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Research Paper

ENERGY EFFICIENCY AND TRANSPORT PROTOCOLS APPLIED TO WIRELESS SENSOR NETWORKS

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Transport protocols applied to WSNs have gathered increased attention in recent years due to the increased application of the WSNs for different surveillance situations. This paper surveys the research related to the transport protocols in Operation Research for WSNs with a focus on this characteristics of congestion control, reliability, energy efficiency and effective resource utilization. A number of existing transport protocols have been discussed along with their respective merits and limitations. Finally some unresolved issues are listed, which can be the basis for future research in this area.

Keywords: OR model, Basic feasible solution, WSN

INTRODUCTION

Protocol supporting mobility as standardized by IETF. The emergence of advanced technologies in both wireless communication and electronics has made possible the uses of numerous small, cheap, and low power sensor nodes that can communicate only with each other to form a larger network. These Wireless Sensor Networks (WSNs) have found applicability in the field of home, health, and military surveillance .The protocol stack for the sensor networks consist of five layers, i.e., (1) physical layer, (2) data link layer, (3) network layer, (4) Transport Layer, and (5) application layer.

This paper is focused on the transport layer of the protocol stack, which is responsible for the maintenance of data flow. The two most widely known protocols used at the Transport layer of wired networks are Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).

- TCP is a connection oriented protocol, and in classical TCP the sender starts injecting multiple packet segments into the network, the window size advertised by the receiver

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after establishing a connection. By using a three-way handshake protocol. Although TCP provides a reliable mechanism for transporting packets, but the use of window-based flow control might lead to congestion over the network.

- UDP is a minimal, connection less protocol, which don't offer Reliability and ordering of packets, but behaves faster than TCP due to reduced overhead. In this paper we shall discuss the defining characteristics of the transport protocols along with examples of some specifically designed transport protocols for WSNs and the feasibility of using either TCP or UDP for the wireless sensor networks.

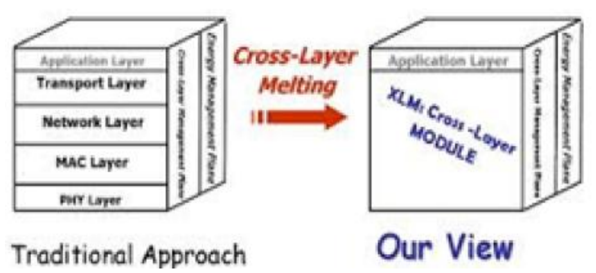
Transport Protocols Characteristics

we are going to provide a introduction to some of the aspects which will be the basis of study of suitability of different kinds already proposed transport protocols.

Congestion Control

The phenomenon of congestion arises in a network when the sender's rate of injecting the packets into the network is greater than the retrieving rate of the receiver. Congestion in a network can be determined by monitoring the node buffer occupancy and the wireless link load. UDP does not offer any congestion control mechanism, whereas TCP employs window based approaches to avoid the congestion scenario. Improves congestion control by attempting to anticipate congestion by taking into account the actual data flow rates and thereby adjusting the window sizes. Futhermore, the applicability of the active congestion avoidance techniques for WSNs needs to be closely investigated due to the limited resources of buffering and processing power available to the sensor nodes.

Figure 1: Cross Layer Melting View



RELIABILITY

Reliability is one of the most important criteria for judging the quality of wireless sensor networks and it covers not only the transport reliability issues but it is also concerned with the ability to sense physical phenomenon. The problem of achieving reliable communication between nodes is further aggravated by the presence of wireless link with higher bit-error rate.

In case of WSNs, the transport reliability requirements from single packet delivery such as highly aggregated data to the delivery of a stream of packets due to periodic data reporting. In addition to this, different applications require different levels of guarantees for data transport, for instance reporting of important events, distribution of queries to the sensor nodes and managing states in tracking application demands guaranteed delivery, whereas the delivery requirements are not very strict or in other words probabilistic when different sensors transmit correlated

Readings: The issues of reliability cannot only be addressed by the transport protocol in case of WSNs, instead it is required to cross-layer solutions to achieve effective reliable network Furthermore, the transport protocols should assure the fairness of traffic throughput for different sensor nodes.

ENERGY EFFICIENCY

Wireless sensor nodes are mostly battery operated devices, so the importance of energy conservation is very significant in increasing the overall lifetime of these devices. The transport protocols cause the energy in efficiency because of its end-to-end re-transmission mechanism as adopted in TCP. As mentioned previously the loss of packets in WSNs can be either due to high bit error rate or the congestion of the network and a protocol like TCP requires the lost packets to be transmitted from the sender and passing all the way thorough the intermediate nodes to reach the final destination. This mechanism not only wastes the available bandwidth, but it also results in a significant waste of energy, apart from limiting the throughput of the message delivery. A possible way to improve the behaviour of TCP in favour of energy conservation is to enable intermediate nodes to buffer message segments, which can be retransmitted locally in case of any loss down the path as proposed in .Other methods to improve the energy efficiency include the scheduling techniques for sleep cycles, reduction in re-transmission by having delayed acknowledgements and by integrating data with the acknowledgements and using header compression technique to reduce the TCP header.

Resource Efficiency

Wireless sensor devices are not only constrained by power, but they also have limited memory and processing power in order to reduce the unit cost of the device. Thus it is highly desirable to adopt the transport protocols, which makes effective use of these limited resources and use simplified connection establishment mechanism to assure shorter transmission delays.

Proposed Transport Protocols

Having presented the desired requirements from the transport protocols for WSNs, now going to account for the salient features of a few of the important existing protocols.

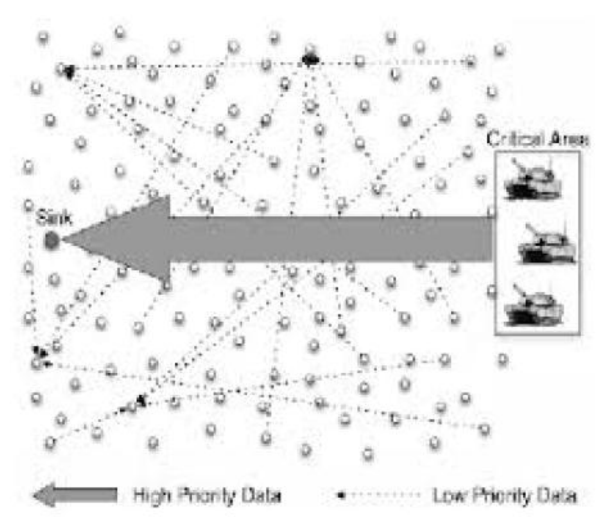
PSFQ

Pump Slowly Fetch Quickly (PSFQ) provides a mechanism for transporting data such as code updates from the sink node to the downstream sensing nodes reliably even in highly error prone environments'. It limits the communication cost by involving minimal signalling.The protocol employs a hop-by-hop technique to recover the loss of packets. The basic protocol consists of a pump operation, a fetch operation and a report action, where the pumping function initiates the packet broadcast at a slow speed with the header containing fields like file ID, file length, TTL (includes a report bit), and sequence number. A fetch operation is invoked by a node on detection of an out of sequence packet delivery and it is possible to aggregate multiple losses of packets in a single fetch operation. A NACK message is communicated to the neighbouring nodes for retransmission of the lost packet fragments. Each node in the fetch mode keeps track of its lost segments, and regularly updates its statistics upon partial reception of lost data. This kind of loss recovery is initiated in response to the detection of some loss of fragments based on sequence number, but it fails to respond if there is a loss at the end of file. In order to resolve this problem PSFQ uses a proactive fetch approach to request the last segment by sending a NACK if the last segment is not delivered after a certain period of time (Wan *et al.*, xxxx). In addition to this, PSFQ protocol provides a scalable method to provide feedback to the sink node by relaying report messages. The report messages start at the farthest node and are appended or aggregated on the Page 3 of 4 way at each intermediate node on hop-by-hop basis to avoid extra communication costs.

ESRT

Event-to-Sink Reliable Transport (ESRT) focuses on reliable transfer of information from the nodes where certain events are monitored to the sink node. Thus it is mainly concerned with upstream data flow and offers an end-to-end delivery service by regulating the report frequency. ESRT proposes a mechanism of adapting the reporting rate of an event by a node to achieve the desired reliability factor in terms of the amount of packets transferred. Thus the protocol defines a threshold in terms of reporting rate up to where the network can operate without causing any congestion, which is the basis of congestion control mechanism adopted by ESRT. The congestion state of the network is determined by detecting the state of the local buffer of a node and this congestion information is conveyed to the sink by the congestion notification bits in the outgoing packets. The adaptive nature of ESRT protocol makes it capable of responding to the dynamic variations in the network topology. ESRT does not require individual node IDs and does not maintain global information about the number of nodes present in the network. ESRT is mainly implemented at the sink node and requires minimal functionality at the source nodes, thus conserving energy and decreasing the processing demands of the sensing nodes.

Figure 2: Event to Sink Reliable Transport



RMST

Reliable Multiple-Segment Transport as the name indicates, it is designed to support reliable delivery of larger blocks of data consisting of multiple segments in the upstream direction and works the directed diffusion stack. Directed diffusion provides multipoint to multipoint connectivity in sensor networks similar to multicasting by subscribing interest by a sink to a source. RMST protocol assures the guaranteed transportation of the fragments of data to all the subscribing sinks, but do not offer any real-time guarantees. In RMST the responsibility of detecting any loss of fragment lies at the receiving node which can be either sink node or any of the intermediate nodes and data segment loss is derived from at timer. In case of the non-caching mode the sink node initiates the recovery process by sending a NACK message along the path to the source node, where as in caching mode case, any of the path nodes can request the retransmission of lost fragments. If a node is able to provide all the lost segments from its cache, then the NACK message is Dropped at that node. The caching of segments in intermediate nodes result in energy conservation by avoiding end-to-end retransmissions, where as MAC layer has been used in case of non-caching mode to reduce the overhead of transport layer .In case of a node failure the new path is discovered based on the diffusion mechanism and it is this dynamic reconfiguration capability of RMST protocol that it is suited for sensor networks with multiple sinks.

DTC

The Distributed TCP Caching (DTC) is a mechanism based on TCP adaptation for the wireless sensor networks. Although classical TCP protocol is not suitable to be applied for sensor nodes because of end to end acknowledgement based transmission scheme, but by adding the feature of distributed caching of TCP segments in the sensor nodes the communication costs for achieving reliability can be reduced. Thus, whenever an intermediate node receives an ACK message with a certain sequence number, it performs a local retransmission if that segment is already cached in its memory and does not forward the ACK message further towards the sender. DTC resides in the intermediate nodes and thus does not impose any modifications in the end nodes. As mentioned earlier, that wireless sensor devices have limited resources in terms of memory, so the segment selection algorithm to be cached is derived from the highest sequence number observed. This helps in caching segments that are most probable to be dropped further along the route to the receiver. Packet loss detection relies on the techniques of detecting timeouts and duplicate acknowledgements and in order to avoid retransmissions from the original sender the response of DTC for packet loss has to be faster than the regular TCP. Furthermore, the nodes estimate the round-trip times to differentiate between an acknowledgement for a lost packet and one for the new segment in order to avoid extra re transmissions.

Cross-Layer Optimizations

As pointed earlier, WSNs suffer from the error prone nature of the wireless media, which cannot be only dealt with by the transport layer. Thus, different layers should coordinate among each other to improve the quality of the network. For instance, the information of any particular route failure can be passed to the transport layer in order to make sure that it does not drops the transmission rate. It has also been proposed to use techniques at link layer such as using error recovery methods like forward error correction to reduce the packet loss. Another method used to improve the delivery probability of a data packet is based on MAC layer retransmissions for single hop delivery of single packet. MAC layer techniques have found their applicability because it’s easier to introduce timers to account for the packet propagation time, and bit errors can be easy to recover at MAC layer. The transmitter makes trials based on a number and drops the packet after expiry of the number.

Unresolved Issues

The major issues to be tackled by the transport protocols for WSNs comprises of providing reliability and congestion control mechanisms while being energy efficient. We have seen examples of transport protocols assuring reliability in one direction such as PSFQ in the upstream and ESRT is down-stream direction, RMST in the down-stream direction, but there is still no attempt made to provide bi-directional reliable transport possible in one protocol. The other problem that is faced by the hop-by-hop packet recovery techniques is that they require extra memory resources for buffering. Furthermore, an unexplored area related to the reliability criteria is the use of end-to-end semantics for supporting application level reliability in conjunction with the techniques for hop-by-hop packet guarantees. Another important point to be noted is that except for ESRT, which provides a passive congestion control along with the reliability support, none of the presented protocols deals both the facilities simultaneously. In addition to above, there is a need for WSNs to support Transport mechanisms compatible with the IP based networks. The implementation of a stripped down version of TCP/IP stack for WSNs with extensions like DTC to support reliability is a first step in that direction.

SUMMARY

We have pointed out trends in the evolution of protocol stack to be applicable to the WSNs domain, which has seen rowing use in the field of home, medical and military surveillance because of the small size, low cost and low power characteristics of the sensor nodes. The increased applicability of the numerous sensor nodes resulted in the requiring additional facilities from the protocol stack. We have focused on the most important features of the transport layer such as providing effective congestion control mechanisms without compromising the throughput of the network, to assure reliable transfer of data, not only at the packet level but also at the application level, which is very important because of the nature of the wireless media. Both the factors of congestion control and reliability helps in reduce packet loss, which results in an energy efficient operation of the network, which is a key factor is increasing the lifetime of the sensor network. The factor to be taken into account by the transport protocols is the limited resources of the node devices. We have presented some transport protocol examples that are specifically tailored for WSNs, along with one example adaptation of TCP to ease the connectivity of WSNs with the larger internet. Discussed some of the cross-layer optimizations that can be applied to improve the working of WSNs. It has been observed from the study that no single protocol is broad enough to guarantee the requirements of an end to end reliable solution and congestion control while being energy efficient and conserve resources at the same time.

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