Improving Energy Efficiency through Transport Control Protocol in Wireless Sensor Network

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Abstract- Today, the study of energy efficient networking solutions in sensor networks has been focusing on networks with always-on connectivity between communication end-points and short link delays. The reliability of data transfer is vital for commercial and enterprise applications of Wireless Sensor Networks (WSN). Likewise, mission-oriented and critical military applications of these networks demand dependable and timely data transport. Designing a reliable transport protocol is a new challenging area in Wireless Sensor Networks (WSNs). Generally transport layer is responsible for congestion control and reliable packet delivery. Congestion is an essential problem in WSNs. Although TCP is a time-tested transport layer protocol of Internet that ensures reliability, flow control and congestion control, being a heavy protocol, it is considered unsuitable for resource constrained sensor networks. As a result new transport layer protocols have been developed for these networks. . In this paper we present a reliable transport protocol for wireless sensor networks which not only controls the congestion in the network, but also provides reliability in packet delivery.

Index Terms*-* Energy Efficiency, Congestion Control, Transport Protocol, Wireless Sensor Network

I. Introduction

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices that use sensors to monitor physical or environmental conditions. These autonomous devices, or nodes, combine with routers and a gateway to create a typical WSN system. The distributed measurement nodes communicate wirelessly to a central gateway, which provides a connection to the wired world where you can collect, process, analyze, and present your measurement data. WSNs have many applications in different areas of technology. It is used in many different applications including commercial and industrial applications, environment applications, healthcare applications, home automation, traffic control and monitoring, object tracking and fire detection. Each node in a WSN is typically equipped with one or more sensors, a wireless communications device, a processor, and an energy source, usually a battery.

With a reliable transport mechanism we can achieve 100% packet delivery ratio in WSNs. In traditional communication networks, the transport layer is responsible for bridging the application and network layers using multiplexing and demultiplexing. It is also charged with providing end to end reliable data delivery and with performing congestion control by regulating the amount of traffic injected into the network. Generally, transport control protocols, especially for connection-oriented transport protocols, may include two main functions: *congestion control* and *loss recovery*. As for congestion control, it is firstly required how to detect whether or not congestion happens, and when and where it happens. Congestion can be detected through monitoring node buffer occupancy and link (or wireless channel) load.

In addition to the challenges for reliable data transport in WSN, there exist additional challenges due to the unique requirements of the multimedia transport such as bounded delay and delay variation, minimum bandwidth demand, smooth traffic variation for multimedia streaming, and error control according to the specific requirements of the multimedia application. Therefore, it is important to develop a reliable transport protocol for WSNs to ensure that the often differing QoS requirements of various applications can be met.

II. FEATURES OF TRANSPORT CONTROL PROTOCOLS WHILE DESIGNING WSNS

Generally, the transport control protocol for WSNs should consider the following factors.

(i) It should provide congestion control mechanism and guarantee reliability, especially the latter. The most data streams are flowed from sensor nodes to sink in WSNs, so congestion might occur around sink. Also there are some high-bandwidth data streams produced by multi-media sensors. Therefore it is necessary to design effective congestion detection, congestion avoidance, and congestion control mechanisms for WSNs.

(ii) Transport control protocols for wireless sensor networks should simplify initial connecting process or use connectionless protocol so as to speedup start and guarantee throughput and lower transmission delay. Most of applications in WSNs are reactive which passively monitor and wait for event occurring before reporting to sink. These applications may have only several packets for each reporting, and the simple and short initial setup process is more effective and efficient.

(iii) The transport control protocols for WSNs should avoid as few packets dropping as possible since packet dropping means energy wastage. In order to avoid packet dropping, the transport protocol can use active congestion control at the cost of a bit lower link utility. The active congestion control (ACC) can trigger congestion avoidance before congestion occurs. An example of ACC is to make sender (or intermediate nodes) reduce sending (or forwarding) rate when the buffer size of their downstream neighbors overruns a threshold.

(iv) The transport control protocols should guarantee fairness for different sensor nodes in order that each sensor nodes can achieve fair throughput. Otherwise the biased sensor nodes cannot report the events in their area and system may misunderstand there is no any event in the area.

(v) It would be better if the transport control protocol can enable cross-layer optimization. For example, if routing algorithm can tell route failure to transport protocol, the transport protocol will know the packet loss is not from congestion but from route failure and the sender will frozen its status and keep its current sending rate to guarantee high throughput and low delay.

III. PERFORMANCE OF TCP IN WIRELESS SENSOR NETWORKS

TCP is time-tested transport layer protocol in Internet that implements end-to-end reliability, flow control and congestion control. This protocol was developed for wired links but lately Internet is being extended to include wireless links as well. For such wired-cum-wireless networks, TCP has been found to lack suitability as well as efficiency. There are some of the main factors that results in inferior TCP performance in these networks are:

(i) Low Bandwidth

Wireless Sensor Networks have limited bandwidths as compared to wired networks. In Wireless Local Area Networks (WLANs) bit rates are around 10-100 Mbps, Wireless Personal Area Networks (WPANs) bit rates are around 2-10 Mbps. In heterogeneous networks comprising wired cum wireless links, mismatched bandwidths of the two networks results in bottleneck that affects TCP. Thus limited bandwidth in wireless networks is responsible for degradation in TCP performance.

(ii) High Latency

As compared to wired links, latency of data transfer is more in wireless links. TCP congestion window at the sender end evolves in proportion to acknowledgements received from receiver. As a result of long delays in wireless links, congestion window evolves slowly which affects throughput.

(iii) Arbitrary Losses

The transmission losses on wireless links are considerably more as compared to wired links. The losses cause packets to drop thus resulting in sender not receiving acknowledgments inside the retransmit timeout. The sender retransmits packet, exponentially reduces timer and cuts the congestion window to unit. Thus when it occurs repeatedly, it results in reduced throughput. In wired-cum-wireless, wireless link is generally the last link and losses on this last link result in end-to-end retransmission by TCP and thus reduces throughput.

(iv) Wireless Network Mobility

When wireless networks support mobility like cellular networks where end users are mobile, handoff takes place when user moves from one cell to another such that new channel is allocated through other cell's base station and all control information has to be shifted. There could be very short loss of connectivity resulting in losses which can cause reduction in TCP congestion window this causing reduced throughput. Similarly in ad hoc networks, topology changes can cause losses resulting in affecting throughput.

(v) Underutilization of Capacity

Services like web browsing and e-mail involve small amount of data transfer between the client and the server. The TCP sender increases its congestion window progressively as it receives acknowledgments from the receiver (Slow Start). There is a high probability that the transfer completes even before the sender's window reaches the maximum possible size. This results in under utilization of the network capacity.

(vi) Power Utilization

Power utilization is an important issue in case of battery operated end devices like laptops, PDAs, wireless phones and wireless sensor nodes. As stated earlier, TCP was basically developed for wired Internet. In order to make it suitable for wireless networks in terms of performance parameters like throughput and latency, it has to be adjusted. In this regard new transport layer protocols are suggested for different types of wireless networks according to their particular features. Protocols developed for cellular networks are specifically developed for conditions and issues in these networks, protocols developed for sensor networks are developed according to their features and so on.

IV. CONCLUSION

The transport protocol enables end-to-end reliable message transmission. Its main functions are: orderly transmission, flow and congestion control, loss recovery, and possibly QoS guarantees such as timing and fairness. Due to limited wireless bandwidth in WSNs, congestion may occur.

In this paper we proposed a reliable transport protocol for WSNs. The characteristics of WSN which are low cost, low power resource constrained end devices called sensor nodes very low link bandwidths and ad-hoc network topology make application of TCP even more challenging in these networks. This approach is classified as making TCP suitable for WSN by various methods like parallel TCP, link layer retransmissions, splitting TCP across proxy, distributed TCP caching and retransmissions as well as designing new transport layer protocols for WSNs according to the features and restrictions of these networks

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey," Computer Networks, vol. 38, 2002, pp. 393-422.

[2] J. B. Postel, "Transmission control protocol," *RFC 793*, September 1981.

[3] J. B. Postel, "User datagram protocol," *RFC 768*, August 1980.

[4] M. Mathis, "TCP selective acknowledge options," *RFC 2018*, October 1996.

[5] C.-Y. Wan, S. B. Eisenman, and A. T. Campbell, "CODA: Congestion detection and avoidance in sensor networks," *in Proceedings of ACM Sensys'03*, November 5-7, 2003, Los Angeles, USA.

ISSN 2250-3153

[6] Y. Sankarasubramaniam, O. B. Akan, and I. F. Akyidiz, “ESRT: Event-to-sink reliable transport in wireless sensor networks,” *in Proceedings of ACM Mobihoc'03*, June 1-3, 2003, Annapolis, USA.

[7] F. Stann and J. Heidemann, “RMST: Reliable data transport in senor networks,” *in Proceedings of IEEE SNPA'03*, May 11, 2003, Anchorage, USA.

[8] C.-Y. Wan, A. T. Campbell, “PSFQ: A reliable transport protocol for wireless sensor networks,” *in Proceedings of ACM WSNA'02*, September 28, 2002, Atlanta, USA.

[9] S.-J. Park, R. Vedantham, R. Sivakumar, and I. F. Akyildiz, “A scalable approach for reliable downstream data delivery in wireless sensor networks,” *in Proceedings of ACM MobiHoc'04*, May 24-26, 2004, Roppongi, Japan.

[10] K. Sundaresan, V. Anantharaman, H.-Y. Hseeh, and R. Sivakumar, “ATP: A reliable transport protocol for ad-hoc networks,” *in Proceedings of ACM Mobihoc'03*, June 1-3, 2003, Annapolis, Maryland, USA.

[11] C. Wang, K. Sohraby, and B. Li, “SenTCP: A hop-by-hop congestion control protocol for wireless sensor networks,” *in Proceedings of IEEE INFOCOM 2005* (Poster Paper), Miami, Florida, USA, Mar. 2005.

[12] Ian F. Akyildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci,” A survey on wireless sensor networks”, IEEE Communication Magazin(2007) 108-114.

[13] Chonggang Wang, Kazem Sohraby, “A Survey of Transport Protocols for Wireless Sensor Networks”, IEEE Network • Magazine, May/June 2006, 34-40.

[14] Y. G. Iyer, S. Gandham, and S. Venkatesan, “STCP: A Generic Transport Layer Protocol for Wireless Sensor Networks,” Proc. IEEE ICCCN 2005, San Diego, CA, Oct. 17–19, 2005.

[15] B. Hull, K. Jamieson, and H. Balakrishnan, “Mitigating Congestion in Wireless Sensor Networks,” Proc. ACM Sensys '04, Baltimore, MD, Nov. 3–5, 2004.

[16] C.-Y. Wan, S. B. Eisenman, and A. T. Campbell, “CODA: Congestion Detection and Avoidance in Sensor Networks,” Proc. ACM Sensys '03, Los Angeles, CA, Nov. 5–7, 2003.

[17] C. Wang, Member, K. Sohraby, M. Daneshmand, Y. Hu,” Upstream Congestion Control in Wireless Sensor Networks Through Cross-Layer Optimization”, IEEE Journal on Selected Areas in Communications, vol. 25, no. 4, May 2007, 786-795.

[18] Natani A., Jakilinki J., Mohsin M., and Sharma V. TCP for Wireless Networks. Computer Journal of ACM SIGCOMM. 2001. 26(5). 163-243.

[19] Jones, J., Atiquzzaman, M. Transport Protocols for Wireless Sensor Networks: State-of-the-Art and Future Directions. International Journal of Distributed Sensor Networks. 2007. 3: 119-133.

[20] Balakrishnan, H., Padmanabhan, V., Seshan, S., Katz, R. H. A Comparison of Mechanisms for Improving TCP Performance over Wireless Links. IEEE/ACM Transactions on Networking. 1997. 5(6). 756-769.

[21] Bakre, V., Badrinath, B. R. I-TCP: Indirect TCP for Mobile Hosts. Proc. IEEE ICDCS. 1995. 136-143.

[22] Bakre, V., Badrinath, B. R. Implementation and Performance Evaluation of Indirect TCP. IEEE Transactions on Computers. 1997. 46(3). 260-278.

[23] Yusung, K., Kilnam, C., and Lisong, X.. Adjusting the Aggregate Throughput of Parallel TCP flows without Central Coordination, IEICE Transactions on Communications. 2010. E91.B (5). 1615-1618.

[24] Swastik, K., Srikanth, V. K., Michalis, F., Satish, K. T. Split TCP for Mobile Ad Hoc Networks. Symposium on Ad-Hoc Wireless Networks (SAWN in GLOBECOM). 2002.

[25] Dunkels, A., Voigt, T., Alonso, J. Making TCP/IP Viable for Wireless Sensor Networks. Work in Progress Session at 1st European Workshop on Wireless Sensor Networks (EWSN 2004).

[26] Zafar, S., Akbar, A. H., Jabbar, S., Sheikh, N. M. SET: session layer-assisted efficient TCP management architecture for 6LoWPAN with multiple gateways. EURASIP Journal on Wireless Communications and Networking. 2010, Article ID 936457. 20 pages.

[27] Kuschnig, R., Kofler, I., Hellwagner, H. Improving Internet Video Streaming Performance by Parallel TCP-based Request-Response Streams. Proc. the 7th Annual IEEE Consumer Communications and Networking Conference (IEEE CCNC 2010).

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