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EER transport protocol for Wireless Sensor Networks

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Abstract –

Wireless sensor network (WSN) is an event-driven system, in which sensor nodes collectively report the data pertaining to certain event to the sink. Reliable event detection is based on the collective information provided by the source nodes and not on their individual reports. However, traditional means of providing reliability, such as end-to-end reliability, when used in sensor networks, is not effective in terms of utilizing scarce resources of sensors, such as battery power, memory, etc. The energy efficient transport protocol provides the desired event reliability to the application, also minimizes the energy consumption among all the active nodes in the network. The Energy Efficient Reliable (EER) transport protocol achieves the desired reliability by distributing the load at a sensor among its children. The distribution happens in such a way that the rate of event detection at the sink is same as it was desired, and at the same time, the overall energy consumption of the children nodes is minimized. The protocol is dynamic in its operation, thus adjusting to the changing topology of the network. The above protocol gives near optimal results, while using minimum resources on the nodes. But the protocol shows some pitfalls in case of congestion. The EER transport protocol assumes no MAC layer contentions also each transmission is successful with probability of collision zero. In real life situations this is not true so the actual energy spent in congestion phase by nodes is different from the estimated in the EER transport protocol. Thus protocol very slowly converges from the state of congestion wasting scarce energy of sensor nodes. To nullify the above problem we analyzed the EER transport protocol considering MAC level contentions. Also we observed the behavior of the EER transport protocol in presence of different load requirements of the applications and its response in the vicinity of the different MAC layers.

Keywords -Wireless sensor networks; Congestion; Contention; Energy Efficient; Transmission rate; Data flow

I. INTRODUCTION

Wireless Sensor Network (WSN) is a self-configured dynamic network that consists of hundreds or thousands of inexpensive tiny resource constraints sensor nodes. Wireless sensor network applications require high reliability as they are more prone to the failure. WSN can be deployed in various domains and applications like agriculture or environmental sensing, object tracking, wild life monitoring, health care, military surveillance, industrial control, home automation, security. In a sensor network nodes are densely deployed to sense a phenomenon, so multiple sensors sensing same phenomena produces redundant data. The slow change in phenomena increases redundant data in sensor network. Redundant data transmission affects the WSN severely. Redundant data drains the energy of the node, increases congestion, communication and computational overhead. In network, data redundancy is checked by packet sequence number. This technique helps the receiver to identify the duplicate data and discard it. A packet sequence number cannot help a sender to control redundant data transmission. The data aggregation eliminates redundant data. In data aggregation, multiple sources send their data to aggregation point (typically a sensor node) which eliminates redundant data using various methods.

A transport protocol for WSNs should be reliable or provide different levels of reliability depending on the type of applications. The reliability can be measured with different parameters, one of them is congestion control, which involves congestion detection and avoidance, loss detection and recovery, and packet delivery ratio. In many applications of WSN, reliability is determined by the quantity of data packets delivered to the Base Station (BS). The reliability can be achieved with the tradeoff energy. The packet loss and poor loss recovery schemes may lead to significant packet delivery delay in the network. Hop-by–hop data recovery maximizes the efficiency than end-to-end recovery scheme. Many transport protocols have been proposed for energy efficiency reliable data transmission in WSNs.

In this paper, we aim to maximize the network lifetime and achieve end-to-end reliability by controlling the redundant data transmission with the co-ordination of BS. Sensor node senses the redundant data in many applications and transmits it to the BS. The proposed transport protocol identifies the redundant data at the sender side (i.e. sensor node) instead of receiver side and minimizes the transmission overheads by ignoring the sensed redundant data transmission. To achieve end-to-end reliability, it uses both implicit and explicit acknowledgement schemes. The transmission from source to destination is divided into two hops. The first hop is from sensor node to leader node, and the second hop is from leader node to the BS. The BS is an intended data receiver in WSN, which is energy empowered device. We propose an algorithm for BS that computes and generates an acknowledgement for redundant data without being received. We aim to achieve end-to-end reliability by using hop-by-hop acknowledgement for loss recovery.

In common scenarios, sensor nodes rely on limited energy supply and replacing energy sources in the field is not practical. Meanwhile, a WSN should operate at least for a given mission time or as long as possible. Thus, the lifetime of a sensor network is an important performance criterion. Extensive research has been performed to exploit the physical, MAC, and Network layers for energy-efficient design. In this paper, we propose a new energy-saving strategy, called outsourcing. The basic principle is to allow sensors to outsource tasks to other sensors such that the overall energy consumption as well as the energy consumption of the sensors with low remaining energy is reduced. In sensor networks, each sensor performs two types of tasks: non-substitutable tasks (NS-task) that must be performed by this individual sensor and substitutable tasks (S-task) that can be performed by other sensors. For example, sensing is a NS-task and forwarding data generated by other sensors is a S-task. When a sensor has low energy, it is nature that this sensor only performs NS-tasks and outsources S-tasks to others. Although the basic idea is simple, the utilization of the idea is more complicated. It involves how to separate S-tasks and NS-tasks and how to assign/outsource S-tasks to other sensors. In this paper, we design an energy-efficient reliable transport protocol using the outsourcing idea. Wireless sensor networks usually experience high data loss rate to unreliability of wireless channel, congestion, and failure of sensors that are deployed in a hostile and hash environment with little maintenance. Since many sensor networks are mission critical, reliability of data transmission is a fundamental requirement. To achieve reliability, several MAC standards, such as IEEE 802.11, IEEE 802.15.4 and S-MAC, adopted the ARQ technique [1] that can recover bit-errors occurred during one-hop transmission. However, ARQ in these standards cannot handle packets loss over several hops due to congestion

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or temporary sensor/link failure. Therefore, reliable transport protocol is necessary [2]. In reliable transport protocols, retransmission based on acknowledgment(ACK) or negative acknowledgment(NACK) [3] is a basic method for data recovery. When the data rate is high, a sensor usually sends consecutive packets to the data sink. In this case, NACK is preferred [3]. The data sink can detect data losses (e.g. by checking for missing sequence numbers in data packets) and request retransmission using NACK. When the data rate is low, sensors may send one or a few packets to the data sink occasionally. In this case, the data sink may not be able to detect data loss. Thus, the data sink should send ACK when receiving data such that the source node can detect data loss based on timeout of the ACK packets. In this paper, we focus on the second scenario, where the source node waits for ACK from the data sink to ensure reliable data transmission. In order to reduce energy consumption, we first examine the energy models. In sensor networks, data transmission is usually the dominating energy consumption source [4]–[6]. For data transmission, radio consumes energy not only when sending and receiving data, but also when idle listening. As shown in [7], the power consumed in the listening, receiving and sending stages is at the same order. The study in [8] suggested that a significant amount of energy can be spent in the idling listening stage. Inspired by this phenomenon, we use the outsourcing strategy to transfer the retransmission task from the source node to intermediate nodes on the route, which can greatly reduce the idle listening time. Thus, the proposed reliable transport protocol can save energy for the source node, as well as reduce the overall energy consumption, especially when the packet loss rate is high.

II. RELATED WORK

Sandip Dalvi et al [2] have proposed a transport protocol which provides the desired event reliability to the application, by distributing the load at a sensor among its children based on their residual energies and average MAC layer data rate. The event rate distribution happens in such a way that the application at the sink gets its required event rate and the overall energy consumption of nodes is minimized. They have derived a method for computing average MAC data rate for these two protocols and using simulations they have shown that our transport protocol performs close to optimal. energy-efficient and reliable transport protocol for low data streaming in WSNs. ERTP is a hop-by-hop recovery algorithm using Implicit Acknowledgment. ERTP requires that each node i after sending a packet to the next node to the sink overheads the next forwarding. The forward of a packet by node i □1 is considered as an implicit acknowledgment to node i . The authors present a hop-by-hop reliability control, which adjusts the maximum number of retransmission of a packet in each node based on the link loss rate.

Nurcan Tezcan et al [12] have addressed the problem of reliable data transferring by first defining event reliability and query reliability to match the unique characteristics of WSNs. They have considered event delivery in conjunction with query delivery. They have proposed an energy-aware sensor classification algorithm to construct a network topology that is composed of sensors in providing desired level of event and query reliability. They have analyzed their approach by taking asymmetric traffic characteristics into account and incorporating a distributed congestion control mechanism. They have evaluated the performance of their proposed approach through an ns-2 based simulation and show that significant savings on communication costs are attainable while achieving event and query reliability.

Yao-Nan Lien et al [13] has proposed the Hop-by-Hop TCP protocol for sensor networks aiming to accelerate reliable packet delivery. Hop-by-Hop TCP makes every intermediate node in the transmission path execute a lightweight local TCP to guarantee the transmission of each packet on each link. It takes less time in average to deliver a packet in an error-prone environment.

Sunil Kumar et al [14] have studied the performance of ESRT in the presence of over-demanding event reliability, using both the analytical and simulation approaches. They have shown that the ESRT protocol does not achieve optimum reliability and begins to fluctuate between two inefficient network states. With insights from update mechanism in ESRT, they have proposed a new algorithm, called enhanced ESRT (E2SRT), to solve the over-demanding event reliability problem and to stabilize the network. Their simulation results show that their E2SRT outperforms ESRT in terms of both reliability and energy consumption in the presence of over-demanding event reliability. It also ensures robust convergence in the presence of dynamic network environments.

Damayanti Datta et al [15] have proposed a new protocol for reliable data transfer in time-critical applications with zero tolerance for data loss in wireless sensor networks which uses less time and fewer messages in comparison to an established protocol PSFQ. The two key features of their proposed protocol are out-of-sequence forwarding of packets with a priority order for sending different types of messages at nodes and delaying the requests for missing packets. They have also presented two methods for computation of the delay in requesting missing packets.

III. PROBLEM DESCRIPTION

The EER [2] transport protocol consider some environmental monitoring applications used in WSN for monitoring different environmental parameters such as temperature, humidity, etc. There could be multiple applications running simultaneously in the network, each interested in different parameters. The EER transport protocol assume that the measurement is to be done in a periodic manner. The period of duration τ, referred to as the observation period, is used by all the nodes in the network and is same for all the applications. The rate is expressed as a number of data values required by the application in every period.

IV. PROBLEM DEFINITION

The EER transport protocol works well under the assumptions that no MAC layer contentions and probability of collision is zero but during real deployment of this transport protocol in sensor field the behavior of protocol is unknown under given MAC layer. This is because the MAC layer is responsible for the successful delivery of data to next hop. So the problem is that the MAC layer should fulfill the requirement of transport layer i.e. the rate asked by transport layer then only the application running on sink will get their desired event reliability. Congestion in sensor network is said to have happened, if a node cannot fulfill the requirement of data reporting, i.e. the node is able to send the data values less than it was supposed to send in some interval. In the case of congestion, the EER transport protocol uses a Success Ratio as the ratio of number of values transmitted to the number of values the node was supposed to transmit. The node adjusts the rate value to be sent depending upon the Success Ratio. It sends the fraction of values based on Success Ratio to its parent instead of required rate. This helps in decreasing the load on the node under congestion scenario but this Success Ratio is not the realistic because it could happened that the values successfully transmitted may used multiple retransmissions due to congestion and the energy spent in these multiple retransmissions is not accounted in this Success Ratio. So the problem is given a network of well deployed sensors1 , is to maximize the network lifetime2 also to minimize the energy consumption among all the sensors nodes while providing the desired event reliability to each application, in the case when multiple application are running in the network in congestion phase also. Also the selection of

MAC layer for real deployment of the EER transport protocol in sensor fields is a important from the point of energy consumption by sensor nodes. The MAC layer is mainly concerned with transmission of data across a hop. The choice of good MAC layer protocol will definitely result in efficient working of upper EER transport layer protocol. So the problem is also the selection of MAC layer to suit given EER transport layer.

a) Energy Efficiency:- Transport protocols should provide reliability with the minimum number of exchanged messages. This constraint comes from the low capacity of energy of sensor node batteries. ESRT proposes to reduce the sending events frequency to reduce the total consumed energy. Others propose to use hop-by-hop recovery instead of end-to-end recovery to reduce the retransmissions. For example, RMST, PSFQ, Widen, DTC and TSS reduce the amount of exchanged messages by caching not already acknowledged segments in intermediate nodes and process a recovery once a lost is detected. DSTN proposes to reduce the consumed energy by using Selective Acknowledgment (ACK and NACK) after an Acknowledgment Windows of messages. DSTN reduces the number of control messages, which make it more energy-efficient than other protocols. TSS and ERTP propose not to use explicit acknowledgment instead of implicit acknowledgment. These approaches need a cross-layer mechanism between the link layer and transport layer (e.g. DTC and TSS). These mechanisms permit to reduce the transport acknowledgments. However, some of these schemes are difficult to be implemented in memory-constraint wireless devices. Finally, ART increases the lifetime of the network by choosing node with more energy capacity to relay packets from sources to the sink nodes. All these works have tried to reduce the amount of control messages in the WSNs and thus increase the lifetime of all the networks.

V. CONCLUSION AND FUTURE WORK

In this paper, we present an energy-efficient reliable transport protocol for WSNs. The proposed scheme is inspired by the outsourcing idea and the energy model in sensor networks. It can reduce overall energy consumption and balance energy consumption adaptively according to the remaining energy in sensors. The sole purpose of transport layer protocol is to provide desired event-reliability to the applications on the sink also heal the protocol in congestion. The protocol achieves the reliability in event detection, at the same time minimizes the energy consumption of the sensors during its operation in congestion phase by adapting correct rate given by MAC layer. The load-distribution strategy gives results close to the optimum as far as energy conservation is concerned also in congestion. The protocol is also simple in terms of steps needed to be carried out at each sensor, thus requiring very little memory and processing power. The protocol runs in a distributed manner, it can also work in a dynamically changing topology. The main advantage of the protocol is that it works with multiple applications. Also the issue of selection of MAC layer is resolved by the analysis of MAC layers in the vicinity of protocol. Thus the user using this protocol in the sensor field can use the analysis to select the protocol at MAC layer subject to given load constraints. Currently, we analyzed the protocol in the presence of the two MAC layers under various load conditions for a single level. We are interested in analysis for tree and graph topology of sensor network. Also devise of MAC layer which when in use will give optimal results in all states of network. In the future, we are planning to study and analyses the EER transport protocol for tree and graph topologies, also want to look for a MAC layer protocol which exactly fulfills the requirement of above transport layer and completes the protocol suite

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