A Survey of Reliable Transport Layer Protocols for Wireless Sensor Network

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ABSTRACT

Wide research in the field of Wireless sensor network (WSN) made it applicable into various domain of organization, health, home appliances and many more. WSN has various issues in transporting data from one node to another. Reliability is considered to be one of the important requirements of WSN. Reliability concerns with the loss of data, retransmission of data, connection of links, energy consumption etc. So reliable transmissions of data from source to destination either node-node or node-sink is a challenging task. To meet Quality of service (QoS), congestion free and reliability is mandatory. Some protocols consider congestion in the network only while some consider reliability only and some consider both congestion and reliability in the network. In this survey we considered various reliable transport protocols for WSN in which few consider congestion control too.

Keywords

Wireless sensor network, Reliable transport protocol

1. INTRODUCTION

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro- Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. Transmission can be done through wired or wireless connection.

WSNs have great potential for many applications such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring, and hazardous environment exploration and seismic sensing. In military target tracking and surveillance, a WSN can assist in intrusion detection and identification. Specific examples include spatially-correlated and coordinated troop and tank movements. With natural disasters, sensor nodes can sense and detect the environment to forecast disasters before they occur. In biomedical applications, surgical implants of sensors can help monitor a patient's health. For seismic sensing, ad hoc deployment of sensors along the volcanic area can detect the development of earthquakes and eruptions. Wired connections are lot more reliable than wireless but also possess some drawbacks. For example deploying wired connections in volcanoes monitoring, lake monitoring or battle field monitoring is quite difficult or not possible. Hence wireless technology is used for transmission. Wired data is less susceptible to error than WSN since congestion is the only issue in wired data transmission while in WSN various factors participate in transmission that eventually degrades the performance of network. Some factors are environment interface, node failure and many more. High bit rate enhance the reliability too. Different types of data flows into network streaming, one packet data etc. Different applications require different level of guarantee for data transport for instance reporting of events, distribution of queries to sensor nodes and managing states in tracking application demands guaranteed delivery.

2. ASSUMPTION AND RELEVENT TERMS

In network architecture of transport layer protocols include sensors (slaves) and actors (masters). Why two types of node are used here? It is to separate sensing and decision taking task among the nodes. There are two types of nodes namely sensor and actor. Sensor detects and monitors physical phenomenon while actor gather data and eventually take decision with some delay bound. As discussed in previous section sensors have very less memory as well as low processing power so it is welfare to divide the task among sensors and actors. Actually sensors detect, monitor a network field. This physical phenomenon is eventually transmitted to actors to which some neighboring sensor nodes are attached with. This is called as sensor-actor communication. Now actors will gather data, process them and collectively take decision. Communication among actors is called as actor-actor communication. All actors are attached to each other by an ad hoc communication channel. Sink node is master of all node where ultimately all data will be stored.

3. SURVEY OF RELIABLE TRANSPORT LAYER PROTOCOLS

In [1] i.e. Real time and reliable transport (RT)2 achieves reliability and timely event detection with minimum possible energy consumption and no congestion. (RT)2 has to deal with sensor-actor and actor- actor transport reliabilities. In sensor- actor, densely deployed sensors are correlated with both spatial and time. Thus, the sensor–actor transport paradigm requires a collective event transport reliability notion rather than the traditional end-to-end reliability

notions. Since actor- actor communication is ad hoc, incorporates adaptive rate-based transmission control and (SACK)-based reliability mechanism to achieve 100% packet reliability in the required ad hoc communication. Moreover for $(RT)^2$ real time event transport actor has to take decision with some delay bound i.e. event- action delay bound, . This delay has to greater than or equal to sum of transport delay, processing delay and action delays.

In $(RT)^2$ congestion is detected and controlled by actor nodes only. Since they have higher capability and priority than sensor nodes. Delay constrain reliability act as congestion indicator. Delay constrain reliability is ratio of observed and desired delay constrain reliabilities. Actor node calculates updated reporting frequency by determining Ti amount of time needed to provide delay-constrained event reliability for a decision interval i, Tsa, the application-specific sensor–actor communication delay bound and ratio of observed and desired delay-constrained event reliabilities. In (RT)2 different reporting frequency update policies along with possible network conditions are considered. Depending upon early, low and adequate reliabilities with and without congestion conditions are considered and accordingly reporting frequency rate is adjusted some multiplicative constants or exponentially.

In [2] paper that we have considered in this survey refers to design idea of TCP with LWIP stack compiled by the Swedish Institute of Computer Science (SICS). It introduces gateway concept to transmit sensed and monitored data to remote computer or sink node to achieve remote monitoring for the target area. In introductory part of this paper comparison is made between TCP and UDP and through this discussion it is suitable to use TCP protocol for transportation of data since it considers reliability. Though TCP is suitable but indeed overloads the network by increasing complex flow control algorithm, data queue control, state machines and timers, etc. So TCP with LWIP stack is introduced. In LWIP state control block is design to form chained list to make many connections. But here only one connection is established i.e. from gateway to sink node. Moreover data sensed by sensor is of very small amount. Wastage of Network bandwidth takes by frequent transmission of small data packets. Even channel between gateway and sink may block indeed reduce reliability. In addition energy consumption is quite high since excessive power is required to frequent transmission of small packets. Small packet issue is overcome by Nagle algorithm. Nagle algorithm form large block of small packets equal to MSS (maximum size segment). If assembled packet does not reach to MSS then would experience transmission delay and hamper real- time transmission. Nagle algorithm is self timed sending manner acknowledgement based and before the acknowledgement arrives, it starts assembling the packet till it either equal to MSS or sender receives acknowledgement. But networks which are more concerned with communication cost and communication energy consumption, this delay costs more. So improved nagle algorithm is used to deal with this issue. Two types of delay parameters were added to existing nagle algorithm and a fast timer is introduced to achieve a fair amount of delay for Nagle algorithm. Values of delay can be modified according to application need and congestion conditions. All this alteration to standard nagle algorithm makes itself adaptive, self timed and most important a reliable transport protocol.

In [3] that we have surveyed considers bit rate adjustment. In its proposed model it uses hop-by-hop reliability guarantee model with receive buffer and retransmission buffer for each node in network. Sensor nodes send packet in upstream direction towards sink node by putting packets in receive buffer. Each intermediate node cache packets into its own memory and send acknowledgement to their respective senders depending upon order of packets. If node receives packets in order by sequence number then it sends ACK otherwise NACK is sent. If sender receives ACK then it deletes particular packet from its cache and if it receives NACK then sender puts particular packet into retransmission buffer to resend. Timer plays a crucial role in loss detection. Timer looks after if a request is received in specific interval of time otherwise send NACK. Degree of congestion dynamically adjust timer. Conversely congestion degree can be calculated by recovery timer by introducing constant α (less than 1). Each node in network except sink, congestion degree is calculated and forwards towards sink. Sink selects maximum of congestion degrees of nodes called as effective congestion degree which helps sink to detect congestion in network using some threshold values. To tackle congestion in network, rate adaption technique uses AIMD. Packet loss of each source is calculated by average loss interval technique (ALI). In ALI probability of loss packets for source is determined which is nothing but reciprocal of maximum of the sum of interval containing the packets that have arrived since the last loss. Once probability is known its multiplicative decrease factor can be determined. No congestion occurs when probability is zero and hence multiplicative decrease factor is initialized to 1. So no source rate is changed. When probability of loss packet is increased ultimately congestion occurs in network, consequently multiplicative decrease factor decreased towards zero which causes source rate to be decreased. Hence in this way congestion density is controlled and reliability is ensured.

In [4] paper comprises of three modules for congestion i.e. congestion control, congestion detection and congestion notification. In congestion control module every node calculates its own congestion index by considering free memory space, total memory space in the intermediate nodes with time elapsed for serving each hop. Congestion control module also considers time to execute one packet, queue index, one hop propagation time and time for RTS/CTS information exchange. Once index is calculated packet latency for E-2-E communication helps to determine new source rates. New rate is nothing but ratio of time latencies with congestion index and total number of intermediate nodes. Sink node is solely responsible for processing and computation. These new rates are broadcasted by congestion notification module to all source nodes and on receiving source update their rates. This is how new rates mitigate congestion in the network. Reliability is achieved by sending and receiving ACK and NACK packets. If source packet generates new packet then it sets ACK=NACK=0, packets with ACK=1, NACK=0 is acknowledgement for particular sequence number packet while packets with ACK=0, NACK=1 is no acknowledgment. So by setting value to 0 or 1 for ACK/NACK packets reliability is being achieved.

Following are steps how [5] protocol proceeds:

1. Sense and send physical phenomenon

2. For new packets set ACK=NACK=0

3. Intermediate nodes stores packet

4. On successful reception, sink sends ACK=1, NACK=0 towards intermediate nodes in reverse direction and delete that particular packet from its cache

5. On unsuccessful reception, sink sends ACK=0, NACK=1 towards immediate intermediate node in reverse direction. If that node has the lost sequence number packet then it resends

packet with ACK=NACK=0 otherwise it forwards ahead in reverse direction till sink receives packet successfully.

6. Sources update rate plans and starts sending packets with new rates.

Through these steps congestion is mitigated and reliability is achieved with minimum energy consumption.

In [5] paper Farizah Yunus, Nor-Syahidatul N. Ismail et calculates performance metrics which includes reliability metrics, congestion metrics and energy metrics. In reliability metrics packet success ratio is calculated using number of successful packet reception to the total number of packets transmitted. Node reliability is also calculated for node i as number of packets of node i received by sink to total number of packets node i generates. In this way at each node reliability is measured. In congestion metrics calculation, congestion degree is calculated by taking ratio of mean of packet servicing ratio to mean of packet inter-arrival time. In this way congestion metrics are used to measure network efficiency which nothing but detecting, mitigating and maintaining congestion degree of network.

In [5] FarizahYunus, Nor-Syahidatul N. Ismail et. Also provides energy efficiency metrics so as network consumes minimum energy for transmission. Energy metrics includes calculation of packet loss ratio, energy loss per node, energy loss in network and also considers remaining energy in nodes. Packet loss ratio is number of packets lost in network to number of packets generated by sensing nodes. Energy loss per node is ratio of no. drop packets by node i to total number of packet received by node i. While energy loss for network is ratio of no. of packets dropped by network and total no. of received packet by the sink. Lastly remaining energy is calculated by taking ratio of energy remained in node to initial energy of nodes. With this calculation of different metrics i.e. congestion, reliability and energy, [4] controls congestion, maintain reliability as well as efficiently consume energy. In section IV, comparison is made between five protocols that we have considered in this survey. This comparison is based on various metrics considered for mitigating and helps in achieving reliability.

4. COMPARISION

Table I. Comparison between protocols

Name of Protocols / Transport Layer Metrics	(RT)^{2}reliable protocol	Improved RCRT rate protocol	Enhanced Nagle Mechanism	Energy efficient reliable protocol	Priority enabled protocol
Reliability	Event& Packet	Packet	Packet	Packet	Packet
Congestion Control mechanism	Yes	Yes	Yes	Yes	Yes
Real-time	Yes	No	No	No	No
Energy Efficiency	Good	Fair	Fair	Fair	Fair
Hop-by-hop reliability	No	Yes	No	Yes	Yes

5. CONCLUSION

Though WSN achieved large applications in various fields its reliability is of great concern. WSN finds applications in sensitive and crucial areas where secure transmission, flow control, ordering with time bounds and most importantly reliability is required. So in the paper we have surveyed some reliable transport layer protocols in which one discusses delay bound real time transmission with reliability while other discusses improvement in existing nagle algorithm by introducing with faster timer and delays. Lastly bit error rate with congestion control is discussed. So through this survey we can conclude that reliability is a matter of great concern and should be dealt effectively.

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