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Energy Efficient Approach for Collision Avoidance in Wireless Sensor Networks

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Abstract

One of the main challenges in the wireless sensor network is to improve the performance of the network by extending the lifetime of the sensor nodes. Excessive packet collisions lead to packet losses and retransmissions, resulting in significant overhead costs and latency which in turn makes a need to design a distributed and scalable time slot allocation. A new proposal is proposed which avoids collisions between packets and also provides increased energy efficiency and further prolong network lifetime, in wireless sensor network.

1. Introduction

The ideal wireless sensor is networked and scalable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Wireless sensor networks (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as sound temperature, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location[11]. The more modern networks are bi-directional, enabling also to control the activity of the sensors. WSN is built of "nodes" from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. Wsn generally consists of a base station (gateway) that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection. Sensor networks comprise large number of sensor nodes densely located in an area for sensing purposes. The size and cost of sensor nodes is variable depending on the complexity of the individual sensor nodes which result in corresponding constraints on resources such as energy, memory, computational speed and communication bandwidth.

In the past few years, an intensive research that addresses the potential of collaboration among sensors in data gathering and processing and in the coordination and management of the sensing activity were conducted. However, sensor nodes are constrained in energy supply and bandwidth. Thus, innovative techniques that eliminate energy inefficiencies that would shorten the lifetime of the network are highly required. Such constraints combined with a typical deployment of large number of sensor nodes pose many challenges to the design and management of WSNs and necessitate energy-awareness at all layers of the networking protocol stack. For example, at the network layer, it is highly desirable to find methods for energy-efficient route discovery and relaying of data from the sensor nodes to the BS so that the lifetime of the network is maximized

2. Related Works

Geographical Adaptive Fidelity (GAF) [2]algorithm that reduces energy consumption in ad hoc wireless networks has been introduced. GAF conserves energy by identifying nodes that are equivalent from a routing perspective and then turning of unnecessary nodes, keeping a constant level of routing fidelity. GAF moderates this policy using application and system level information; nodes that source or sink data remain on and intermediate nodes monitor and balance energy use. GAF is independent of the underlying ad hoc routing protocol; GAF over unmodified AODV and DSR is simulated. Analysis and simulation studies of GAF show that it can consume 40% to 60% less energy than an unmodified ad hoc routing protocol. Moreover, simulations of GAF suggest that network lifetime increases proportionally to node density; in one example, a four-fold increase in node density leads to network lifetime increase for 3 to 6 times (depending on the mobility pattern). More generally, GAF is an example of adaptive fidelity, a technique proposed for extending the lifetime of self-configuring systems by exploiting redundancy to conserve energy while maintaining application fidelity.

In this paper[3] a novel approach to the localization of sensors in an ad hoc net work is presented. A system called AHLoS (Ad-Hoc Localization System) that enables sensor nodes to discover their locations using set distributed iterative algorithms is described. The operation of AHLoS is demonstrated with an accuracy of a few centimeters using our prototype testbed while scalability and performance are studied through simulation.

DRAND is the first fully distributed version of RAND. The algorithm[4] is suitable for a wireless network where most nodes do not move, such as wireless mesh networks and wireless sensor networks. The algorithm is implemented in TinyOS and demonstrates its performance in a real testbed of Mica2 nodes. The algorithm does not require any time synchronization and is shown to be effective in adapting to local topology changes without incurring global overhead in the scheduling. Because of these features, it can also be used even for other scheduling problems such as frequency or code scheduling (for FDMA or CDMA) or local identifier assignment for wireless networks where time synchronization is not enforced.

The IEEE 802.15.4 standard utilizes random contention access using CSMA/CA [8] but it suffers from poor performance in DISNs. A contention-based protocol called Sparse Topology and Energy Management (STEM) to save energy is proposed. STEM implements a two-radio architecture that allows the data channel to sleep until communication is required. Channel monitoring alleviates collisions and retransmission. However, a busy tone has to wake up the entire neighborhood of a node since the intended receiver’s identity is not included on the monitoring channel. Thus, neighbors waste extra energy. This problem was tried to address such issues not considered in STEM by introducing a rate estimation (RE) scheme on top of it. They wake up the node, which had previously been involved in communication, via RE using an optimal wakeup interval. In this way, overall energy consumption is minimized. Both STEM and RE schemes assume a two-radio architecture. The complexity of adopting the second radio in a resource-constrained sensor that may result in difficult transceiver design and additional energy consumption by the second radio is ignored. Note that a probabilistic access approach can reduce overhead in terms of control messages to access the channel.

An algebraic optimization framework called DTA that performs [7] collision-aware query scheduling in Wireless Sensor Networks was proposed in this ideology. The DTA approach makes use of a set of operations that take transmissions between sensors as input and produce a schedule of transmissions as output by a DTA optimizer. The generated transmission schedule is collision-free due to the knowledge of the collision domains of elementary transmissions. The results have shown that the DTA framework considerably outperforms the existing 802.15.4 CSMA-CA as it enables concurrent transmissions to a high degree and reduces collisions. However, the overhead cost of generating the DTA transmission schedule is a concern. This problem can be further magnified in dynamic networks. Sensor MAC (S-MAC) is a static-scheduling-based energy saving protocol that allows neighboring nodes to sleep for long periods and wake up, both in a synchronized fashion, to avoid wasting energy from idle listening, collisions, and retransmissions. Thus, neighbors conserve energy when a node is transmitting. However, S-MAC does not provide an on-demand interaction with the receiver (it uses a static sleep interval).

An Energy-Conserving Medium Access Control protocol (EC-MAC)[7] for ad hoc networks was proposed in this research mode. Using this protocol, a central controller is responsible for reservation and scheduling strategies. The EC-MAC protocol can only operate in an environment where every sensor hears each other. Lightweight MAC (LMAC) implements a distributed time slot scheduling algorithm for collision-free communications. Time is divided into slots and sensor nodes broadcast information about time slots, which, as they believe, they control. Neighboring sensor nodes will avoid picking up those slots and choose other slots to control. Within its time slot, a sensor node will transmit a message with two parts: control and data. The control part includes sufficient information for neighbors to derive a time slot schedule of local sensors so that transmissions among neighboring sensors will not collide. Sensors must listen to the control parts of their neighbors. Time slots can be reused at distances where interference is small (three hops for instance). With such an algorithm, the goal of collision avoidance is achieved at the price of extra control overhead and listening time. The LMAC was enhanced with Adaptive, Information-Centric, and Lightweight MAC (AILMAC) that uses captured local data about traffic patterns to modify operations accordingly. While AI-LMAC is adaptive and information-centric, it still shares LMAC's extra control overhead and faces possible performance deficiency from unexpected burst traffic. Both LMAC and AI-LMAC were designed not with the goal of supporting high data loads, but with the objective of reducing the switching time/cost from sleep mode to transmit mode.

T-MAC, a contention-based Medium Access Control protocol [5] for wireless sensor networks has been discussed. Applications for these networks have some characteristics (low message rate, insensitivity to latency) that can be exploited to reduce energy consumption by introducing an active sleep duty cycle. To handle load variations in time and location T-MAC introduces an adaptive duty cycle in a novel way: by dynamically ending the active part of it[4]. This reduces the amount of energy wasted on idle listening, in which nodes wait for potentially incoming messages, while still maintaining a reasonable throughput. The design of T-MAC, and provide a head-to-head comparison with classic CSMA (no duty cycle) and S-MAC (fixed duty cycle) through extensive simulations are done. Under homogeneous load, T-MAC and S-MAC achieve similar reductions in energy consumption (up to 98%) compared to CSMA. In a sample scenario with variable load, however, T-MAC outperforms S-MAC by a factor of 5.

3. Problem Identification

The emergence of sensor networks as one of the dominant technology trends in the coming decades has posed numerous unique challenges to researchers. These networks are likely to be composed of hundreds, and potentially thousands of tiny sensor nodes, functioning autonomously, and in many cases, without access to renewable energy resources. There are performance deficiencies that hamper the deployment of Wireless Sensor Networks (WSNs) in critical monitoring applications. Excessive packet collisions lead to packet losses and retransmissions, resulting in significant overhead costs and latency. Event-driven sensor networks operate under an idle or light load and then suddenly become active in response to a detected or monitored event. As a result, collisions between packets can be a considerable obstacle to achieving the required throughput and delay for such applications. As the data load increases, we observe severe degradation of network performance. Packet success ratio drops due to frequent collisions and retransmissions.

Packet collision causes packet loss and wastes resources in wireless networks. It becomes even worse in dense WSNs, due to burst-traffic and congestion around sinks. Packet collision in Wireless Sensor Networks is one of the major problems which can even affect the whole system performance. Furthermore, when algorithms are proposed for avoiding packet collisions and implemented, a new dimension of problem arises in energy efficiency. When these packet collision algorithms are introduced, they are procedure overhead to the sensors and also energy debited to execute these algorithms also an overhead which further reduces the overall performance of the network.

4. GLASS protocol

The implementation of the GLASS protocol comprises of three phases. The first phase of the GLASS deals with the Grid Searching (GS). A GS algorithm to assign sensors in a monitoring area to grid cells has been devised. The proposed system has an assumption that the monitoring area is virtually split into square grid cells with uniform shapes and sizes. R is the length of one edge of any grid cell, and it ranges between 2r and 2.1r, where r is the sensor's transmission range. In addition, each grid cell is identified by a unique ID, associated with its location, i.e., a pair of coordinates (GS_Xi, GS_Yi). GS_Xi and GS_Yi represent the vertical and horizontal coordinates of a grid cell correspondingly.

The second phase of the Glass protocol concentrates on Transmission Frame (TF) Assignment. A Transmission Frame as a group of continuous time slots is defined. The TF structure repeats to handle sensors' transmit, idle, or receive states. The TF can be divided into multiple equal Subtransmission Frames (STFs) that are orthogonal. The proposed work uses a configuration with two STFs. The sensor uses the GS result from the first phase to independently assign itself an STF. As a result, sensors in adjacent grid cells operate at different STFs, reducing the potential for collisions.

The third phase of the GLASS protocol is based upon determining a time slot for the transmission state of each sensor. Latin Squares Matrix (LSM) has been used to assign time slots for sensors, thereby avoiding collisions between neighbors. First, each sensor performs neighborhood discovery to prepare for time slots scheduling. The neighborhood discovery requires all sensors to broadcast their information about GS and STF to one-hop neighbors. In this way, every sensor is aware of its neighbors and maintains a neighbor table which records neighbors' ID, distance/hop count, GS, and STF. Furthermore, sensors need to keep complete and accurate neighbors' information within their grid cells (local data), so each sensor must broadcast newly received data and update its neighbor table.

5. Proposed System

The proposed system contributes a solution for the avoidance of packet collisions and a energy efficient approach in the wireless sensor networks. The GLASS protocol and the PBEEC (Prediction Based Energy Efficient Clustering) are combined to get a well-organized model for the WSN. Though the time slot methodology plays a role in energy savings, the results are not so prominent when the network grows larger. So, the proposed work incorporates the algorithm PBEEC (Prediction Based Energy Efficient Clustering) which makes full use of the history information is developed to clustering the network. The inter-cluster communication cost and cluster size are also considered when clustering. Nodes with high residual energy and low energy consumption ratio have more possibility to be cluster heads. The proposed model uses the energy dissipation ratio, which means the percentage of energy consumption per unit time, generated from the history information to predict the time the node may survive. The cluster head selection is primary based on the parameter, Predicted Survival Time (PST) of the node. To increase energy efficiency and further prolong network lifetime, cluster communication cost as a secondary clustering parameter. The proposed algorithm is simple enough to load on sensor nodes which have limited memory and computing ability.

5.1 Grid Searching

A GS algorithm is devised to assign sensors in a monitoring area to grid cells. Assume that the monitoring area is virtually split into square grid cells with uniform shapes and sizes.

$$2r < R <= 2.1r$$

R is the length of one edge of any grid cell, and it ranges between 2r and 2.1r, where r is the sensor's transmission range.

5.2 Transmission Frame Assignment

After a sensor locates its grid cell, it proceeds with TF assignment. TF is defined as a group of continuous time slots. The TF structure repeats to handle sensors' transmit, idle, or receive states. The TF can be divided into multiple equal Sub transmission Frames (STFs) that are orthogonal. In this paper, configurations with two STFs are used. The sensor uses the GS result from the first phase to independently assign itself an STF (either A or B). As a result, sensors in adjacent grid cells operate at different STFs, reducing the potential for collisions. It can also configure four STFs via a minor modification of the algorithm.

$$\text{Length of TF} = 2*STF = 2*\left(\left\lceil \frac{\text{No of deployed Sensors}}{\text{No of Grids in the Network}} \right\rceil + \alpha\right)$$

The number of deployed sensors and number of grid cells are known in the pre-deployment stage. α is an adjustable variable between zero and Number of deployed sensors/Number of grid cells. If sensors in the network are evenly distributed, α will be small. If sensors are not evenly distributed, α will increase. To avoid uncertainty in sensor deployment, α should not be too small, but this may slightly impact packet delay due to longer transmission cycle/frames.

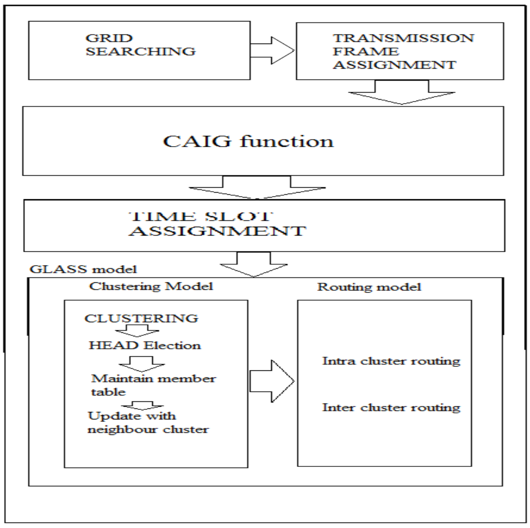

Figure 5. 1 Architecture of system diagram

6. Simulation Results

From the figure we can see that the delivery ratio is high, the delay is less, the energy consumption is low and the throughput is high for the proposed protocol, when compared to traditional while varing the nodes.

6. Conclusion

A solution for packet collision problem with energy efficient approach for wireless sensor networks is proposed. The proposed ideology has two major modules, namely GLASS protocol and PBEEC (Prediction Based Energy Efficient Clustering). The GLASS protocol has the methodology of avoiding the packet collision which comprises of three phases- Grid Searching (GS), Transmission Frame (TF) Assignment and Assignment of Time slots. It is evident that this GLASS protocol reduces packet collision by exploiting the time slots and grids for the sensor nodes.. The results shown that the GLASS protocol over perform the other traditional packet collision avoidance strategies.

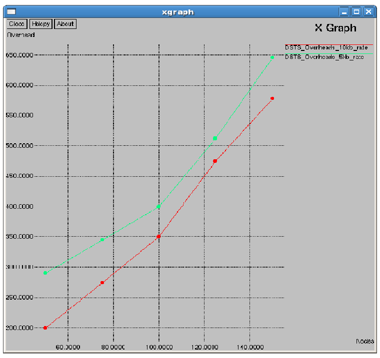

Figure 6.1: Analysis of Overhead

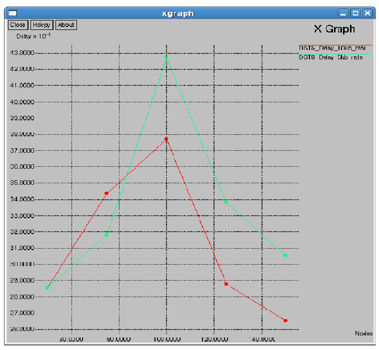

Figure 5.2: Analysis of Delay

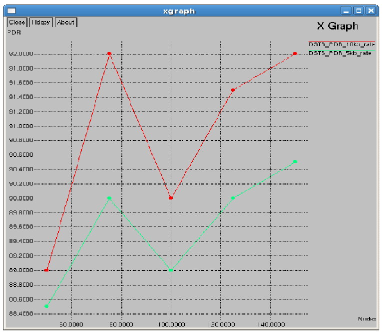

Figure 5.3: Analysis of Packet Delivery

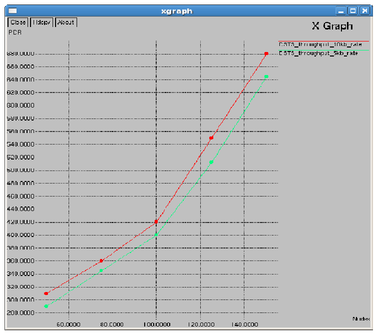

Figure 5.4: Analysis of Throughput

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