Dependency of Transport Functions on IEEE802.11 and IEEE802.15.4 MAC/PHY Layer Protocols for WSN: A Step towards Cross-Layer Design

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ABSTRACT

In WSN, transport layer protocol plays a significant role in maintaining the node’s energy budget. To find out the dependency of Transport layer on MAC/PHY layer, the authors have extensively tested various transport protocols using IEEE 802.11, IEEE 802.15.4 MAC/PHY protocols for WSN. For IEEE802.11 and IEEE802.15.4 with RTS/CTS ON the TCP variants has shown >80% packet delivery ratio and 5-20% packet loss, while for UDP it is around >63% and 19.54-35.18% respectively. On average 1-3% additional energy is consumed for packet retransmissions in IEEE 802.11 with RTS/CTS OFF whereas significant energy efficiency is observed in IEEE802.15.4 case. For IEEE 802.11 with RTS/CTS ON high throughput, low packet drop rate and increased E-2-E delay is observed, while for IEEE 802.15.4 improved power efficiency and jitter behavior is observed. This has led the foundation for the future development of the cross-layered energy efficient transport protocol for WSN.

Keywords: Congestion Control, IEEE 802.1, IEEE 802.15.4, MAC, Reliability, Transport Protocol, WSN

INTRODUCTION

The idea of low power, low cost, embedded wireless devices capable of gathering useful environmental information has led the development of Wireless Sensor Networks (WSNs) (Akyildiz et al., 2007; Potdar et al., 2009; Sharif et al., 2009). Today WSN technology has gained fundamental importance in a range of application scenarios like military, modern healthcare, environmental monitoring, surveillance etc. Fundamentally energy is considered as the biggest threat to WSN node design including both the hardware and the communication protocol.

DOI: 10.4018/jbdcn.2010070101
design. WSN pays high energy cost in data retransmissions due to path loss, congestion and high bit error rate (BER) caused by interference or collisions at the receiving node. Either case will have a direct impact on the overall network throughput (Sharif et al., 2010), E-2-E packet latency and of course the longevity of the WSN. Reliable and high data transfer rate are the main concerns in event-critical applications e.g. Wireless Multimedia Sensor Network (WMSN). So facilitating congestion control and E-2-E reliability mechanism will be the primary objective of any transport layer protocol design.

In WSN, the transport layer protocol functionality is comprised of a congestion control component (Sharif et al., 2010) that handles minimum number of data packets (either scheduled or prioritized) in order to ensure the minimum latency and energy conservation (achieved by minimum retransmissions) under congested network conditions. Also the transport function must ensure the event and query reliability. In the WSN network dealing with multimedia information, (i.e., WMSN) the effect of congestion is even more pronounced. The nodes near the sink or those that are experiencing large amount of data above their handling capacity (bottleneck nodes) experience congested paths during data transmission that requires high data rate. This condition would result in performance degradation (due to collisions and retransmissions) and rapidly depletes the node’s energy. Thus the transport protocol should effectively detect the congestion and try to mitigate it immediately in order to avoid excessive collisions and retransmissions.

Second important functionality of the transport layer protocol is the data reliability feature (Sharif et al., 2010), which ensures how efficiently the transport protocol detects the data packet loss and notifies it to the nearby storage node for data packet retrieval (to epitome the correct information from the received data) in order to ensure the Quality of Service (QoS) objective of the application is not compromised e.g. event-critical applications (Sharif et al., 2009). Currently the WSN supports packet level and application level reliability. For packet level the transport protocol guarantees the reliable transmission of each and every data packet (packet level reliability) while certain applications (like Military) demand proportionally reliable transmission of all data packets (application reliability).

The Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) schemes of the existing wireless network are not well suited for WSN because of having strict E-2-E reliable aspect, unfairness for multi-hop environment (as in TCP) and connectionless with no congestion control feature (as in UDP). New proposals using multi-path transmission have been introduced such as Congestion Detection and Avoidance (CODA) (Wan et al., 2003) and Multi-flow Real-time Transport Protocol (MRTP) (Mao et al., 2003). CODA has considerable delay since it decides on the basis of the status of the intermediate nodes and MRTP does not consider energy efficiency in WMSN. Some other transport protocols have been designed recently for scalar WSNs with the aim of decreasing energy consumption, providing reliability, and controlling congestion. These protocols do not fulfill major factors of QoS, such as high bandwidth and real-time communication, which are required for multimedia communication in sensor networks, e.g., Reliable Multi-Segment Transport protocol (RMST) (Stann & Heideman, 2003), Reliable Bursty Convergecast (RBC) (Zhang et al., 2005), Garuda (Park et al. 2004), Pump Slowly Fetch Quickly (PSFQ) (Wan et al., 2002), Event-to-Sink Reliable Transport (ESRT) (Sankarasubramaniam et al., 2003), Distributed TCP (DTC) (Dunkels et al., 2004) and Sensor TCP (STCP) (Iyer et al., 2005) do not support real-time communication while providing reliability. Also, Fusion (Hull et al., 2004) is another transport protocol that is not compatible with the limited energy sources of video sensor nodes. Also existing work in transport protocol development targets either upstream (source-to-sink) (Park et al., 2004; Wan et al., 2002) or downstream (sink-to-source) reliability (Stann & Heideman, 2003; He et al., 2003; Sankarasubramaniam et al., 2003).

In this paper we primarily focus on the role of transport agent for ensuring data delivery
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