

Increasing Lifetime and Reducing Power Consumption of Wireless Sensor Network using Energy Efficient Cluster Routing

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Abstract: *This project is to avoid duplicate transmission, node reconfiguration and power consumption in Wireless Sensor Networks (WSN). Wireless sensor network requires robust and energy efficient communication protocols to minimize the energy consumption as much as possible. However, the lifetime of sensor network reduces due to the adverse impacts caused by radio irregularity and fading in multi-hop WSN. The scheme extends High Energy First (HEF) clustering algorithm and enables multi-hop transmissions among the clusters by incorporating the selection of cooperative sending and receiving nodes. The work proposed focuses to develop any node to act as cluster head (CH) instead of affected CH because we need to get a data from CH continuously. To reduce energy consumption, proposed scheme extends with the help of S-MAC layer to get the efficient energy saving. The performance of the proposed system is evaluated in terms of energy efficiency and reliability. Simulation results show that tremendous energy savings can be achieved by adopting hard network lifetime scheme among the clusters. The network simulator 2 (NS2) is used to verify the proposed network lifetime predictability model, and the results show that the derived bounds of the predictability provide accurate estimations of the energy saving and network lifetime.*

Keywords: Cluster head, HEF, S-MAC, DSDV

1. Introduction

Wireless Sensor Networks consists of many sensor nodes working as relay agents to pass information hop by hop to a central station. Sensor node is a part of wireless sensor network that can gather and sense the information from the environment and send it to another node or to the gate node. It consists of one or more sensor, controller, transceiver, external memory and power source. Each component of a sensor node is performing different parts of the work, and requires a power source to perform its function

Wireless sensor networking is an emerging technology that has a wide range of potential applications including environment monitoring, smart spaces, medical systems and robotic exploration. Each node has sensors, embedded processors and low-power radios, and is normally battery operated. Prolonging battery life is a principal objective in the design of wireless sensor networks (WSNs) due to the difficulty and high cost associated with replacing or recharging exhausted batteries in a deployed network. This has in large part, driven the research and development of numerous technologies that aim at minimizing WSN energy consumption. Typically, these nodes coordinate to perform a common task.

Like in all shared-medium networks, medium access control (MAC) is an important technique that enables the successful operation of the network. One fundamental task of the MAC protocol is to avoid collisions so that two interfering nodes do not transmit at the same time.

To design a good MAC protocol for the wireless sensor networks, we have considered the following attributes. The first is the energy efficiency. As stated above, sensor nodes are likely to be battery powered, and it is often very difficult

to change or recharge batteries for these nodes. Prolonging network lifetime for these nodes is a critical issue. Another important attribute is the scalability to the change in network size, node density and topology. Some nodes may die over time; some new nodes may join later; some nodes may move to different locations. The network topology changes over time as well due to many reasons. A good MAC protocol should easily accommodate such network changes. Other important attributes include fairness, latency, throughput and bandwidth utilization. These attributes are generally the primary concerns in traditional wireless voice and data network, but in sensor networks they are secondary [2].

2. Energy Related Issues

Energy consumption is the most important factor in determining the life of a WSN as the sensor nodes comprising the network are all battery-powered and thus limited by very low energy resources for tasks involving data sensing, processing and communications. Energy optimization techniques therefore take precedence in WSNs to allow preservation of energy for prolonged network lifetimes. This can be done by considering energy awareness issues in every aspect of design and operation of each sensor node. Energy saving protocols and techniques also need to be addressed for collective groups of communicating sensor nodes in order to have better overall performance and improved energy efficiency in the entire WSN. The lifetime of a sensor network can be increased significantly if the operating system, the application layer and the network protocols are designed to be energy aware. The power consumed by the sensor nodes can be reduced by developing design methodologies and strategies that support lower energy wastage.

Traffic can also be distributed to maximize the life of the network by researching methods on distributing traffic more uniformly throughout the network. Methods that discourage using the same path for routing traffic/packets continuously regardless of how much energy is saved should also be looked into for better fault-tolerance and robustness. Such methods are required because frequent rupturing in the connectivity of the network due to failure/sleep-schedules of participating nodes can cause sensor nodes that are in close proximity of the detected event to not allow dissemination of data within various sections of the WSN.

3. Architectural Block Diagram

Step 1 After starting the network, the wireless sensor nodes will be divided into several clusters in the WSN.

Step 2 One node will be chosen as the cluster head in each cluster area. This cluster head will use a negotiation system to send joining messages to the nodes near the cluster head.

Step 3 After that, the cluster-heads will send invitations to the wireless sensor nodes in each cluster asking them to join the cluster-heads to form the clusters. The second phase includes the "transferring data process" and the "distributing the role of cluster head process" including the following three steps. The DSDV routing protocol is responsible for sending the data from the source to the destination nodes. The role of distribution is determined by regularly selecting a set of new cluster-heads based on the weight value.

Step 4 When any wireless sensor node needs to send a message, it has to check its routing table and look for a path to the destination node. Therefore, if the route is available in the routing table, it will forward the message to the next node. Otherwise, the message will be saved in a queue, and the source node will send the RREQ packet to its neighbors to commence the discovery process.

Step 5 During the forwarding of the message to the destination, the rate at which power is consumed by the cluster head will be calculated based on the energy model. If the energy consumption speed is high, then the procedure will choose another node to act as the cluster head based on the value.

Step 6 Then, the procedure will remove the route from the routing table of the source, which will lead the source node to initiate the discovery process in phase 2 again and a new path to the destination node through the new cluster head.

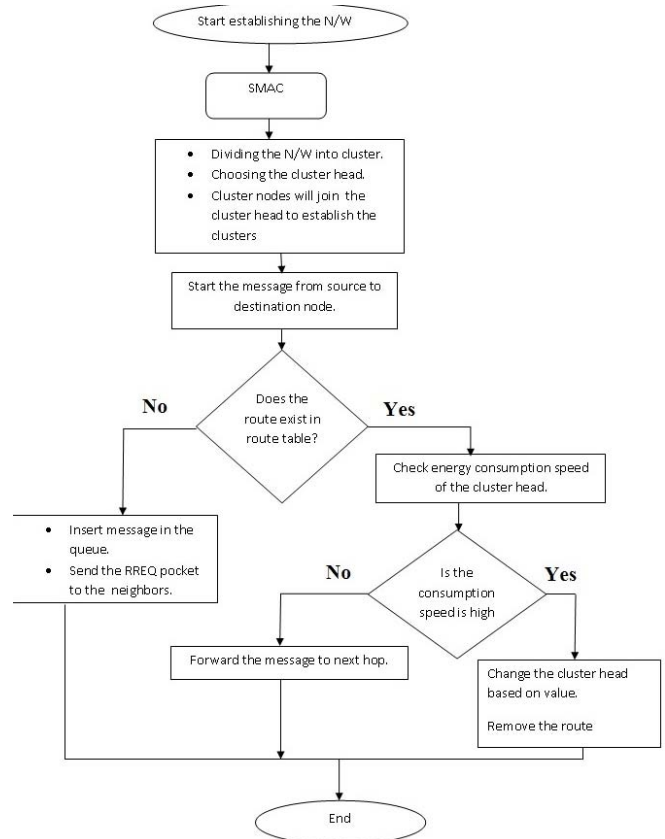


Figure 1: Architectural Block Diagram

4. Modules

4.1 Cluster Head Selection

The cluster heads may be special nodes with higher energy or normal node depending on the algorithm and application. Here base station is a cluster head performs computational functions such as data aggregation and data compression in order to reduce the number of transmission to the base station (or sink) thereby saving energy. One of the basic advantages of clustering is that the latency is minimized compared to flat base routing and also in flat based routing nodes that are far from the base station lacks the power to reach it. Clustering based algorithms are believed to be the most efficient routing algorithm for the WSNs.

4.2 Energy Consumption

Transmission in WSNs is more energy consuming compared to sensing, therefore the cluster heads which performs the function of transmitting the data to the base station consume more energy compared to the rest of the nodes. Clustering schemes should ensure that energy dissipation across the network should be balanced and the cluster head should be rotated in order to balance the network energy consumption. Since energy consumption in wireless systems is directly proportional to the square of the distance, single hop communication is expensive in terms of energy consumption [5].

4.3 Network Lifetime

It is obvious from the simulation result that by exploiting the density property of the WSNs it is possible to enhance the

network life time and also efficiently balance the energy consumption load across the network[3],[4]. Also the energy consumption of the network becomes uniform and it doesn't matter even if the cluster are balanced or unbalanced compared to LEACH.

5. Schedulability Analysis of HEF

The most important property of the WSN network lifetime is not longevity, but predictability. Schedulability tests are essential for the time-critical system because it provides predictability to complement online scheduling. Cluster head selection algorithms produced by empirical techniques often result in highly unpredictable network lifetimes. Although an algorithm can work very well to prolong the network lifetime for a period of time, a possible failure can be catastrophic, resulting in the failure of a mission, or the loss of human life. A reliable guarantee of the system behaviors is hence a requirement for systems to be safe and reliable. However, there are currently no known analytical studies on the network lifetime predictability for cluster head selection algorithms. Apply the worst-case energy consumption analysis to derive the predictability of HEF. The core idea of the HEF clustering algorithm is to choose the highest-ranking energy residue sensor as a cluster head.

5.1 HEF Algorithm

HEF selects the set of M highest ranking energy residue sensors for cluster heads τ at round where M denotes the required cluster numbers at round τ [1]. HEF is designed to select the cluster head based on the energy residue of each sensor to create a network-centric energy view. Intuitively, HEF is a centralized cluster selection algorithm.

5.2 Operation of HEF

The interactions and detailed operations between components are discussed as follows.

- HEF selects cluster heads according to the energy remaining for each sensor node, and then the "setup" message (indicating cluster members, and the cluster head ID for each participated group) is sent to the cluster head of each cluster.
- The cluster head of each group broadcasts the "setup" message inviting the neighbor sensor nodes to join its group.
- After receiving the "setup" message at this round, the regular sensors send the "join" message to its corresponding cluster head to commit to associate with the group.
- Each cluster head acknowledges the commitment, and sends TDMA schedule to its cluster members.
- All sensors perform its sensing and processing and communication tasks cooperatively at this clock cycle (round). Each sensor sends its energy information to its cluster head at the end of this clock cycle.
- Upon collecting cluster members' information at a given period, the cluster head sends the summative report to the base station.

6. Schedulability Test

The most important property of the WSN network lifetime is not longevity, but predictability. Schedulability tests are essential for the time-critical system because it provides predictability to complement online scheduling. Cluster head selection algorithms produced by empirical techniques often result in highly unpredictable network lifetimes. Although an algorithm can work very well to prolong the network lifetime for a period of time, a possible failure can be catastrophic, resulting in the failure of a mission, or the loss of human life. A reliable guarantee of the system behaviors is hence a requirement for systems to be safe and reliable [1].

Schedulability tests allow engineers to assess what actions (e.g. changing energy budget or lifetime, etc.) should be taken to improve the dependability and reliability of the systems. The schedulability test flow chart consists of three major stages

- Deployment Planning
- Energy Estimation
- Schedulability Analysis

In the Deployment Planning stage, efforts are made to plan the shape of the network topology, the initial energy level of sensor nodes, and the necessary configurations to perform. Activities and measures for the minimum and maximum energy consumption of the cluster head and the regular node are conducted in the Energy Estimation stage. In the Schedulability Analysis stage, Schedulability test results provide the necessary information to all running scenarios. If the running case is not schedulable, the feedback process can be used to alternate the WSN deployment plan or other configuration parameters (such as coverage range), which can be used to re-design the system.

7. S-MAC (Sensor - MAC)

Sensor-MAC (S-MAC) is a new MAC protocol designed explicitly for wireless sensor networks. While reducing energy consumption is the primary goal in our design, our protocol also has good scalability and collision avoidance capability. It achieves good scalability and collision avoidance by utilizing a combined scheduling and contention scheme. To achieve the primary goal of energy efficiency, we need to identify what are the main sources that cause inefficient use of energy as well as what trade-offs we can make to reduce energy consumption [6].

7.1 Major Sources of Energy Waste

- *Collision*: When a transmitted packet is corrupted it has to be discarded, and the follow on retransmissions increase energy consumption. Collision increases latency as well.
- *Overhearing*: A node picks up packets that are destined to other nodes.
- *Control packet overhead*: Sending and receiving control packets consumes energy too, and less useful data packets can be transmitted.
- *Idle listening*: Listening to receive possible traffic that is not sent. This is especially true in many sensor network

applications. If nothing is sensed, nodes are in idle mode for most of the time.

S-MAC tries to reduce the waste of energy from all the above sources. In exchange we accept some reduction in both per-hop fairness and latency. Although per-hop fairness and latency are reduced, we will argue that the reduction does not necessarily result in lower end- to-end fairness and latency.

7.2 S-MAC Major Components

The main goal in our MAC protocol design is to reduce energy consumption, while supporting good scalability and collision avoidance. Our protocol tries to reduce energy consumption from all the sources that we have identified to cause energy waste, i.e., idle listening, collision, overhearing and control overhead. To achieve the design goal, we have developed the S-MAC that consists of three major components: periodic listen and sleep, collision and overhearing avoidance, and message passing [6].

8. DSDV

Destination-Sequenced Distance-Vector (DSDV) is a highly dynamic routing protocol for ad-hoc networks. It is classified as a distance-vector protocol and is based on multi-hop routing and the Bellman-Ford algorithm. By definition, an ad-hoc network comprises of mobile devices/nodes called hosts that communicate within the network without the intervention of any centralized Access Point. To form such a network, each device/host has to operate as a specialized router. When the DSDV protocol was created it has been taken into account that the topologies in ad-hoc networks may be highly dynamic and that most users will desire not to have to perform any administrative actions in order to set up the network.

The protocol’s main aim is to solve the routing loop problem. The solution that it provides regarding this problem is the usage of a sequence number for each of the routes within the routing table. For differentiating between valid and non-valid links the protocol uses even (valid link) and odd (invalid link) numbers. These sequence numbers are generated by the destination.

Since wireless sensor networks can be quite dynamic, it seemed logical to compare the RPL protocol to a MANET routing protocol such as DSDV. Other routing protocols (such as RIP, EIGRP, OSPF, IS-IS) that are used by regular computer networks could not be taken into account for comparison with RPL because they place too heavy a computational burden on the device running them, thus they are not suitable for use on wireless sensors (which have very limited resources). Even though RIP is somewhat similar to DSDV, since both are rather simplistic distance vector protocols and both use the number of hops as a metric, RIP will not be suitable for an ad-hoc environment because its design cannot handle highly frequent topology changes.

DSDV avoids the looping problem by tagging each route with a sequence number. Based on the sequence number, nodes will be able to differentiate old and new routes.

DSDV, being a distance vector protocol, “in order to keep the distance estimates up-to-date, each node monitors the cost of its outgoing links and periodically broadcasts, to each one of its neighbors, its current estimate of the shortest distance to every other node in the network”.

9. Implementation Methodology

In this paper it focuses on the Clustering that is to form the group of vehicles. For that I need to the following steps,

- Fifteen nodes created.
- One base station nodes.
- Communication provided between that nodes.
- Cluster Head with Communication.

10. Results

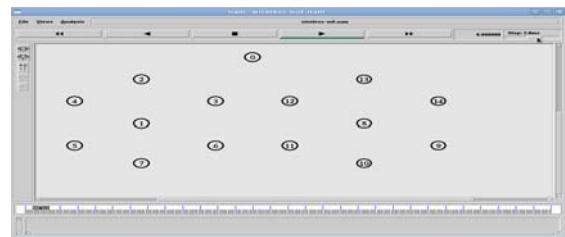


Figure 2: Formation of Cluster

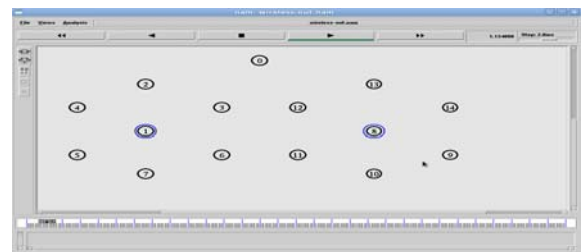


Figure 3: Cluster Head Selection Output

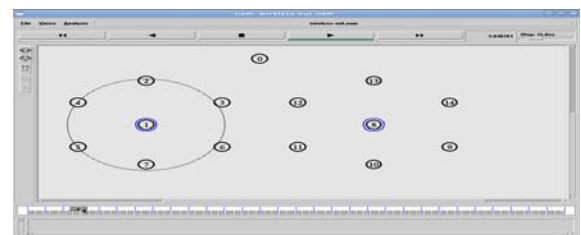


Figure 4: Communication between Node & Cluster Heads

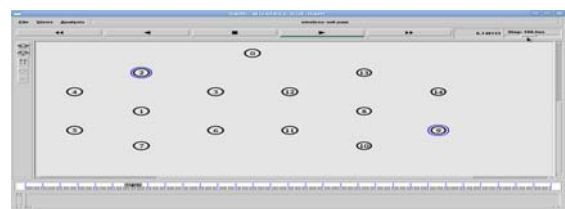


Figure 5: Cluster Changing Output - 2

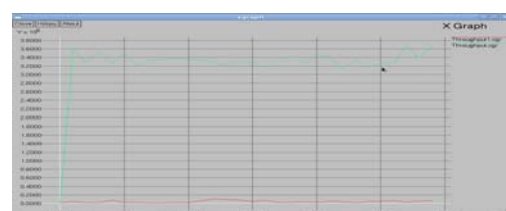


Figure 6: Throughput Comparison Graph Output

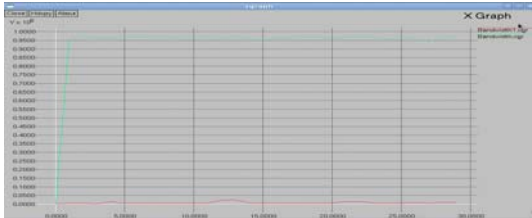


Figure 7: Bandwidth Comparison Graph Output



Figure 8: Delay Comparison Graph Output

Conclusion and Future Work

This is the first protocol to use sleep/active schedules and it offers major decrease in energy consumption and overcome of latency problem. We quantified the performance impact of sleep in a sensor MAC protocol by queuing analysis and simulation. Our results demonstrate the tradeoff between latency and energy consumption under varying duty cycles and for different packet arrival rates. Our future work includes more analytical study on the energy consumption and the latency as well as how protocol parameters affect their trade-offs. More implementation work is needed for the case of topology changes.

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