) where N is the number of nodes.

5. RRCH

Round-Robin Cluster Header (RRCH) [12] performs cluster formation only once to avoid the high energy consumption during clustering. Within the fixed cluster, RRCH uses the round-robin method to choose the node to be the CH. RRCH uses a similar method to LEACH to set up clusters. Once the clusters are set up, the nodes follow the schedule to change their role in turn. Every node has a chance to be CH during a frame. When a node has been detected as an abnormal node, the CH modifies the scheduling information and broadcasts it to the entire cluster during frame modification; then its cluster members delete the abnormal node based on the received schedule information.

With the single clustering process, RRCH can avoid the energy dissipation of re-clustering. With the round-robin method, the CH role is rotated through the whole cluster, thus the energy dissipation can be uniform. RRCH shows better performance with energy efficiency. But RRCH has the same defect of LEACH: no guarantee of cluster quality. Once clusters are set up, RRCH keeps the fixed clusters and only adjusts the schedule when there is an abnormal node. LEACH with the periodic re-clustering can alleviate the deterioration of cluster quality. RRCH cannot handle clusters with bad quality, such as overlays and too small or too big a cluster size.

6. EXISTING PROTOCOLS

WSNs bring significant advantages over traditional communications in today's applications, such as environmental monitoring, homeland security, and health care. However, harsh and complex environments pose great challenges in the reliability of WSN communications. The reliable wireless communications within WSNs, it is essential to have a reliable routing protocol and to have a means to evaluate the reliability performance of different routing protocols. The reliability of two different types of sensor nodes: 1) energy harvesting sensor nodes and 2) battery-powered sensor nodes. Wireless link reliability models for each type of sensor nodes, where effects of different parameters, such as battery life-time, shadowing, noise, and location uncertainty, for analyzing the wireless link reliability is discussed in [13]. Based on the sensor node and wireless link reliability models, the performance of different routing algorithms in terms of end-to-end path reliability and number of hops is discussed. A dynamic routing approach is then to achieve the most reliable end-to-end path in WSNs. Furthermore, to facilitate a fair and comprehensive comparison among different routing algorithms, a cost function approach that integrates the end-to-end path reliability and number of hops is proposed, providing an indicator of quality of service of applications running on WSNs.

7. CONCLUSION:

WSN contains of a large number of tiny sensing devices. These are capable of detecting an event, processing the information, and transmitting that processed data. In WSN network there is a sink which conveys all information to the end user. The sink is placed anywhere in the target area. The nodes which are closer to the sink easily convey their message to it but the nodes which are at a great distance from it cannot directly forward their data to the sink, they have to send their data to the node which is closer to it than its neighbor forwards its data to sink. In this way the nodes which are closer to the sink have to send the data of the distant nodes along with their own so they get depleted in terms of energy, as their energy is used in sending their data along with the data of farther nodes. This problem is called HOT SPOT problem. The location of the sink node is optimized by using ACO. The simulation results on MATLAB software demonstrated that it has reduced the network's energy consumption and improved other parameters like packet delivery rate.

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