Cluster level optimization of residual energy consumption in wireless sensor networks for lifetime enhancement

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***Abstract*:** Network lifetime is perhaps the most important metric for the evaluation of sensor networks. In a resource-constrained environment, the consumption of every limited resource must be considered The network can only fulfill its purpose as long as it is considered alive, but not after that. It is therefore an indicator for the maximum utility a sensor network can provide. Energy efficiency is therefore of paramount importance in sensor networks that are constrained by limited resources. Designing an efficient routing protocol for a sensor network is challenging due to factors such as limited resources, concentration of load in a limited portion of the network, and routing of redundant information. In this paper we have analyze how the residual energy level of each cluster can be optimized to make a significant improvement in the functional lifetime of the wireless sensor network.

Keywords: Network, sensor network, optimization, cluster, lifetime

1. Introduction:

A *wireless sensor* network (WSN) is a computer network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. The developments of wireless sensor networks were originally motivated by military applications such as battlefield surveillance. However, they are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control.

Each node in a sensor network is typically quipped with a radio transceiver or other wireless communication device, a small microcontroller, and an energy source, usually a battery. The size of a single sensor node can vary from shoebox-sized nodes down to devices the size of grain of dust. The cost of sensor nodes is similarly variable, ranging from hundreds of dollars to a few cents, depending on the size of the sensor network and the complexity required of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth, among which energy is the scarcest resource of WSN nodes. Every sensor in a WSN has a *sensing range* and a *transmission range*. An object can be discovered by a sensor if it is within the sensing range of the sensor, and two sensors can transmit data to each other if they are within each other's transmission range. Routing, one of the most energy-expensive operation, is usually multi-hop (from the source, node to node, towards the destination), due to the polynomial growth in the energy-cost of radio transmission with respect to the transmission distance.

WSNs are to be deployed in large numbers in various environments, including remote and hostile regions, with ad-hoc communications. The energy in nodes determines the lifetime of WSNs. The lifetime of WSNs will be shortened if some sensors are used more often than others as their battery power is depleted sooner. For this reason, sensor deployment, algorithms and protocols need to address lifetime maximization, robustness and fault tolerance issues. Therefore, in sensor deployment, network topology is important. To be fair, it is always better to deploy sensors in similar positions if possible. That is, every sensor has about the same number of neighbors. In this way, suppose the probability of any node becoming a source or a destination is equal, no sensor will be more frequently used as a router due to the network topology. In addition, between communicating sensors there should be multiple paths so that the network is more fault tolerant and robust.

With the energy constrained nature of sensor nodes, it is very important to make efficient use of battery power in order to increase the lifetime of network [6]. In most cases, sensor nodes rely on batteries for power.Since battery replacement is very difficult if not impossible, the sensors have to operate on an extremely frugal power budget. Even in some cases where the sensors gather renewable energy from the environment, the power budget remains very similarly, other resources such as communication bandwidth and computational power are also limited. Therefore, a sensor network that is efficient in the use of resources is required. In conventional routing algorithms, some nodes are constantly involved in forwarding data packets, hence more energy will be depleted among those nodes and the nodes will die much earlier than others causing disconnection of the network.

2. Related Work:

A two-tier hierarchical distributed sensor network [7] has been proposed for underwater target tracking applications (Fig. 1). The network consists of sensor nodes, cluster nodes, and master nodes. The sensor nodes, organized in clusters, detect the target and report the measurements to cluster nodes which fuse the data to form a local estimate. Each cluster forwards its local estimate to the master node, which produces a global estimate and reports the result to the command center. However, due to exigencies in the sensor network, delays may be encountered in transmitting the cluster estimates to the master node. The filter tracking algorithm is designed to accommodate delayed and out-of sequence data. Suppose a delayed measurement made at time instant *'t-t1'* is available at time instant *'t'*, then the measurements from the last *'t1'* time instants are reprocessed in the filter to complete a measurement update using all available information. The essential entities that warrant modeling are sensor nodes, cluster nodes, master nodes, communication model, and the target. Batteries were modeled as a separate entity for convenience. Whenever the nodes use computational and communication resources, battery-power is consumed. Each node activity is assigned with a 'battery weight' that can be used to decrease the battery power whenever the corresponding activity takes place. The delays in the communication between nodes were also modeled based on the resources available to the sending and receiving nodes. If the communication was routed through other nodes, the resources available at these nodes were also used for computing the delays. Important factors such as the computational capacity of the node and the communication capacity of the system were modeled as the resources that affect delays..

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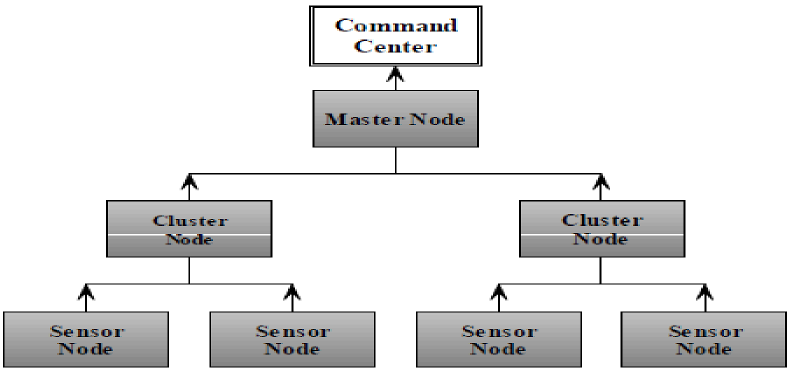

Figure 1: Cluster Based Wireless Sensor Network

3. (a)Static Multi Hop Routing

In the Static Multi-hop Routing protocol, the node sending the data communicates with the receiving node through intermediate sensor nodes [4]. Each node maintains a routing table that contains information for routing data to a given receiver node. In other words, each potential receiving node in the sensor network has an entry listing the corresponding routing node. Such an entry is also called a next-hop address.

3. (b) Probabilistic Multi-Hop Routing

The Probabilistic Multi-Hop Routing protocol aspires to equalize the routing load uniformly among all the nodes in the sensor network. In contrast to static routing, where every node has only one next-hop node for routing data Probabilistic Multi-Hop Routing protocol has multiple next-hop nodes and selects one of these possibilities depending on the preset probabilities in run time. In the operation of Probabilistic Multi-Hop Routing protocol, the sending node generates a random number and, depending on this result, selects one of the next-hop nodes for routing the data.

3. (c) Modified Probabilistic Multi-Hop Routing

The Modified Probabilistic Multi-Hop Routing protocol is similar to Probabilistic Multi-Hop Routing except that while calculating the next-hop node from the pool of possible next-hop nodes, the previous use of nodes is taken into account. In other words, if a node was used previously for routing data, its probability of selection in the current instant is reduced. In Modified Probabilistic Multi-Hop Routing, the past history of the selection of intermediate nodes is taken into account while deciding the new intermediate address. The probability of a node being selected for routing decreases as the number of times that the node has been selected increases. The number of nodes in the "history" of past selected nodes used for selection of the current next hop can be varied.

4. Cluster level Optimization

For each routing protocol discussed above, whenever there is a need to update the routing table due to such factors as low residual power in the routing nodes, the resulting communication overhead is aggravated by redundant communications between nodes. Cluster level optimization is a scheme aspiring to reduce these overheads. it exploits the fact that a cluster node has access to the information about residual power levels at sensor nodes in the cluster with negligible communication overhead and possesses the required computational power to perform the localized network reconfiguration. Consider a sensor network with N clusters, each containing *s* sensor nodes with corresponding cluster nodes and *m* master nodes. Also, *r* nodes in each cluster are available to route the data. In this scheme shown, whenever the residual energy of a routing node falls below a preset threshold, the cluster node chooses another node in the cluster to act as a replacement routing node with following conditions:

1. The network address of the node to be replaced *i* is assigned to the replacement node *j*.
2. The communication range of node *j* is increased such that it encloses the communication range of *i*

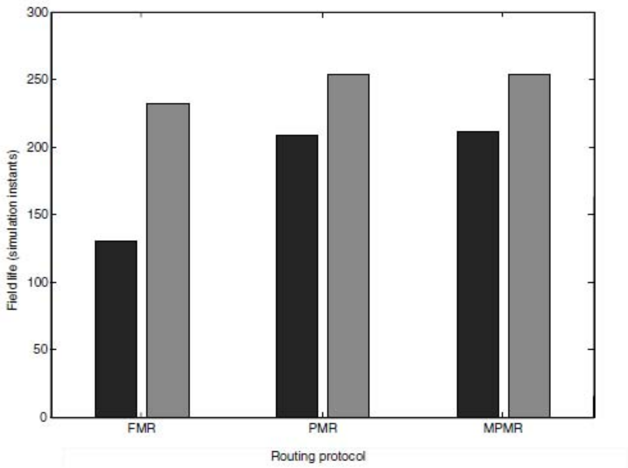

Figure 2. Lifetime comparison in Routing protocols with or without Cluster level optimization

Many practical sensor nodes possess the capability to change the communication range. Setting this scheme eliminates the need to propagate the change of routing node to other clusters in the sensor network, resulting in a substantial decrease in the communication overhead that would otherwise have resulted. Since this concept involves only changing the network address and range setting of a given sensor node, this scheme requires very little computational and communication overhead. This concept of localized optimization was applied to all of the routing protocols .For all of the routing protocols the improvement in the field life was due to effectively using the inherent redundant resources available in the sensor network. However, localized optimization resulted in a relatively large mean and RMS error of the estimates. This increase in error is due to the delays introduced by the localized optimization algorithm.

6. Conclusion

A resource-based sensor network model was developed using cluster level optimization technique to study the performance of different routing protocols. For the cluster level optimization algorithm, the results demonstrate a significant improvement in the functional lifetime of the sensor network.

8. References

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