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A hybrid and dynamic reliable transport protocol for wireless sensor networks ☆

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ABSTRACT

Wireless sensor networks are formed by a large number of sensor nodes which are commonly known as motes. In the past few years, several reliable, congestion controlled and energy efficient transport layer protocols in wireless sensor networks have been developed and proposed in the literature. In this paper, we have presented a hybrid and dynamic reliable transport protocol which provides the mechanism to dynamically assign the timing parameters to the nodes as well as enhance the protocol performance by using a hybrid Acknowledgement/Negative Acknowledgement scheme. The performance of proposed protocol is tested under TinyOS Simulator varying different parameters and protocol settings and found that proposed protocol is able to program all the nodes when given proper pump/fetch ratios, is able to solve the booting sensor nodes problem by being able to wait till all the nodes finished booting and solves the all-packets-lost problem by acknowledging the receipt of its first packet delivered that is the inform message.

1. Introduction

Wireless sensor networks (WSNs) are formed by a collection of hundreds or thousands of sensor nodes working together and are used to monitor events in a region to obtain data about the environment. Sensor nodes are composed of processor, memory, transceiver, one or more sensors and a battery [1]. In wireless sensor networks, transport protocols are used to decrease congestion and reduce packet loss to provide fairness in bandwidth allocation and to guarantee end-to-end reliability [2]. However, the Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are popular transport protocols and deployed widely in the Internet, neither may be a good choice for wireless sensor networks due to many constraints in terms of throughput and energy efficiency [3]. One of the major drawback of TCP is that it uses end-to-end retransmission-based error control and the window-based Additive-Increase Multiplicative-Decrease (AIMD) congestion control mechanisms that may not be feasible for the wireless sensor networks domain and hence, may lead to waste of scarce resources [4]. In contrast, UDP is connectionless transport control protocol and is not suitable for wireless sensor networks due to lack of flow and congestion control mechanisms [5].

The main focus in this paper is on the design of reliable transport protocol for wireless sensor networks. Reliable data transport is an important research area in the field of wireless sensor networks. Many wireless sensor network applications require the reliable transport of data. For example, consider a wireless sensor network deployed in a chemical plant to detect harmful gas. It is essential for sensor nodes to reliably transport every sensor reading back to the base station. Due to many

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unique characteristics and constraints of sensor nodes, providing reliable transport of data in wireless sensor networks can be a challenging task. Another challenging task in designing a reliable transport protocol in wireless sensor networks is frequent node failure. Node failure in the sensor network can be the result of system crashes, harsh environment or energy depletion [6].

The rest of this paper is organized as follows. An outline of related transport layer protocols is presented in Section 2. In Section 3, hybrid and dynamic reliable transport protocol (HDRTP) is presented. The performance analysis of both Pump Slowly Fetch Quickly (PSFQ) and HDRTP protocols has been presented in Section 4. Finally, Section 5 concludes the paper.

2. Related work

For wireless sensor networks, several transport layer protocols have been designed to address various issues such as reliability, congestion control or both. A brief summary of the related protocols is provided in this section.

PSFQ [7] is designed to be downstream, scalable and energy efficient transport layer protocol. It distributes data from sink to sensors by pacing data at a relatively slow speed but allowing sensor nodes that experience data loss to recover any missing segments from immediate neighbours. It provides a hop-by-hop error recovery technique in which intermediate nodes also cache fragments and share accountability for loss detection and recovery. NCMPT [8] (nodes cooperation based multipath transmission protocol) is based on ReInForM algorithm. In this algorithm sensor node designs the set which comprise of before hop ($H-$), this hop ($H0$) and next hop ($H+$) based on the hop distance between itself and sink node. To achieve better transmission reliability, data from source node are transmitted not to one sensor node, but to multiple sensor nodes in the inner cluster, when source nodes have data packets to be transmitted. ARTP [9] (Adaptive Reliable Transport protocol) is designed as receiver controlled based on a new protocol stack and uses slightly different semantics of acknowledgement messages. In order to reduce the energy consumption it uses three different types of acknowledgements, i.e. Acknowledgement (ACK), Negative Acknowledgement (NACK) and Forward Looking Negative Acknowledgement (FNACK). FNACK with a sequence number is sent by the receiver to the sender, to inform that no more data packets have been received and an interval of time has passed during which remaining unoccupied receiver cache would have got filled up if the data packets were continued to be collected at the present average packet receiving rate.

QERP [10] (Quality-based Event Reliability Protocol) is designed to optimize event reliability by incrementing the number of data packets successfully transmitted by regulating transport process. In QERP, reporting data from sensor nodes are distinct in the contribution degree (CD) for event detection according to their environmental conditions. It consists of two different processes, a collection process for collecting sensor nodes to send their reporting data to the sink node according to CD and a transport process for differentially transporting them by CD based buffer management and CD based load balancing in data congestion. RP2PT [11] (Reliable Point-to-Point Transport Protocol) uses virtual circuit between the source nodes and the sink node and provides assured reliability by local caching and local retransmission. In RP2PT, data packets at the intermediate node can be cached with a given probability such that retransmission can be implemented between this intermediate sensor node and the sink node.

A new reliable data delivery protocol [12] is designed as hop-by-hop reliable transport layer protocol for wireless sensor networks. It detects loss by using NACK and recovery pattern by end-to-end sequence numbers. It provides a new queue management pattern that gives priority to new data. It is also based on dequeue policy in which if a new packet is received and the transmission queue is full, then the node discards the packet at the head of the queue and makes space for the newer packet. MPLOT [13] (Multi-Path LOss-Tolerant) is designed around the basis of separability of reliability and congestion control functions in an end-to-end transport protocol. It performed congestion control separately on individual paths, and the reliability method works over the collective set of paths available for an end-to-end session. It uses combination of Forward Error Correction (FEC) coding and adaptive Hybrid Automatic Repeat Request (HARQ) to decrease the number of data packet retransmissions, and exploits Explicit Congestion Notification (ECN) to separate between congestion and link losses.

GLRD [14] (Geographic Location based Reliable Data transmission over multipath) provides reliable data transmission over multipath in the wireless sensor networks and accomplish improved performance on transmission time delay and energy utilization. The achievement of GLRD protocol is based on the success of the forwarding node election at each hop. If higher than two candidate nodes locate at the first transmitting slot, and further crash at the first transmitting time slice, this data packet fails to continue to be forwarded to next hop. RETP [15] (Reliable Event Transmission Protocol) is designed as real time event detection and reliable packet forwarding in wireless sensor networks. It consists of two procedures, Accurate Event Detection and Real-time and Reliable Transmission. In Accurate Event Detection, each sensor collects the event information and makes the decision cooperatively in order to ensure whether a particular event happened or not. In RETP, to perform real-time event transmission a timer is set for each sensor and the event packet reliability is achieved with the technique called multi-transmission.

Reliable and Efficient Caching-Based WSN Transport Protocol [16] is designed to improve Distributed Transport for Sensor Network (DTSN) protocol (denoted as $DTSN^{+}$) and compared its performance with TCP and Datagram Transport Protocol for Ad Hoc Networks (DTPA). This protocol comprises of enhanced $O(1)$-time complexity NACK recovery technique, experimental verification of the optimal DTSN acknowledgement window (AW) and performance evaluation of DTSN with transport protocol TCP and a newly proposed protocol DTPA. HRDG-MS [17] (High-Reliability Data Gathering Protocol Based on Mobile Sinks) is designed on the basis of two mechanism i.e. No-Route-Buffer mechanism and adaptive BEACON interval strategy