Congestion Control in Wireless Sensor Networks using Prioritized Interface Queue

Meera.S B.Tech.(M.E.)
Dept. Of CSE
Jerusalem College Of Engg
Chennai,India

R.Beulah Jayakumari
Assistant Professor,Dept. Of IT
Jerusalem College Of Engg
Chennai,India

V.Jawahar Senthilkumar
Assistant Professor,Dept. Of ECE
Anna University
Chennai,India

ABSTRACT
Wireless Sensor Networks are a class of wireless networks intended for monitoring physical and environmental phenomena. The main task of sensor nodes is to collect specific data from surrounding environment and then route it to the base station or sink. The power efficiency and life time maximization are the foremost requirements of sensor networks. When a particular event is detected, the sensor nodes become active and there is a sudden burst of traffic towards the sink. This may lead to buffer overflow at the nodes causing packet drops and finally degrades overall network performance. Congestion leads to wastage of energy and minimizes the lifetime of sensor nodes. In sensor networks more energy is spend for communication rather than for computation. Hence it is necessary to ensure that the drop rate of transit packets which travel many hops in the network is reduced. This in turn brings down energy consumption and increases lifetime of sensor nodes. This paper proposes an efficient cross layer congestion control scheme that can detect and avoid congestion in an event driven peer to peer sensor network .It provides priority based traffic scheduling with a dual queue scheduler which favours transit packets. Congestion is detected based on the buffer occupancy and a hop by hop back pressure mechanism is used as a fast reaction to congestion .In order to prevent persistent congestion the source sending rate is updated by the sink periodically with the help of an adaptive rate control algorithm.To route packets through less congested paths, the routing protocol in the proposed scheme makes use of the interface queue length of neighbourhood nodes to select the best next hop. The dual queue scheduler , hop by hop back pressure and adaptive rate control algorithm can together control both persistent and transient congestion in wireless sensor network .

General Terms
Algorithms, Congestion Control.

Keywords
Congestion ,Wireless Sensor Networks , Routing, Cross Layer Optimization.

1. INTRODUCTION
Sensor Network consists of a collection of autonomous sensor nodes that are spatially distributed and cooperatively monitor physical and environmental conditions. Such networks find increasing usage in diverse areas like military applications,health, agriculture, forestry etc .A large number of sensor nodes sense the phenomena and report the event through wireless links to the sink . A wireless sensor network (WSN) may consist of tens or thousands of sensor nodes scattered in an area. When an event is detected , there is a sudden outburst of data .The data generated by the nodes increases and the offered load exceeds available capacity and the network becomes congested. Congestion is WSN can be transient (link level congestion) or persistent (node level congestion).Transient congestion is caused by the temporary oversubscription of a link due to sudden burst of packets arriving at the switch or router buffer. It happens due to link variations.

Persistent or sustained congestion occurs when the long term arrival rate at a link exceeds its capacity. This happens when the source data sending rate increases and the buffer over flows. While transient congestion only introduces a delay in data transmission , persistent congestion results in data loss.

Congestion results in packet drops, increased delays, unreliability, lower throughput, wastage of communication resources , power , and eventually decreases lifetime of the WSN. Congestion control involves methods for monitoring and regulating the total amount of data entering the network to keep traffic levels at an acceptable value. Congestion control in WSN has a rich history of algorithm development and theoretical study. Various schemes for congestion control have been proposed and implemented over the years. The existing works differ in the algorithms they use for adjusting source sending rate and techniques to deal with transient congestion like dropping packets or using back pressure mechanism that reduces rate of links feeding the congested buffer. Also they can be classified based on whether they follow a traditional layered approach or cross layer approach.

Considering the scarce energy and processing resources of WSN ,joint optimization and design of network layers (Cross layer approach) stands as the most promising alternative to layered approach. Network layers can be jointly optimized to maximize overall network performance while minimizing the energy expenditure. .The knowledge has to be shared among all layers to obtain highest possible adaptivity.

The rest of the paper is organized as follows :Section 2 presents most relevant work.Section 3 and 4 describes the proposed scheme for congestion control in detail. Section 5 presents simulation results and finally paper is concluded in Section 6.

2. RELATED WORK
Several congestion control techniques have been proposed for the Wireless Sensor Network in the recent years . The existing works can be classified in many ways. In general transient congestion is effectively dealt with using buffers at the links and dropping the excess packets. The sustained or persistent congestion is alleviated by transport protocols which reduce the transmission rate of a source when its packets are dropped or marked. Some mechanisms for congestion control operate at a particular layer like network ,MAC or transport layers while others are distributed among various layers involving

sharing of information across layers. The latter is the Cross Layer Approach. The works of Li Qiang Tao[2010] and Mehmet C. Vuran[2010] are examples of cross layered approach.

Most of them have been following the layered approach of designing protocols to alleviate congestion[4] .It has been proved through various works that a cross layer design of protocols for communication which involve joint participation of network, MAC or transport layers can enhance the network performance and minimize energy expenditure.

One of the earlier works [4],CODA focuses on an energy efficient congestion control scheme ,involving three mechanisms distributed across the network and MAC layer. It handles both persistent and transient congestion ,but do not provide differentiated services to multiple class of traffic. ESRT[20] which implements an efficient transport protocol for wireless sensor has an explicit congestion notification mechanism which enables the sink to control sending rate of sources . A source sets the congestion bit in its outgoing packets when its buffer overflows. However ESRT uses high energy signals to broadcast network state to sensor nodes at regular intervals , which consumes a lot of energy. Also in the event of congestion it regulates sending rate of all sources irrespective of where the congestion hotspot is present. However there is a need to support heterogeneous sources and regulate only the source which is responsible for congestion. There have been considerable efforts in developing congestion control schemes that give importance to high priority data or data with specific delay or QoS requirements in the event of congestion. One of the works [3] classifies data according to the static priority of sources and introduced dual queues for the source and transit traffic. The more recent ECODA[9] introduces three mechanisms to detect and control persistent and transient congestion. It uses the concept of dual buffer threshold. However to deal with persistent congestion it uses a technique based on overhearing which is coarse and unreliable. Also during extreme congestion when packets are dropped , no priority is given to the transit packets. Each node has the extra overhead of calculating the weighted buffer difference to identify high priority data which is costly considering the limited power of sensor node.

3. OVERVIEW OF PROPOSED SYSTEM

The proposed system aims at developing an efficient congestion control Protocol for WSN using cross layer approach. The architecture of the system is as shown in Fig.1.Source has sensors and forwards the sensed data towards the sink .Intermediate nodes have congestion control mechanisms to improve the network performance. The dual queue scheduler selects the next packet to send and if congestion is detected, the hop by hop backpressure technique is used by the transient congestion module ,which reduces the data forwarding rate of downstream nodes. The packets are forwarded using an intelligent routing technique which uses congestion information to select the best next hop. The persistent congestion control involves periodic updating of the source sending rate by the sink.

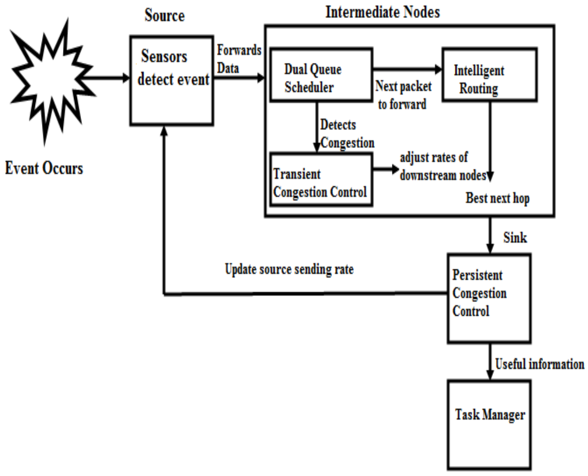

Fig 1: Overall Architecture

Accordingly different sources are assigned different sending rate.The sink forwards received data to the Task Manager who processes the useful information.

4. MODULE DESCRIPTION

The proposed system implements an efficient congestion control scheme for WSN. It has different mechanisms distributed across the Link layer, Network Layer and Transport Layer.

4.1 Dual Queue Scheduler

The node in WSN can act as both source and forwarder. Based on this function there are two types of data ,namely locally generated data and transit data. The data generated from any source node is called locally generated data .The data at any source node can be differentiated in to transit data, which it receives from a downstream node and generated data, which is its own sensed data. In a multi hop WSN ,the sensed data has to travel many hops to reach the sink. Hence dropping of such transit data leads to more energy wastage And also the TTL (Time To Live) of packets is small in sensor networks , so it is necessary to route the transit packets immediately when compared with generated packets at a node.

A flexible queue scheduler as shown in Fig.2 is used at the interface of network and MAC layers at each node .It is implemented as a dual queue in which the generated traffic at the nodes and transit traffic are queued separately .Both queues are of the same length. It is considered that dropping of transit traffic leads to more energy wastage and in the event of buffer overflows the packets from generated traffic queue is dropped to make space for the transit traffic .The transit packet queue as shown in Fig.2 has dual thresholds. Buffer occupancy above the minimum threshold signals the onset of congestion and incoming packets from other nodes are queued in the generated packet queue .This is done to make space for transit traffic which are having high priority.

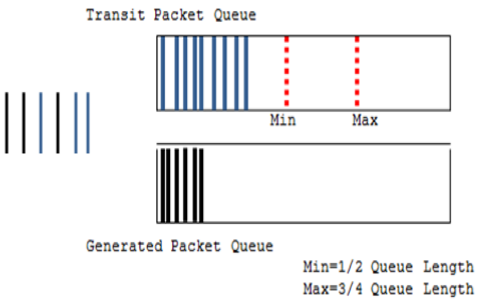

Fig.2:Dual Queue Scheduler

When the buffer occupancy crosses maximum threshold both queues are utilized for storing transit packets and all the generated packets are dropped. As soon as the congestion is alleviated by the back pressure messages propagated to downstream nodes ,the transit queue occupancy falls down minimum threshold and queues are used in normal way. The minimum threshold is set to half of the queue length and the maximum threshold is three fourth of the queue length. These values are considered ideal as the congestion control schemes will neither be initiated too early leading to excessive drop of generated packets nor too late causing drop of transit packets.The algorithm for the dual queue scheduler is as follows .

Input: Ptr-> transit data packets

Pgen-> node generated packets

Output: Queue in which packet is to be stored.

Variables :Qg =Queue for generated packets(Droptail)

Qt=Queue for transit packets(Droptail)

Qmin=minimum threshold of Qt

Qmax=maximum threshold of Qt

L=current length of Qt

Pin=incoming packet

Pseudo Code:

```
If ( L < Qmin ){
        If (Pin=Pgen)
        Queue in Qg
         Else
        Queue in Qt

         }

Else if ( L > Qmin )
  {
        If ( L < Qmax ){
            If ( Pin==Pgen)
                Queue in Qg
            Else{
        Queue at the head of Qg  if it is not full ,
        else in Qt.Propagate backpressure
        message to nodes
            }
                }
   E lse if ( L > Qmax)
                {
            If(Pin==pgen)
                Discard the packet.
            Else{
        Queue at the head of Qg  if it is not full
        else in Qt.
         Drop all Pgen in Qg.
            }
   }
```

The novelty in the proposed algorithm is that higher priority transit packets always has a higher chance of reaching the sink During congestion ,when the maximum threshold of transit queue is exceeded both queues are utilized for transit packets .In most of the existing queue models during congestion transit packets are dropped randomly .Further the proposed model can be extended to group packets based on priority of sources within each queue.

4.2 Transient Congestion Control

Transition congestion occurs due to temporary oversubscription of a particular link and leads to buffer over flow at the routers. Hop by Hop back pressure is used to control transient congestion .In the proposed system the transit queue occupancy is used to trigger back pressure messages .If the transit queue is occupied beyond the minimum threshold back pressure is set towards downstream nodes. On receiving the back pressure messages the node reduces its forwarding rate ,and based on its queue occupancy decides whether to propagate the backpressure further downstream .Also a node receiving back pressure can choose alternate paths to route its out going packets. When the transit queue occupancy falls back to normal ,the node can stop propagating back pressure messages and the normal sending rate is set again.

4.3 Persistent Congestion Control

Persistent or sustained congestion occurs when the long term arrival rate at a link exceeds its capacity. This happens when the source data sending rate increases and the buffer over flows. While transient congestion only introduces a delay in data transmission, persistent congestion results in data loss. In order to avoid persistent congestion the sink node monitors the incoming packets from each source for the delay they took in reaching the sink.The sending rate for each source is set as the reciprocal of maximum delay that a packet from that source took to reach the sink.This is estimated periodically and send to the sources through control messages.In

Fig.3,the red lines from the sink indicates the control messages towards sources.

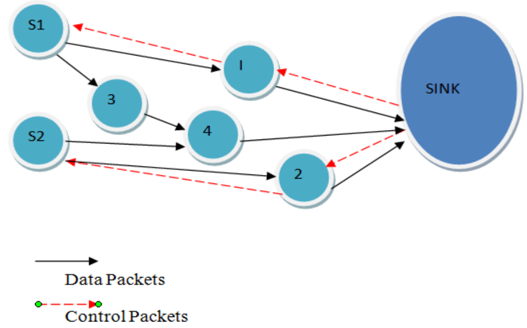

Fig.3 : Adaptive Rate Control Of Sources

The sink follows the algorithm given below to update sending rate for sources periodically. The sink executes following algorithm at regular intervals depending on the application.

Input : Timestamps Receive(p) & Send(p) of received packet p.
Output: Rate Ri for source i.

Variables :D(p) :Delay of packet p
Dmax(i):Maximum delay for a packet from source i

Pseudo Code :

```
for every source i=1 to n
{
  for every packet p received from i
  {
    D(p)=Receive(p)-Send(P)
    Dmax(i) = MAX{D(p)}
    Ri=1/Dmax(i)
  }
}
```

4.4 Intelligent Routing

Congestion in wireless sensor networks (WSN) may lead to packet losses or delayed delivery of important information rendering the WSN-based monitoring or control system useless. A dynamic routing scheme that works in concert with the congestion control mechanism to forward the packets through less congested nodes ,can reduce transient congestion and also improve overall network performance.. AODV is the most prominent among the reactive routing protocols. It uses shortest path as the route selection criteria. This leads to poor performance causing power consumption and packet drops, when traffic load increases. Possible solution is to consider the traffic load on each node during the route selection. The proposed intelligent routing involves modifying AODV to take in to account the buffer occupancy also. The transit queue occupancy of nodes can be used as a route selection criteria. A node whose transit queue is filled beyond minimum threshold can be purposefully avoided and another node in the transmission range can be chosen for next hop of a packet.Thus the proposed intelligent routing protocol AODV-IFQ works in concert with the interface queue and uses both hop count and transit packet queue occupancy as its route selection criteria. This approach leads to shorter end to end delays and improves the packet delivery ratio. The following steps outlines the basic principle of AODV-IFQ

x,y: Nodes which wants to forward data.
Nx : set of neighbors of node x

Step 1: When x forwards any packet, it piggy backs its current buffer occupancy in packet header.
Step 2: When y € Nx receives a packet from x ,it caches the current transit packet queue length of x.
Step 3 : When y has to forward a packet to x ,it does so only if x's transit packet queue is not filled beyond minimum threshold.
Step 4: When x has to forward a packet to sink it chooses from Nx, the node whose queue is not filled beyond minimum threshold.

5. RESULTS AND DISCUSSION

The simulation of proposed protocols in carried out in the NS2 network simulator. As the initial step towards the implementation of the congestion control protocol, the interface queue between the Network and MAC layers is modified .A dual queue scheduler is implemented. It gives priority to transit packets and in the event of congestion, the generated packets are dropped giving space for the transit packets. The simulation of above scenario is performed with normal drop tail queue (NQ) and with the modified queue (MQ) and the results are analyzed. The normal queue is used as the interface queue in the initial simulation. The queue enqueues all incoming packets at its tail and drops packet from tail whenever the maximum limit is exceeded.
The normal queue is modified to perform differentiated service. The proposed dual queue scheduler will ensure that during overflow incoming transit packets are transmitted and the generated packets are dropped. The transit packets are enqueued at the head of the queue for generated packets after transit queue is filled beyond the minimum threshold .Hence during dropping at the tail the transit packets are saved to an extent, though during heavy congestion transit packets might also be dropped.The graph given below in Fig 5 clearly depicts the performance advantage gained through the modified queue. Less transit packets are dropped and hence the energy of sensor nodes is also saved.

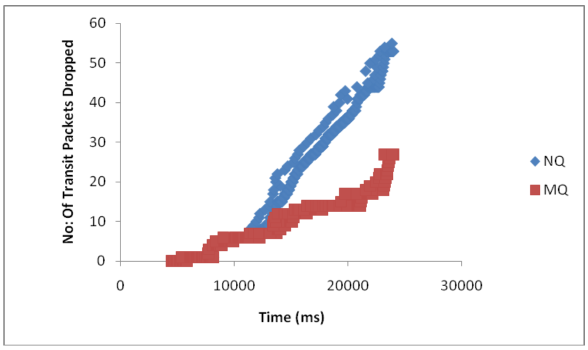

Fig.5. Comparison Of Performance with Normal Queue(NQ) and Modified Queue(MQ)

The simulation was performed for ten different scenarios,with the sources positioned differently and also by altering the source sending rates.The scenarios were simulated both using the normal queue and the modified queue.In all the cases,there was significant decrease in the transit packet drop when the modified queue is used.Fig 6 illustrates the performance of both queues under different scenarios.

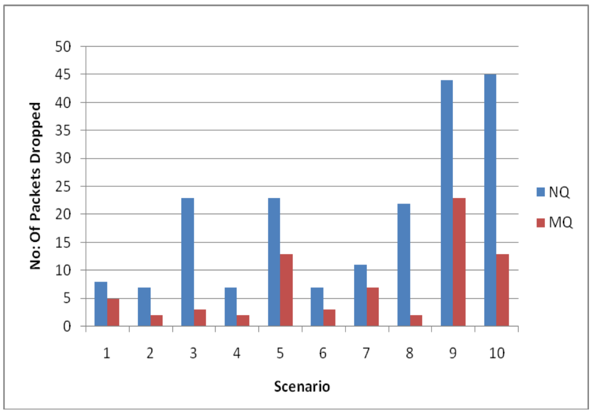

Fig.6 :Comparison of queue performance for different scenarios

6. CONCLUSION

An efficient cross layered congestion control scheme for WSN is proposed. It enables joint optimization of different layers and is more advantageous compared to the traditional layered approach. Here congestion can be detected using the buffer occupancy in queue. During congestion more priority is given to transit packet than generated packet. Simulation has been carried out to demonstrate the effect of dual queue scheduler and the results show that the proposed queue model significantly brings down the drop rate of transit packets. Hence an overall improvement of energy consumption and throughput is achieved.

7. ACKNOWLEDGEMENTS

I must thank, first and foremost my internal guide Mrs.R.Beulah Jayakumari ,Assistant Professor, Department of Information Technology, and project coordinator Dr.C.R.Rene Robin, Head of the Department, Department of Computer Science and Engineering, without whose guidance and patience, this dissertation would not be possible .I must also thank Mr.P.Sankar ,Assistant Professor,Department of ECE for helping me. And engineering, project panel members, professors of the Department of Computer Science and Engineering for their consistent encouragement and ideas.

8. REFERENCES

[1] Akyildiz, I. F., Su, W., Sankarasubramaniam, Y. & Cayirci, E. (2002). A survey on sensor network, IEEE Communications Magazine .

[2] Bret Hull, Kyle Jamieson, Hari Balakrishnan(2004)-‘ Mitigating Congestion in Wireless Sensor Networks ‘- MIT Computer Science and Artificial Intelligence Laboratory The Stata Center, 32 Vassar St., Cambridge, MA 02139

[3] C. Wang, B. Li, K. Sohraby, M. Daneshmand and Y. Hu.(2007)-‘Upstream Congestion Control in Wireless Sensor Networks Through Cross-Layer Optimization’- IEEE Journal on selected areas in communications,Vol.25,No.4

[4] C.-Y. Wan, S.B. Eisenman, A. T. Campbell(2003) ‘CODA: Congestion Detection and Avoidance in Sensor Networks’in Proc. ACM SenSys, N

[5] Fengyuan Ren, Tao He, Sajal K. Das, Chuang Lin(2011)- ‘ Traffic-Aware Dynamic Routing to Alleviate Congestion in Wireless Sensor Networks’ -IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS, VOL. 22, NO. 9

[6] Holger Karl,Andreas Wiling(2005) –Protocols and Architectures For Wireless Sensor Networks

[7] Kang Jaewon Zhang Yanyong Nath, B. Rutgers Univ., Piscataway (2007)– TARA: Topology-Aware Resource Adaptation to Alleviate Congestion in Sensor Networks IEEE Transactions on Parallel and Distributed Systems.

[8] Li Qiang Tao and Feng Qi Yu (2010) ‘ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks’ -IEEE Transactions on Consumer Electronics,Vol. 56, No. 3

[9] Maciej Zawodniok, and Sarangapani Jagannathan (2007), ”Predictive congestion control for wireless sensor networks”, IEEE Trans. Wireles Communications, vol. 6, No. 11, pp. 3955-3963.

[10] Mehmet C. Vuran, Ian F. Akyildiz (2010)-‘ XLP: A Cross-Layer Protocol for Efficient Communication in Wireless Sensor Networks’- IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 9, NO. 11, NOVEMBER .

[11] Ms.D.F.Jenolin Flora, Dr.V.Kavitha, Mrs.M.Muthuselvi (2011)- A Survey on Congestion Control Techniques in Wireless Sensor Networks, PROCEEDINGS OF ICETECT.

[12] Pooja Sharma, Deeepak Tyaki, Padawan Bhadana (2010), “A study on prolong the lifetime of wireless sensor network by congestion avoidance techniques”, International Journal of Engineering and Technology, vol 2(9), pp. 4844-4849.

[13] Raju Kumar,Riccardo Crepaldi, Hosam Rowaihy, Albert F. Harris,Guohong Cao, Michele Zorzi, Thomas F. La Porta(2008)-‘ Mitigating Performance Degradation in Congested Sensor Networks’-IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 7, NO. 6.

[14] Shigang Chen, and Na Yang (2006),, “Congestion avoidance based on lightweight buffer management in sensor networks” IEEE Trans.Parallel and Distributed Systems, vol. 17, No. 9, pp. 934-946, Sep. 2006.

[15] Sudip Misra, Vivek, Tiwari, and Mohammed S.Obaidat (2009), “LACAS:Learning automata-based congestion avoidance scheme for healthcare wireless sensor networks”, IEEE Trans. Selected Areas in Communications, vol. 27, No. 4, pp. 466-479.

[16] Teerawat Issariyakul ,Ekram Hossain- Introduction to Network Simulator NS2.

[17] Wei-wei Fang, Ji-ming Chen, Lei Shu, Tian-shu Chu, and De-pei Qian (2009)“Congestion avoidance, detection and alleviation in wireless sensor networks”, Journal of University-Sciencevol. 11(1) pp. 63-73.

[18] X. Lin and N. B. Shroff (March-2005)" The Impact of Imperfect Scheduling on Cross-Layer Rate Control in Multihop Wireless Networks," in Proceedings of IEEE INFOCOM, Miami.

[19] Yogesh Sankarasubramaniam Özgür B. Akan Ian F. Akyildiz (2003)' ESRT: Event To Sink Reliable Transport in Wireless Sensor Networks'- Broadband & Wireless Networking Laboratory School of Electrical & Computer Engineering Georgia Institute of Technology.

[20] P. Sankar and C. Chellamuthu, 2011. Study on the Effect of Video Traffic on Responsive Flows Using Queue Management Algorithms. *Asian Journal of Information Technology, 10: 42-46.*