Class Based Congestion Control method for Wireless Sensor Networks

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Abstract

Wireless sensor network is an emerging technology that consists of a large number of low - cost, low - power, and multifunctional sensor nodes that are deployed in a region of interest. In wireless sensor networks (WSNs), congestion may occur when the packet arrival rate exceeds the packet service rate. This is more likely to occur at the sensor nodes closer to the sink because they usually carry more combined upstream traffic. This congestion has a direct impact on energy efficiency and application QoS and can also cause buffer overflow that may lead to larger queuing delay and higher packet loss. In this paper, a class based congestion control protocol is proposed to reduce queuing delay and provide reliable data transmission for them. The simulation results show that our method reduces loss probability, loss energy and consequently improves throughput and life time of network.

Key words: Wireless sensor network, congestion control protocol, Active queue management, Scheduling, Quality of service

1. Introduction

Wireless sensor networking is an emerging technology that has a wide range of potential applications including environment monitoring, habit monitoring, health care, intelligent buildings ,Multimedia and battle field control[1][2]. With integration of information sensing, computation, and wireless communication, the sensor node can sense physical event, process rough information, and report them to the sink.

The energy of these nodes is limited, and WSNs always work under the environment which has no man to guard. The operation that replaces battery or supplement energy almost cannot carry on. Therefore the nodes should be managed efficiently to reduce the network's energy consumed and prolong the lifetime of network.

In diverse classes of WSN's applications, the types of sensors used may send multiple flows that have diverse requirements in terms of transmission rate, delay and throughput, towards the sink.

Transport protocols are used to mitigate congestion and reduce packet loss, to provide fairness in bandwidth allocation, and to guarantee end-to-end reliability [3].

In this paper, a new class based mechanism and queue management is used for congestion control. Our active queue management provides congestion control and fairness for different types of traffic flows. The function of queue management is to control the length or occupancy of the queue and the selection of the flows potentially occupying it.

Active Queue Management (AQM) schemes perform special operations in the node to achieve better performance for end flows. It works at the node for controlling the number of packets in the node's buffer by actively discarding an arriving packet.

In classed based method there are multiple queues. In each queue packets from different upstream nodes that belong to the same class are entered into the same queue at the node. Different applications have their own QoS requirements, such as delay, delay variance and packet loss ratio tolerance, and thus can be classified into different classes. Multi-flow queuing is another alternative for active queue management and we use Weighted Random Early Detection (WRED) algorithm that was introduced in [4].

In this work, we have used 3 different types of traffic with different priorities. Hence, instead of usual congestion control technique, we propose a cross layer techniques involving CODA [5] transport protocol and modified AQM algorithm, named WRED with priority and weighted scheduling protocol for reducing queuing delay for critical and real time traffics.

This paper addresses the problem of congestion control in wireless sensor networks (WSN). We extended CODA protocol to be suitable for different type traffics. CODA is one of such schemes that discuss the congestion for WSNs. It is not specifically designed for different type traffic delivery in WSN.

We added a multi class active queue management to RED to support multi-priority traffic, and also added a delay based scheduling algorithm to reduce queuing delay. Therefore the novel transport algorithm can be used for multi priority traffics.

The rest of this paper is organized as follows. In section 2 we present a review of related research in transport protocols in WSN. In Section 3, we explain our proposed protocol in detail. Section 4 evaluates our simulation results. We conclude the paper in Section 5.

2.Related Works

The study of congestion control in WSNs has been the subject of extensive research. Typically, there are three mechanisms that deal with congestion: congestion detection, congestion notification, and rate adjustment. Accurate and efficient congestion detection plays an important role in the WSNs.

Congestion Detection and Avoidance (CODA), detects congestion based on buffer occupancy as well as wireless channel load. CODA designs both open-loop and closed-loop rate adjustment, and the algorithm used to adjust traffic rate works in a way like additive increase multiplicative decrease (AIMD) and inevitably lead to the existence of packet loss similar to the traditional TCP protocol.

Adaptive Rate Control (ARC), [6], is an LIMD-like (linear increase and multiplicative decrease) algorithm. In ARC, if an intermediate node overhears that the packets it sent previously are successfully forwarded again by its parent node, it will increase its rate by a constant α. Otherwise it will multiply its rate by a factor β where $0 < \beta < 1$. ARC does not use explicit congestion detection or explicit congestion notification and therefore avoids use of control messages. However the coarse rate adjustment could result in tardy control and introduce packet loss.

In Fusion [7], congestion is detected in each sensor node based on measurement of queue length. The node that detects congestion sets a CN (congestion notification) bit in the header of each outgoing packet. Once the CN bit is set, neighboring nodes can overhear it and stop forwarding packets to the congested node so that it can drain the backlogged packets. This non-smooth rate adjustment could impair link utilization as well as fairness, although Fusion has a mechanism to limit the source traffic rate and a prioritized MAC algorithm to improve fairness. Siphon [8] also infers congestion based on queue length in intermediate nodes, but it uses traffic redirection to weaken congestion. There is no rate adjustment in Siphon.

3. The proposed Protocol

CODA [6] is one of the suitable methods for congestion control in wireless sensor networks, with two detecting and preventive mechanism to avoid local and global congestion. Although this solution prevents congestion with low use of energy, it is not proper for multi traffic type situations.

In some applications there are some types of traffic with different properties and priorities in WSNs. Each kind of traffic has its own characteristics and needs. Real time applications are generally sensitive to delay and jitter, while data traffics need reliable transport. In multi traffic networks AQM methods are used for real time traffics to manage the queue.

In the proposed algorithm, called class based congestion control algorithm, there are three queues with different priorities, namely, class1, class2 and class3 in each node. Class1 is for high priority traffics that are delay sensitive. Class2 is non delay sensitive traffics such as file, data, etc that can tolerate some delay. Class3 is for control packets.

The delay sensitive traffics have a high priority to exit from queue, so the queuing delay for these traffics should be as small as possible. For this reason the priority queue (PQ) scheduler is used for delay sensitive traffics to reduce queuing delay and reliability. In output the Class Based Weighted Fair Queue (CBWFQ) scheduler [11] with addition of a PQ is used. The use of PQ ensures low latency for delay sensitive traffics. The scheduler firstly sends class1 packets out of queue. In order to provide fairness between class1 and other classes, at most 20 percent of bandwidth of network is assigned to class1 traffics, so using PQ scheduler does not cause unfairness to other traffics. Indeed fewer queuing delays for class1 traffics results from PQ scheduler which use for delay sensitive traffics.

Packets may be dropped for a variety of reasons such as packet loss, noise, congestion and buffer overflow. The queuing mechanism decides which packet should be dropped when congestion occurs. To prevent drop sensitive packet, from being dropped, class 2 traffics are selected to be dropped to ensure that there is enough space for drop sensitive traffics to get through. CBWFQ is a priority queuing mechanism that assigns a weight to each class of traffic and removes the packet based on its class priority. In our scheduling algorithm class2 packets are transmitted faster than class3 packets. Class2 queue gets more weighted so its traffic get service more often than class3 but class1 queue get service before any other the weighted queues, thus real time traffics can have less queuing delay than others.

Fig.1 shows the structure of a node. There are 3 queues in each intermediate sensor node, namely, class1 for real time traffics, class2 for non delay but drop sensitive traffics, class3 for control packet queue for non data packets that have controlling information such as NACK packets.

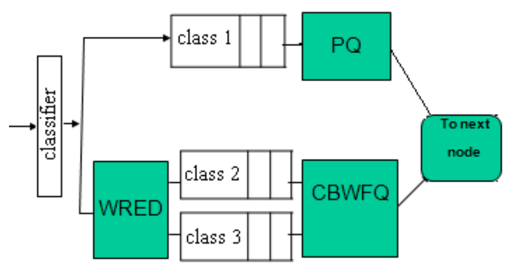

Fig 1: The structure of an intermediate sensor node

Some algorithms have been developed based on RED such as BLUE [11], DRED [12], WRED [4], etc. RED considers just one queue in every node. All kinds of traffic come to this unique queue because there is no difference in priority between them. Weighted RED (WRED) is an extension to RED that drops packets based on their weight. Different queues may have different thresholds based on their priority so the higher priority traffic enters the queue with a higher probability than the lower priority. Priority means the need for fewer drops in the process of delivery packets to sink. WRED uses priority value to drop lower priority packets from the queue with a higher drop probability.

In our algorithm we calculated congestion degree for each queue as d_k. If congestion degree is above a pre defined value (like 0.6) a node decides to accept or drop the packet. We use two thresholds min_{th} and max_{th}. Every incoming packet is assigned a priority based on its data type, queue length, and the percentage of that type of data in queue. A node decides to accept or drop this packet according to its priority and its two low and high thresholds (Fig. 2).

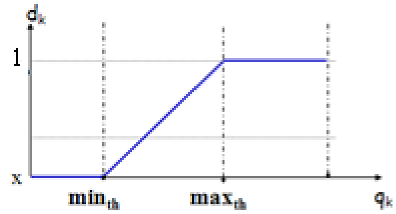

Fig 2: (a) Congestion degree and WRED thresholds

We preset two thresholds min_{th} and max_{th} for queue occupancy. When a new packet arrives, the node computes the hit frequency *h*(*t*) by examining whether the packet is from the same flow as one of the *M* packets randomly selected from the buffer. The hit frequency *h*(*t*) is increased by one if one of the packets and the newly arrived packet belong to the same flow. Intuitively, a higher hit frequency *h*(*t*) implies that a larger number of packets exist in the buffer for a particular flow. To achieve fairness, we need to give more chances to those flows with lower occupancy. Therefore, the arriving packets that belong to higher occupancy flows have higher dropping probabilities. We calculate the dropping probability *pd* of the arriving packet based on the hit frequency *h*(*t*) as Eq. 1.

$$p_d = \begin{cases} 0, & Q(t) < \text{Minthresh} \\ h(t)/\text{M*priority} & \text{Minthresh} \leq Q(t) < \text{Maxthresh} \\ 1, & Q(t) \geq \text{Maxthresh} \end{cases} \tag{1}$$

4. Simulation Results and Analysis

In this section, we present some simulation results using Opnet Modeler simulator [18]. The Opnet simulator is a discrete-event network simulation development and used for the analysis of the computer networks. Fig. 2 shows the topology that was used in our simulation. Simulation parameters are:

Radio Range 40 meters , Transmission energy 12 unit
Network size 400*400 meter in square , Receive Energy 10 unit

To evaluate the performance of CODA with our algorithm metrics like end to end delay, Total packet loss, fairness and Node energy consumption are considered.

Fig. 3 shows the topology that we used in simulation. We implemented both CODA and our proposed algorithm with three kinds of traffic.

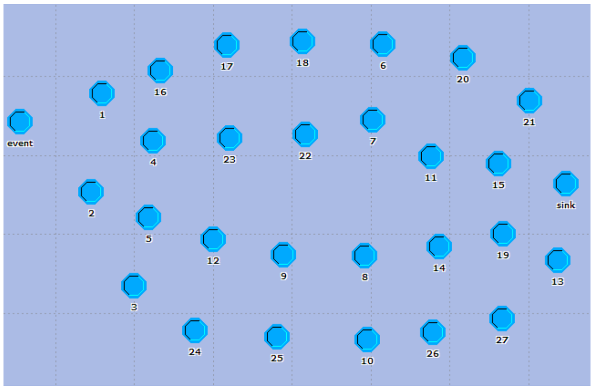

Fig 3: The topology that is used in simulation

In Fig. 4 the end to end delay for class1 and class2 of our proposed algorithm and the total end to end delay for CODA are plotted versus the time. It can be seen that the performance of our algorithm for real time traffic is better than CODA algorithm. This is because our proposed protocol pays attention to different kind of data and uses multi class. The delay for class1 flows is less than others because of our PQ scheduler. Class 2 and 3 end to end delays were the same, so we plotted one of them.

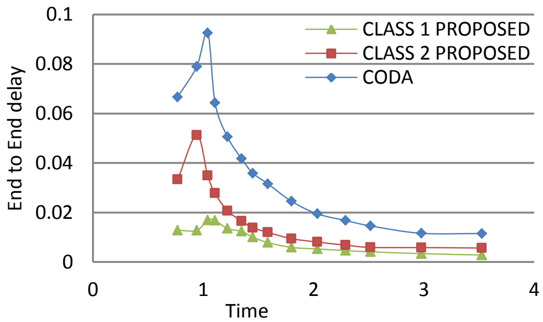

Fig 4: End to End delay comparison between proposed and CODA protocol

In Fig. 5, fairness in the consumption of energy of the network nodes is examined Eq. 2.

The higher the amount of *DEV*, the less success the protocol has achieved success in maintaining balance in the energy consumption of nodes since the variance of energy nodes has increased. In worst case half of the nodes get energy empty and half remain full, so if we normalize the relation we can achieve normalized fairness relation as:

$$DEV = \sum_{i=1}^{n} (Energy_i - Ave)^2 \qquad \text{Fairness} = 1\text{-DEV/DEV}_{\text{worst}} \qquad (2)$$

As can be seen in Fig. 5, proposed protocol achieves more fairness. The parameters of network lifetime and variance are in some way dependent. If we can keep better balance in the energy consumption of nodes the lifetime of the network increases under the same conditions. As we can see in Fig. 6, lifetime of the proposed protocols is mostly higher.

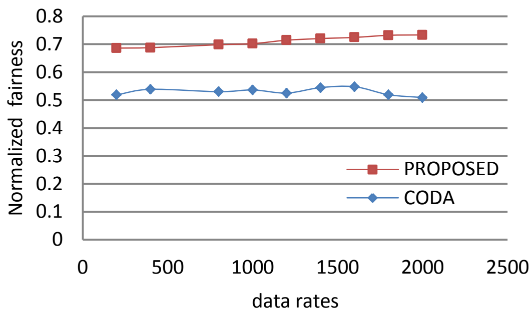

Fig 5: Comparison fairness between proposed and CODA protocol

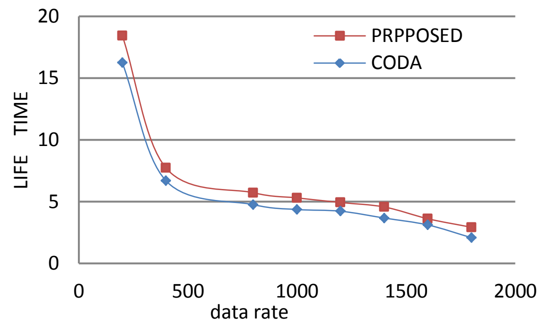

Fig 6: Lifetime comparison between proposed and CODA protocol

The number of packet loss versus total number of packets is illustrated in Fig. 7. It is obvious that packet loss for real time and drop sensitive traffics are lower. The delay increases due to packet drop. So there is no constraint for real time traffics to enter the queue except the queue length reaches to maximum size (here 48 packets). Thus the total number of drop packets for real time traffics is low. CODA manages all packets in one queue and so packet loss in it is more than proposed method.

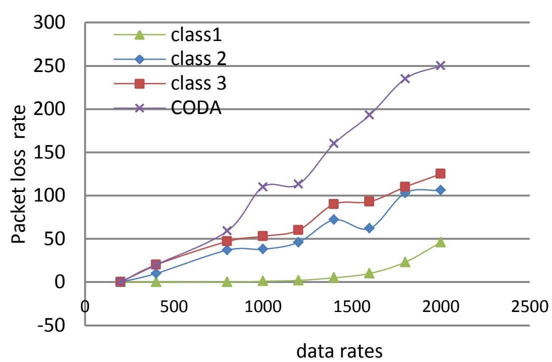

Fig 7: Packet loss comparison between proposed and CODA protocol

5. Conclusions

In this paper we presented a congestion control under multi priority traffic in WSNs. The proposed congestion algorithm can distinct between different kinds of data. The proposed algorithm can support three kind of traffic source, namely, class1 with delay sensitive flows, class2 with drop sensitive traffics and class3 with command and control flows. We developed a weighted AQM with a hybrid priority based scheduling algorithm which accept the packets and sends out the packets according to their priority. This method causes fairness in the network. As we saw proposed congestion protocol achieved low packet loss and delay. Finally, the results of the simulation show that proposed protocol has achieved its goals.

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References

[1] M. Tubaishat, S. Madria, "*Sensor Networks: An Overview*.", IEEE POTENTIALS April/May, pp20-23, 2003
[2] K. Sohraby, D. Minoli and T. Znati. *Wireless Sensor Network: Technology, Protocols, and Applications*. Wiley. 2007.
[3] C. Wang and Kazem Sohraby, *"A Survey of Transport Protocols for Wireless Sensor Networks " , IEEE Network • May/June 2006.1*
[4] V.Firoiu, and M. Borden, "*A Study of Active Queue Management for Congestion Control,*" IEEE INFOCOM, 2000.
[5] C-Y.Wan, S. B. Eisenman, and A. T. Campbell, "*CODA: Congestion detection and avoidance in sensor networks*," in Proc. 1st ACM Conf. Throughput Embedded Networked Sensor Syst. (SenSys), Los Angeles, CA, Nov. 5– 7, 2003, pp. 266–279.
[6] A. Woo and D. C. Culler, "*A Transmission Control Scheme for Media Access in Sensor Networks,*" *Proc. ACM Mobicom '01*, Rome, Italy, July 16–21,2004
[7] B. Hull, K. Jamieson, and H. Balakrishnan, "*Mitigating Congestion in Wireless Sensor Networks*," *Proc. ACM Sensys '04*, Baltimore, MD, Nov. 3–5, 2004.
[8] C.-Y. Wan *et al.*, "*Siphon: Overload Traffic Management Using Multi-Radio Virtual Sinks in Sensor Networks*," *Proc. ACM SenSys '05*, San Diego, CA, Nov. 2–4, 2005.
[9] M. Fischer, D. Masi and J. Shortle, "*Approximating low latency queuing buffer latency*". 2008 Fourth Advanced International Conference on Telecommunications.
[10] S. Floyd, V. Jacobson, "*Random Early Detection Gateways for Congestion Avoidance*," IEEE/ACM Transaction on Networks, Vol. 1, No. 4 August, 1993, pp.397-413.
[11] W. Fen, D. Kandlur, D. Saha, and K. Shin, "*BLUE: A New Class of Active Queue Management Algorithms,*" UM CSE-TR-387-99, 1999.
[12] B. Zheng and M. Atiquzzaman, "*DSRED: An Active Queue Management Scheme for Next Generation Networks,*" IEEE LCN 2000, Tampa, Florida, USA, November, pp. 8-10, 2000.