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Congestion Control Techniques in WSN and Their Performance Comparisons

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Abstract

Wireless sensor network consist of large number of nodes, when any event occurs these sensor node becomes active in transmitting, it increases data traffic. Due to large volume of data transmission and restricted bandwidth congestion occurs. This leads packets to get delay, they even may get drop, resulting in wastage of energy of the node. A congestion control scheme is necessary to regulate traffic level at an acceptable value. This paper review Data Link Layer Techniques, Network Layer Techniques, Transport Layer Techniques, Cross Layer Based Techniques and Their performance metrics, advantages and disadvantages.

Keywords: *Congestion Control Techniques, Performance Comparisons of congestion control techniques, Wireless Sensor Network etc.*

1. Introduction

1.1 Wireless Sensor Network (WSN)

Wireless sensor network (WSN) is a large network consists of a group of spatially distributed autonomous sensors interconnected by means of wireless communication channels to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The key elements of WSN are the sensor nodes and the base stations.

WSN is a large network of resource-constrained sensor nodes with multiple preset functions, such as sensing and processing with number of low-cost, resource limited sensor nodes to sense important data related to environment and to transmit it to sink node that provides gateway functionality to another network, or an access point for human interface [1].

WSNs are made up of energy constrained nodes embedding limited transmission, processing and sensing capabilities. Therefore, network lifecycle becomes short and hence energy-efficient technique implementation becomes an important requirement for wireless sensor network [2].

1.2 Congestion in WSN

With respect to the characteristics of WMSNs, multimedia traffic produces bursty high-load traffic in the network. Therefore, probability of congestion in WMSNs is higher than traditional WSNs due to the large amount of video traffic. Addition to the waste of communication and energy that it causes congestion negatively affects reliability due to the packet losses and degrades the overall performance of the network and QoS of the application [3]. Congestion can either be transient or persistent. Transient congestion is caused by link variations, and persistent congestion is caused by source data sending rate. [4]

1.3 Reasons for Congestion

Congestion occurs due to several reasons that are briefly discussed below. Nodes that are nearer to the base stations need to transmit more data packets, hence their traffic burden will be more. This situation may lead to serious packet collisions, network congestion and packet loss. In the some critical cases, collapse congestion may happen, which is called the funnelling effect [5]. Congestion can also occur due to the packet loss, which takes place during collision. For the unpredictable bursts of messages, simple periodic events can be generated in this type of network. Congestion becomes more accountable due to interaction of concurrent data transmissions over varying radio links or due to increase in the reporting rate to the base station.

Efficient mechanisms that guarantee the balanced transmission rates for different types of data are required to provide congestion control [6]. From a multi-hop network, the sensor forwards the data generated by the nodes at a constant rate to a single sink. Due to the increase in the offered load, the loss rates can increase rapidly. Lack of buffer space at a sensor node causes error in the wireless channel. Due to this, the losses are separated. The buffer drops are reduced by the channel losses. Finally, the offered load increases rapidly.

There is an opportunity for scarcity of resources due to high reporting rates by numerous events. This occurs though the event is few bytes long and leads to congestion and packet or event drops [7]. As the data traffic becomes heavier in sensor node, packets might be put into the node's buffer and have to wait for access to the medium that is shared by a number of communication entities. In such cases, congestion can happen in the network. If network congestion becomes more severe, some packets will be dropped due to limited buffer size. This will potentially result in loss of packets, decrease in throughput and waste of energy [8].

1.4 Types of Congestion

Two types of congestion could occur in WSNs. They are node level congestion and link level congestion [9].

Node Level Congestion

The first type is node-level congestion that is common in conventional networks. It is caused by buffer overflow in the node and can result in packet loss, and increased queuing delay. Packet loss in turn can lead to retransmission and therefore consumes additional energy. For WSNs where wireless channels are shared by several nodes using Carrier Sense Multiple Access (CSMA) protocols, collisions could occur when multiple active sensor nodes try to seize the channel at the same time. This can be referred to as link level congestion.

Link Level Congestion

Link-level congestion increases packet service time, and decreases both link utilization and overall throughput, and wastes energy at the sensor nodes. Both node-level and link-level congestions have direct impact on energy efficiency and QoS.

2. Techniques for Congestion Control

2.1 Congestion Control Mechanisms in WSN

Congestion is one of the major issues in WSN (which is discussed in chapter 1). Hence, an accurate and efficient congestion detection technique is required as a first step to mitigate congestion. New research directions and recent solutions solving the congestion problem in WSNs were studied. The classical TCP-based congestion detection and avoidance technique is not suitable for the WSN, as it consumes a lot of resources and is very aggressive in case of constrained devices and unstable environment. Channel collision can be overcome using mechanisms employed by the data link layer: Carrier Sense Multiple Access (CSMA), Frequency Division Multiple Access (FDMA), and Time Division Multiple Access (TDMA).

Nowadays, there are several congestion detection techniques that have low energy consumption and computation complexity. Some of the congestion detection schemes are CODA, open-loop hop-by-hop backpressure, closed-loop multi-source regulation, queue occupancy, receiver-based congestion detection, event to sink reliable transport, and intelligence congestion detection technique. A large number of techniques were invented especially for the wireless sensor networks. These methods are deployed by different layers of the OSI stack.

Based on the layer in which the mechanism operates, the congestion control mechanisms are classified. These classifications are briefly analyzed and discussed below:

- Data Link Layer Techniques
- Network Layer Techniques
- Transport Layer Techniques
- Cross Layer Based Techniques

2.1.1 Data Link Layer Techniques

The congestion control mechanisms that operate in the data link layer are as follows:

Self-organizing Medium Access Control (SMACS)

Self-organizing Medium Access Control (SMACS) [10] is one of the SMAC TDMA-based techniques in which TDMA techniques should be included to the data link layer congestion control mechanism as nodes have to switch-off for some time, to avoid idle listening and through this avoid energy starvation of the device. This is an important case because listening and transmitting are both very energy-expensive operations in a low-power radio. However, in other cases, it can consume more energy. Hence, this technique is only suitable for low-power radio application.

On-demand TDMA with Priority Bases Communication Scheduling

On-demand TDMA extension of IEEE802.15.4 MAC layer with priority-based communication scheduling mechanism in nearby routing devices. This approach proposes an idea of extending existing active period of work, by using additional communication period (ACP), in the inactive period of the standard IEEE802.15.4 MAC superframe. This can be mainly used to solve the funneling effect. Moreover, it can guarantee the communication performance and satisfy the requirements of the industrial applications.

Congestion Control and Fairness

Congestion Control and Fairness (CCF) adjusts the traffic rate based on packer service time along with fair packet scheduling algorithms. This technique is designed to work with any MAC protocol in the data link layer. However, it exists in the transport layer. CCF uses packet service to deduce the availability of the service rate. It controls congestion in a hop-by-hop manner and each node uses exact rate adjustment based on its available service rate and child node number. It can eliminate congestion, provide high throughput and ensures the fair delivery of packets to the sink node. It has two major disadvantages: 1) The rate adjustment based on packet service time causes low utilization as it has significant packet error rate, and 2) It cannot allocate the remaining effective capacity as it uses work-conservation scheduling algorithm [11].

2.1.2 Network Layer Techniques

The congestion control mechanisms that work on the network layer are as follows:

Beacon Order Based RED (BOB-RED)

Active queue management techniques such as BOB-RED are effective in networks with dozens of sensors connected to a few intermediate devices such as routers. By using such virtual queues, it becomes easier to calculate priority of each particular piece of data and mark or drop packet when buffer overflows. Through marking packets, it can inform the sensors about congestion that router or some other intermediate device experiences. That can influence on the retransmission counter and retransmission timer values and slow down amount of upcoming packets to the congested intermediate node and filter emergency information. This approach consists of a virtual threshold function, a dynamic adjusted per-flow drop probability, a dynamic modification of beacon order (BO) and super-frame order (SO) strategy that decrease end-to-end delay, energy consumption, and increase throughput when there are different traffic type flows through the intermediate node. The performance metrics used are average end-to-end delay, packet delivery ratio, and energy consumption [12].

Congestion Avoidance, Detection and Alleviation

In Congestion Avoidance, Detection and Alleviation (CADA), all the sensor nodes in the WSN are not responsible to send information to the sink node when some event is detected. Only some of the selected number of sensor nodes can send information about the event to the sink. And other nodes are concealed from sending the same and inaccurate data. Hence, the network traffic from the area where event is detected can be minimized. It helps to reduce the chances of congestion in the network. CADA uses distributed node selection algorithm for the selection of sunset of nodes from the given set of sensor nodes. It is based on some criteria such as the nodes which are having longer distance between them or the nodes which are near to the event spot. The nodes which are away from the event area are not selected because there are chances of addition of noise to the data which can lead to the inaccurate data. Sometimes, it results in the reduced network throughput [13].

2.1.3 Transport Layer Techniques

The congestion control mechanisms that operate on the data link layer are as follows:

Pump Slowly Fetch Quickly (PSFQ)

In PSFQ, a simple, robust and scalable transport is considered and the needs of different data applications are satisfied by PSFQ. PSFQ is a transport protocol that is suitable for constrained devices. It includes three main functions: message relaying, relay-initiated error recovery and selective reporting. However, it is not compatible with IP and needs precise time synchronization between sensor nodes. It is used to distribute data from a source node by pacing data at a relatively slow speed, but allowing nodes that experience data loss to fetch any missing segments from immediate neighbors very aggressively. In this case, there is a possibility of getting packet to be lost [14].

Light UDP

Light UDP transport layer protocol, the main feature of which is that damaged packets are not dropped but delivered for the application layer for further analysis. This approach can be effectively deployed by applications for which delivery of all data has more priority than its integrity (multimedia protocols, stream video, voice IP). The main issue of this approach is that CheckSum field does not cover the whole packet but the current part of the header, which is important for the future transmissions [15].

Reliable UDP

Reliable UDP is also a transport layer protocol, the main feature of which is that it is working on UDP or IP stack and provides reliability in order delivery. This protocol does not support classical congestion control technique or slow start mechanism.

Event to Sink Reliable Transport

Event to Sink Reliable Transport is a unique transport solution that is designed to achieve reliable event detection with minimum energy expenditure and congestion resolution. ESRT operates based on two parameters such as event reliability and reporting frequency. The end-to-end data delivery services are

Table 1 Performance comparison

Technique	Type	Metrics used	Advantages	Disadvantages
Self-organizing Medium Access Control (SMACS)	Data link layer	Energy consumption, throughput	Suitable for low-power radio application	Consume more energy.
On-demand TDMA with Priority Bases Communication Scheduling	Data link layer	-	Solve the funneling effect	Reliability is not discussed
Congestion Control and Fairness (CCF)	Data link layer	Throughput, delivery ratio	High throughput and ensures the fair delivery of packets	It fails to allocate the remaining effective capacity
Beacon Order Based RED (BOB-RED)	Network layer	Average end-to-end delay, packet delivery ratio, and energy consumption	Reduced end-to-end delay, energy consumption with increased throughput	Sometimes, packet drop occurs
Congestion Avoidance, Detection and Alleviation (CADA)	Network layer	Throughput, delay, packet drop, delivery ratio	Reduces the network traffic and the chance of occurrence of congestion	Lead to inaccurate data and reduced throughtput
Pump Slowly Fetch Quickly (PSFQ)	Transport layer	Throughput, delay, packet drop, delivery ratio	Suitable for constrained devices	Not compatible with IP and needs precise time synchronization between sensor nodes
Light UDP	Transport layer	Throughput, delay, packet drop	Suitable for applications in which delivery of all data is more important than its integrity	CheckSum field does not cover the whole packet.
Reliable UDP	Transport layer	Throughput, delay, reliability, delivery ratio	Provides more reliability	It does not support classical congestion control technique or slow start mechanism.
Event to Sink Reliable Transport	Transport layer	Throughput, delay, packet drop, energy consumption	Achieve reliable event detection with minimum energy expenditure and congestion resolution	ESRT affect the on-going data traffic due to the high power single hop channel
SenTCP	Transport layer	Average local packet service and average local packet inter-arrival time	Achieves higher throughput and good energy efficiency	There is no reliability
Congestion Detection and Avoidance (CODA)	Cross layer based	end-to-end delay, response time, fairness	Suitable for event driven networks and achieve better fairness along with congestion control	Under heavy closed loop congestion, reliability is less with more delay and response time
XLP	Cross layer based	Failure rate, throughput, good put, delay, energy consumption and average latency	Achieve better average throughput and good put	It is not reliable and flexible
Priority based congestion Control protocol (PCCP)	Cross layer based	Congestion degree, inter-arrival time, packet service time	Improve energy-efficient and support traditional QoS	Often delay occur

regulated by adjusting the sensor report frequency. The congestion detection in ESRT is performed by local buffer level of the sensors nodes. ESRT achieves better reliability. The major disadvantage of ESRT is that all sensor nodes are controlled at once as a result the regions of higher node density and lower node density are given the same energy levels. Multiple event source congestion is ignored as ESRT lays more emphasis on reliability and energy conservation. ESRT assumes and uses a wireless channel that operates on one hop using high power which might affect the on-going data traffic [16].

SenTCP

SenTCP is a transport protocol that uses open loop hop-by-hop congestion control. It detects congestion using local congestion degree and uses hop-by-hop for control. SenTCP conjointly uses average local packet service and average local packet inter-arrival time to determine the current local congestion degree in each intermediate sensor nodes. They effectively help to differentiate the reasons for packet loss and delay in wireless communication. Each intermediate node issues a feedback signal backward and hop-by-hop control that carries buffer occupancy ratio and local congestion degree that is used to adjust the sending rate of the neighbouring nodes in the transport layer. SenTCP achieves higher throughput and good energy efficiency since it reduces packet dropping by hop-by-hop. The major disadvantage of SenTCP is that it guarantees no reliability [17].

2.1.4 Cross-Layer Based Techniques

The congestion control mechanisms based on the cross layer approach are as follows:

Congestion Detection and Avoidance (CODA)

Congestion Detection and Avoidance (CODA) technique combines three mechanisms: receiver-based congestion detection; open-loop hop-by-hop backpressure; and closed-loop multi-source regulation. As it is proved by simulation results, this mechanism can be very effectively deployed by event driven networks, which perform under the light load most of the time, but after some critical event become heavy loaded. This technique can achieve better fairness along with congestion control. The disadvantages of CODA are: unidirectional control from sensors to sink, decreased reliability, and the delay and response time increases under heavy closed loop congestion [18].

XLP

Cross-Layer Based Protocol (XLP) can achieve media access control (MAC) routing as well as congestion control in the cross-layer mechanism. The performance of XLP protocol along with angle based routing is better in case of failure rate. The performance of XLP without angle based routing is poor in case of failure rate if varying duty cycles. Results show that the average throughput and good put is drastically better for XLP protocol when compared to other protocols varying duty cycles. Moreover, delay, energy consumption and average latency also drastically less for XLP Protocol varying duty cycles [18].

PCCP

Priority based congestion Control protocol (PCCP) is an upstream congestion control protocol in WSN which measures congestion degree as the ratio of packet inter-arrival time to the packet service time. PCCP is intended to improve energy-efficient and support traditional QoS in terms of latency, throughput and packet loss ratio. PCCP can be of three components: Intelligent Congestion Detection (ICD), Implicit Congestion Notification (ICN) and Priority-based rate adjustment. PCCP tries to avoid packet loss with weighted fairness and multipath routing with lower control overhead. It utilizes a cross-layer optimization and imposes a hop-by-hop approach to control congestion. PCCP achieves an efficient congestion control and flexible weighted fairness for both single-path and multi-path routing [19].

3. Performance Comparison

It is shown in table 1.

Conclusion

The above techniques give show the best attempts to control congestion and improve the efficiency of the system to the best possible level. Several data link layer, network layer, transport layer and cross layer based congestion control techniques are studied. These analysis leads to the following conclusion: Cross layer design can make the network more specific and reliable. WSN should design protocols for cross-layer design methodology. A unified protocol that can handle both reliability and congestion control is needed. An integrated protocol that levers both the direction of flow, sensor-to-sink (upstream) and sink-to-sensors (downstream) would be preferred. Energy efficiency over transport protocols in future needs emphasized.

References

[1] T. Kavitha and D. Sridharan, “Security Vulnerabilities In Wireless Sensor Networks: A Survey”, Journal of Information Assurance and Security, Vol. 5, pp. 031-044, 2010.

[2] Nagamalar. T and T.R. Rangaswamy, “Sleeping Cluster based Medium Access Control Layer Routing Protocol for Wireless Sensor Networks”, Journal of Computer Science, Vol. 8, No. 8, pp. 1294-1303, 2012.

[3] Cagatay Sonmez, OzlemDurmaz Incel, Sinan Isik, Mehmet Yunus Donmez and Cem Ersoy, “Fuzzy-based congestion control for wireless multimedia sensor networks”, EURASIP Journal on Wireless Communications and Networking 2014.1 (2014): 1-17.

[4] Li Qiang Tao and Feng Qi Yu, “ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks”, Consumer Electronics, IEEE Transactions on 56.3 (2010): 1387-1394.

[5] Yong-min Liu, Xiao-hong Nian and Wu-yi Lu, “Some Control Strategy relate to Congestion Control for Wireless Sensor Networks”, International Conference on Computer Engineering and Applications, vol. 2, 2011.

[6] C. Wang, B. Li, K. Sohraby, M. Daneshmand, and Y. Hu “Upstream Congestion Control in Wireless Sensor Networks Through Cross-Layer Optimization” IEEE 2007.

[7] Moufida Maimour, C. Pham, and Julien Amelot “Load Repartition for Congestion Control in Multimedia Wireless Sensor Networks with Multipath Routing”IEEE 2008.

[8] Guowei Wu, Feng Xia, Lin Yao, Yan Zhang, and Yanwei Zhu, “A Hop-by-hop Cross-layer Congestion Control Scheme for Wireless Sensor Networks”.

[9] Saeed Rasouli Heikalabad, Ali Ghaffari, Mir Abolgasem Hadian and Hossein Rasouli, “DPCC: Dynamic Predictive Congestion Control in Wireless Sensor Networks”, IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 1, January 2011.

[10] Katayoun Sohrabi, Jay Gao, Vishal Ailawadhi and Gregory J Pottie, “Protocols for Self-Organization of a Wireless Sensor Network”, 37th Allerton Conference on Communication, Computing and Control, September 1999.

[11] T. Zhong, M. Zhan and W. Hong, “Congestion Control for Industrial Wireless Communication Gateway”, In Proc. of International Conference of Intelligent Computation Technology and Automation 2010, pp 1019-1022, 2010.

[12] M.-Sh. Lin, J.-Sh. Leu, W.-Ch. Yu, M.-Ch. Yu and J.-L. C Wu, “BOB-RED queue management for IEEE 802.15.4 wireless sensor networks”, EURASIP Journal on Wireless Communications and Networking 2011.

[13] Wei-wei Fang, Ji-ming Chen, Lei Shu, Tian-shu Chu, and De-pei Qian, “Congestion avoidance, detection and alleviation in wireless sensor networks”, Journal of Zhejiang

university-SCIENCE C (Computer & Electronics), 2010-11 (1):63-73.

[14] C.-Y. Wan, A. T. Campbell, and L. Krishnamurthy, “PSFQ: a Reliable Transport Protocol for Wireless Sensor Networks”. *In Proc. of First ACM International Workshop on Wireless Sensor Networks and Applications (WSNA 2002)*, pp. 1-11, USA, Atlanta, September 2002.

[15] L-A. Larzon, M. Degermark, S. Pink, G. Fairhurst, “The Lightweight User Datagram Protocol (UDP-Lite)”, July 2004, RFC 3828.

[16] Sankarasubramaniam, Y., Ozgur, A., Akyildiz, I, ‘ESRT Event-to-Sink Reliable Transport in Wireless Sensor Networks”, In the Proceedings of ACM Mobihoc, pp. 177-189, ACM Press, New York, 2003.

[17] 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.

[18] Mehmet C. Vuran, Ian F. Akyildiz, XLP: A Cross-Layer Protocol for Efficient Communication in Wireless Sensor Networks, IEEE Transactions on Mobile Computing, vol. 9, issue 11, pp. 1578- 1591, 2010.

[19] C. Wang, B. Li, K. Sohraby, M. Daneshmand, Upstream Congestion Control in Wireless Sensor Networks Through Cross-Layer Optimization”, IEEE Journal on Selected Areas in Communications, VOL. 25, NO. 4, pp.786-795, MAY 2007.