RESEARCH ARTICLE OPEN ACCESS

Congestion Control in Wireless Sensor Networks: A survey

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ABSTRACT
Congestion is a major problem in almost all kinds of wireless networks such as mobile ad-hoc networks; wireless sensor networks (WSNs). There are variety of applications of WSN such as defense, temperature monitoring, health monitoring. Congestion occurs in the sensor network because of limited resources such as low processing power of the sensor node. As all the sensor nodes are battery powered. Hence, congestion in the sensor network results in waste of energy of sensor nodes. All the layers of protocol suite of the network can be involved in the congestion control process. This paper gives a brief idea about various congestion control methods. In some of the schemes, cross-layer design is applied for better results.
Keywords - Wireless Sensor Networks, Congestion Control, Congestion Detection, Cross-layer Design, QoS.

I. INTRODUCTION

Wireless Sensor Network consists of many sensor nodes which are spread in a large area according to the type of applications. WSN can be used in variety of applications such as health monitoring, habitat monitoring, and climate condition like temperature, pressure. All the sender sensor nodes are battery powered and with less processing power. Hence, there is need to use these limited resources efficiently in the network.

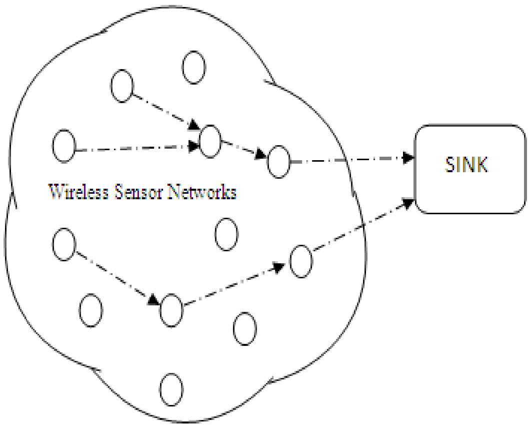

Figure 1 Structure of wireless sensor networks

Figure 1 shows the structure of wireless sensor networks which includes many sensor nodes and one sink node. Source nodes send the packets to sink node hop-by-hop or multi-hop manner. Wireless Sensor network has a two kind of Sink. Static as well as Mobile Sink can be used in wireless sensor networks to collect the information or data packets.

When an event is occurred then large amount of data traffic is sent from the respective sensor nodes to the sink node. Sometimes it results in the congestion in the network. Because of congestion, the data packets which are carrying important data may be lost in the network. Also, there is waste of energy of a node. So, congestion problem in WSN must be solved efficiently to avoid wastage of energy as well as to increase the lifetime of a network. In turn it will increase the network throughput.

Congestion in WSN can be avoided. But if it occurs in the network then it can be mitigated or it can be controlled. Many protocols are invented to solve the problem of congestion in the WSN. Still it is an open challenge to find the most efficient way to solve it.

There are two types congestion: Node-level congestion and Link-level congestion. Node-level congestion occurs when the buffer at the sensor node is overflowed. After overflow, all the incoming packets are simply dropped. Also it leads to the increased queuing delays. In case of link-level congestion, all the nodes are trying to send traffic on the link at the same time. It results in packet collisions. Also, the link utilization decrease because of link-level congestion in the network.

For congestion control, cross layer design can be adapted. All the layers of protocol stack from physical layer to the application layer can be used to control congestion in the network. In the literature, most of the congestion control protocols are based on cross-layering of protocols such as transport layer and network layer or MAC layer and Network layer.

In this paper, some of the congestion control methods from the literature are discussed. The goal of all the congestion management schemes is to increase the QoS of the network. All schemes help to increase the parameters such as network throughout, packet delivery ratio. Also, it increases network lifetime.

The rest of this paper is organized as follows. Section II covers some of the congestion control protocols. And lastly Section III concludes the whole paper.

II. RELATED WORKS

Congestion is the major problem in wireless sensor networks. Heavy congestion is not only the reason of loss packets but also wastage of more energy. Congestion control can be used to increase the performance of the wireless sensor networks. Due to the congestion control quality of channel increases, energy consumption by the sensor nodes decreases and energy efficiency also increases. Most of the congestion control protocols are based on reliability. Some of are based on fairness. Congestion control in wireless sensor network increases the network lifetime.

In fairness aware congestion control (FACC) [13] scheme, nodes are categorized according to their position from sink. Nodes which are near to sink are called as near-sink nodes. Nodes which are far away from sink are called as near-source node. Now, near-sink node according to state of per flow allocate rate to each passing flow.

For the change of flow, there is use of lightweight probabilistic dropping algorithm. This algorithm is used as per queue occupancy and hit frequency. In this scheme, near sink nodes have to transfer more traffic as compare to near source node. Near sink node do not need to maintain per flow state and it just generate warning message after drop of a packet. And send it to near source node. According to it source node allocate approximately fair rate share to each flow. Hence, this scheme has better performance in case of controlling congestion.

Consequently, for loss FACC becomes stable after a certain time. But to adjust the flow rate is time consuming process. And near source node have to maintain per flow state which may reduce energy of near source node. So, it may result in to unfairness in terms of energy consumption. This can reduce network lifetime.

In Congestion Control and Fairness in Wireless sensor networks (CCF) [5], a distributed congestion control algorithm is proposed for tree based communications in wireless sensor network. According to this algorithm, each node monitors its aggregate output and input traffic rates and as per the difference of these two it decides to increase or decrease the bandwidth allocable to flow. This algorithm is independent of routing topology. It controls congestion and seek to assign a fair and efficient rate to each flow. It can achieve high good put.

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A cross-layer based protocol named as XLP [11] Protocol is proposed by Mehmet C. Vuran et al. XLP Protocol achieves media access control, routing as well as congestion control in the cross-layer mechanism. Performance of XLP protocol with angle based routing is better in case of failure rate.

Performance of XLP without angle based routing is poor in case of failure rate if varying duty cycles. Average throughput and good put is drastically better for XLP protocol as compared to other protocols varying duty cycles. Energy consumption and average latency also drastically less for XLP Protocol varying duty cycles

In case of Priority based congestion control protocol (PCCP) [10], congestion control scheme is implemented for the sensor network. PCCP protocol measures the congestion degree. The PCCP algorithm utilizes the cross layer optimization. In Single-path and multi-path routing, PCCP achieved efficiency of congestion control as well as fairness. In PCCP, there is achievement of energy efficiency, reduced packet loss ratio as well as latency in the networks.

Using congestion degree, it detects the node level as well as link level congestion in the network. The PCCP algorithm is designed and implemented for working with multi-path, single-path routing mechanisms. PCCP algorithm reduce packet drop ratio and packet delay. It achieves full link utilization.

Traffic management in wireless sensor networks: Decoupling congestion control and fairness [12], proposed a distributed congestion control algorithm for tree based communications in wireless sensor networks that seeks to adaptively assign a fair and efficient transmission rate to each node.

In this scheme, it monitors its aggregate traffic rate and find out difference between input and output traffic rate and according to change the bandwidth. Based on the difference between input rate and output rate, it will also find out total change needed for aggregate traffic. For controlling the fairness, they compare value of aggregate flow rate and with respect to that value, change the network throughput. This scheme gives results in terms of high goodput and assign fair rate to all flows quickly.

In Congestion Avoidance, detection and alleviation in WSNs (CADA) [3], 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 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. These are data sources. 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. In CADA, traffic is controlled. Sometimes, it results in the reduced network throughput.

A Hop-by-hop Cross-layer Congestion Control Scheme for WSN (HCCC) [4], there is cross-layering of MAC layer and transport layer. MAC layer share the channel information such as queue occupancy, congestion degree with the transport layer. Based on this information, transport layer adjusts local channel access probability. If congestion occurs in the sensor network then is informed to all the upstream nodes. At the same time the local congestion is also controlled. So that local node's queue cannot get overflowed.

For the expected network throughput, HCCC dynamically adjusts the channel access priority based on multiplicatively decrease or linearly increase method of data transmission rate adjustment. In HCCC, it used implicit feedback sending mechanism to upstream nodes. It helps to avoid waste of energy because of broadcast. All local nodes are responsible for the local congestion processing and feedback signal processing.

In HCCC congestion control algorithm is implemented on each intermediate sensor node in the network. Hence, the feedback is given to the source node. It is by hop-by-hop. To make the network congestion free, source node adjusts the data rate. HCCC gives lower packet loss ratio as compared with CODA [2] and ESRT [16]. It is an efficient congestion control scheme.

Healthcare Aware Optimized Congestion Avoidance and control protocol for wireless sensor networks (HOCA) [1] is specially designed for healthcare applications. So, it has taken care of delay and energy consumption parameters.

Hence, it increased the network lifetime. Sensor nodes are attached to the patient's body for monitoring the patient's condition or event. Sink node request information to the sensor nodes. Based on it, nodes send event report to it.

HOCA's aim is to control the congestion in the network. Data traffic has different priorities. This protocol uses cross-layering of transport and network layer of protocol stack. There are various classes of dat. The classification of data is done by the network layer classifier. Then classified data will be given to different queues.

Data is of different types such as sensitive, non-sensitive and control. Sensitive data is having high-priority. Class 1 is for sensitive data, class 2 is for low-priority or non-sensitive data and class 3 is control packets. In case of sensitive data, it requires low delays. It must be reached to the sink immediately when some event occurs in the network.

Class 2 and 3 packets are given to the class based weighted fair queue (CBWFQ) scheduler [6]. This works with priority queue (PQ). According to classes of traffic, priority is given to the class1 data traffic. HOCA uses Active Queue Management (AQM) method to deal with the congestion. If congestion occurs in the network then data rates of sources nodes are adjusted.

For fairness, HOCA gives only 20% bandwidth to transmit sensitive data. Otherwise if always sensitive data is more in the network then is should not happen that other types of data are suppressed.

Table 1. Protocols with their QoS

1	Healthcare Aware Optimized Congestion Avoidance & Control Protocol (HOCA)
	1. Reduce End-to-End Delay 2. Reduce Energy Consumption 3. Increase Network Lifetime 4. Congestion Control
2	Congestion Detection & Avoidance (CODA)
	1. Congestion Control 2. Achieve better fairness
3	Congestion Avoidance, Detection & Alleviation Algorithm
	1. Reduce Delay 2. Reduce Congestion
4	Hop-by-Hop Cross-Layer Congestion Control (HCCC) scheme
	1. Increase Network Throughput 2. Reduce Energy Consumption 3. Reduce Packet Loss Ratio
5	Congestion Control & Fairness (CCF) Algorithm
	1. Achieve Fairness 2. Congestion Control 3. Achieve High Throughput
6	Class Based Weighted Fair Queue (CBWFQ) Scheduler
	1. Reduce Latency 2. High Throughput
7	Prioritized MAC
	1. Reduce Congestion & Delay 2. Reduce Packet Loss Ratio 3. Improve Energy Efficiency
8	Heuristic cross-layer Cognitive MAC Protocol (HCC-MAC)
	1. Achieve better throughput 2. Reduce Energy Consumption 3. Increase Network Lifetime
9	Distributed Congestion Feedback Algorithm (DCCA)
	1. Reduce Congestion Near the Sink Node. 2. Increase Packet Delivery Ratio
10	Priority Based Congestion Control Protocol (PCCP)
	1. Achieved efficiency of Congestion Control 2. Achieve Fairness 3. Reduce Packet Loss Ratio 4. Reduce Delay
11	Cross-Layer Based Protocol (XLP)
	1. Control Congestion 2. Better In-case of Failure Rate 3. Less Energy Consumption & Delay 4. Increase Average Throughput
12	Distributed Congestion Control Algorithm
	1. High Throughput 2. High Goodput
13	Fairness Aware Congestion Control (FACC)
	1. Achieve Better Fairness 2. Congestion Control Near the Sink Node
14	Active Network Technology
	1. Congestion Control and Detection 2. Achieve Energy Efficiency
15	Event-to-Sink Reliable Transport Protocol (ESRT)
	1. Achieve Reliable Event Detection with Minimum Energy 2. Achieve Reliability

III. CONCLUSION

In WSN, congestion needs to be either mitigated or controlled. The survey focuses on the various types of congestion control methods which are given in the literature. Also, some of the congestion control schemes which are applied to various layers of protocol suite are given in this paper. All these congestion control techniques help to improve QoS in WSN. Also, it helps to increase the lifetime of the sensor network.

Acknowledgements

We would like to thank the anonymous referees for their helpful guidance that have improved the quality of this paper.

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