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Hop-by-Hop Rate Control Technique for Congestion Due to Concurrent Transmission in Wireless Sensor Network

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Abstract— Congestion plays a vital role in degrading the performance of wireless sensor network. Thus an issue of detecting and controlling congestion becomes essential to improve the performance of the network. There are various sources for congestion like packet collision, buffer overflow, concurrent transmission etc. This paper focuses on congestion due to concurrent transmission. We have proposed an efficient protocol to detect and control congestion in a MAC. The level of congestion is measured using a metric called Depth of Congestion (DC). Based on the measured value the node effectively adapts its transmission data rate to control congestion. This technique is implemented successfully in NS-2 simulator. Finally, simulation results have demonstrated the effectiveness of our proposed protocol.

Keywords- Wireless Sensor Networks; Depth of Congestion (DC); Congestion Detection; Congestion Control.

I. Introduction

Wireless Sensor Networks (WSNs) has emerging applications in various fields like military, health, environment, agriculture etc. These networks deliver numerous types of traffic, from simple periodic reports to unpredictable bursts of messages triggered by sensed events. Therefore, congestion happens due to: i) Buffer Overflow ii) Concurrent Transmission iii) Many to One nature iv) Packet Collision v) Reporting Rate. [1]. As WSN is a multi-hop network; congestion taking place at a single node may diffuse to the whole network and degrade its performance drastically [2]. Congestion degrades the performance of the network with (i) lot of packet loss, which in turn diminish the network throughput and (ii) hinders fair event detections and reliable data transmissions. Thus congestion detection and control plays a vital role in achieving high network efficiency.

A. Motivation

The motivation behind congestion detection and control is to provide high data rate transmission with high efficiency and reliability. When the sensor network has less traffic, network is not prone to congestion whereas when the traffic increases, network is prone to congestion degrading the overall efficiency of the network [24]. This motivates to develop a protocol to detect and control congestion. Though there are various sources for congestion, our work focuses on congestion due to concurrent transmission. This occurs when huge number of sensed data flows through same path to reach the destination node or sink node, thus leading to bottleneck. Applications requiring high data-rate can easily cause congestion problem especially at intermediary nodes. Our proposed protocol detects the congestion at intermediary nodes and controls in order to provide both huge data transfer and high reliability.

Fig. 1 shows the structure of Wireless Sensor Networks (WSNs) with data transmission from different source nodes to sink node. The data packets from different source nodes travel through a particular path leading to congestion.

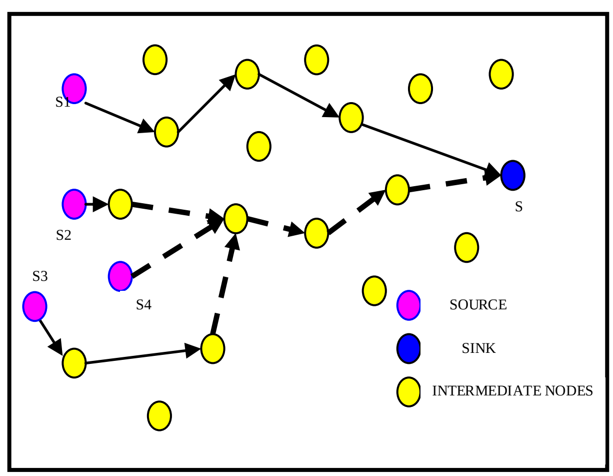

Figure 1. Structure of wireless sensor networks

A. *Our contribution*

The motivation behind congestion detection is to provide high efficiency for high data rate transmission. Applications requiring high data-rate can easily cause congestion problem (i.e) when traffic is high it leads to congestion. In our work, we have proposed a metrics called Depth of Congestion (DC) to detect congestion. When DC exceeds the pre-defined threshold value it intimates, that, congestion has occurred. In this issue, it necessitates to develop an effective and efficient congestion control protocol to prevent the network from entering the congestion collapse state. This is done by implementing Hop by Hop congestion control protocol.

II. RELATED WORKS

In [1], congestion is detected by measuring the queue length. The congestion is controlled by using three techniques i) hop-by-hop flow control , ii) source rate limiting, and iii) prioritized MAC. Even in high offered load it claims to achieve good throughput and fairness. In [2], a congestion control technique in which packet service time is used to infer the available service rate and therefore detects congestion in each intermediate sensor node. The congestion is controlled by hop-by-hop technique and it uses rate adjustment based on the available service rate and number of child nodes. However, it cannot utilize the available link capacity efficiently when some nodes are in sleep state.

In [3] the author proposes a novel distributed congestion avoidance algorithm which uses the ratio of the number of downstream and upstream nodes along with available queue sizes of the downstream nodes to detect incipient congestion. The Monitoring queue sizes of downstream nodes help to ensure effective load balancing and fairness in the avoidance algorithm.[4] To address the challenge in wireless sensor network ,author propose an energy efficient congestion control scheme for sensor networks called *CODA (Congestion Detection and Avoidance)* that comprises three important method (i) receiver-based congestion detection;(ii) open-loop hop-by-hop backpressure; and (iii) closed-loop multi-source regulation. A detailed design, implementation and evaluation of CODA using simulation and experimentation are done. This paper defines two important performance metrics (i.e., energy tax and fidelity penalty) to evaluate the impact of CODA on the performance of sensing applications , also the performance benefits and practical engineering challenges of implementing CODA in an experimental sensor network test bed based on Berkeley motes using CSMA. The results of this method have significant improvement on the performance of data dissemination applications such as directed diffusion by mitigating hotspots, and reducing the energy tax with low fidelity penalty on sensing applications.

The methodology in [6] has given a efficient method for both congestion detection and avoidance, the authors gets the notification of congestion by taking a term Intelligent Congestion Detection (ICD), the packet service time and inter arrival time is taken into account for the detection. When the above method ends in the congestion phase a notification to all the nearby nodes is been provided by the method called implicit congestion notification (ICN). The avoidance of congestion is been made out by assigning (PRA) priority by taking the packet delivery rate as key. In [5] Present a congestion avoidance protocol, which includes *source count* based hierarchical medium access control (HMAC) and weighted round robin forwarding (WRRF) as the two main method to overcome congestion . The Simulation result of the this technique avoid packet drop due to buffer overflow and achieves much higher delivery ratio even under high traffic condition, which claims a good enough method for reliable event detection.

In PCCP [11] a congestion control mechanism has been proposed for WSN. An efficient congestion detection technique addressing both node and link level congestion has been proposed.

III. SYSTEM OVERVIEW

Our main motivation in designing this protocol is to control congestion due to concurrent transmission for high data rate wireless sensor network. In this section we discuss the detail of our scheme including the node level algorithms for congestion detection, notification and control.

Fig. 2 describes the structure of proposed protocol. The Depth of Congestion (DC) is given as input to the congestion detection unit. When the measured DC is less than pre-defined threshold value, then, there is no congestion whereas when DC is equal to or more than pre-defined threshold value, then it intimates the occurrence of congestion. Once congestion is detected, notification signal is send to all the nodes to control the congestion. On receiving the notification signal each node adjust the transmission rate by implementing Hop-by-Hop Rate Control Technique.

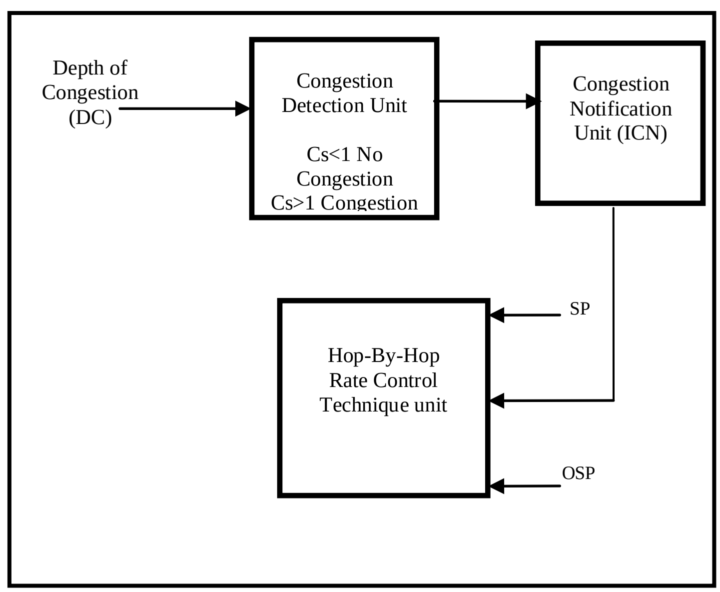

Figure 2. Structure of proposed protocol

A. Congestion Detection Unit

In this section, congestion is detected by calculating depth of congestion at the sink node "*i*". We have used service and arrival rate to calculate depth of congestion. It's the ratio of local packet inter-service rate and local packet inter-arrival rate.

Depth of Congestion (DC) = R^{i}_{s} / R^{i}_{a}

Where R^{i}_{s} = local packet inter-service rate

R^{i}_{a} = local packet inter-arrival rate

```
/* Congestion /
double HRCT::DC()
{
DC = arrRate / serRate;
return DC;
}
```

The calculated depth of congestion (DC) is compared with the pre-defined threshold value. Here the pre-defined threshold value is set as one. When the depth of congestion (DC) is greater than or equal to pre-defined threshold value, it infers that packet arrival rate is faster than packet service rate leading to bottleneck at the MAC layer. When the depth of congestion is less than pre-defined threshold value, it infers that packet arrival rate is less than packet service rate leading to subsiding of congestion.

DC < 1; No Congestion

Packet arrives slower than departure

DC≥ 1; Congestion

Packet arrives faster than departure

B. Congestion Notification Unit

This protocol uses Implicit Congestion notification signal to indicate the occurrence of congestion to all the nodes in the network. Each node i piggybacks the arrival rate, service rate and number of child node in the packet header. On receiving the signal, each node i adapts its transmission rate to control congestion. The technique used to control congestion is described in the next section.

C. Hop-by-Hop Rate Control Technique Unit

In this section, Hop-by-Hop Rate control Technique (HRCT) is implemented to control congestion. The sensor/transmission rate of the node is adjusted based on depth of congestion and overall sensor priority. By adjusting the sensor rate of the parent node, the overall performance of the network is improved. The new sensor rate is piggybacked to the data packet header along with other parameters. Each node adjust its new sensor rate thus reduced the depth of congestion.

```
if(offnodes < offnodes1)
    senRate = senRate / DC[i];
  else if(offnodes > offnodes1)
    senRate = tot_rate *
(overallsen_prio[index]/overallsen_prio[i]);
  else if(offnodes == offnodes1)
  {     if(DC < DC1)
          senRate = senRate / DC[i];
      else
          senRate = base_rate *
(overallsen_prio[index]/overallsen_prio[i]);
  }
  senRate = senRate *
(sen_prio[index]/overallsen_prio[index]);
  tot_rate += senRate;
}
```

D. Algorithm Description

Algorithm 1 Congestion detection and control

Setup initial nodes in the given area

Assign nodes with capability of sensing data when an event is set

Set congestion scale threshold as 1& current as 0

while

Packets are being transmitted in the network and received at nodes

do

calculate for congestion scale(Cs=Ts/Ta)

if

Congestion scale greater than equal to threshold

then

Packet arrival time is faster than departure

Congestion has occurred .

Transmission rate is adjusted using response function

Congestion is controlled

else

Packet arrival time is slower than departure

No Congestion

end if

end while

IV. SYSTEM STUDY

A. Simulation parameters

A wireless sensor network which comprises of 1000 stationary sensor nodes are placed in 800*800 area space with more than one source targeting to a single sink. MAC protocol is used with data generation rate of 10 packets per second. The data packets are generated from sources and are transmitted to other nodes until it reaches the destination. On occurrence of an event, the traffic increases leading to congestion. When congestion is detected, transmission rate is adjusted to control congestion. An accurate and efficient stimulation is carried out using Ns2 with effective proposed congestion detection and control algorithm. Performance of the network is evaluated by calculating the Throughput of the network and Packet Drop.

The simulation parameters used in our experimental setup is given below.

TABLE I. SIMULATION PARAMETERS

Channel Type	Channel/Wireless Channel
Radio-Propagation	Propagation/Two Ray Ground
Network interface	Phy/WirelessPhy
MAC Protocol	Mac/802_11
Interface Queue	Queue/Drop Tail/ PriQueue
Antenna Model	Antenna/Omni Antenna
Routing Protocol	DSDV(Destination Sequenced Distance Vector)
No. of Mobile nodes	50
Simulation start time	1.0
Simulation Stop time	50
Packet size	512
Number of nodes	1000
Total area	800 x 800
Active source	1-10
Data packet generation rate	10pack/sec
Packet size	1000bytes
Buffer size	50packets

B. Simulation Scenario

Fig. 3 & Fig. 4, shows a scenario with high data rate transmission for network size of 700 & 1000 nodes. Due to high data rate transmission the network is prone to congestion. When the data packets flows through particular path it leads to congestion due to concurrent path.

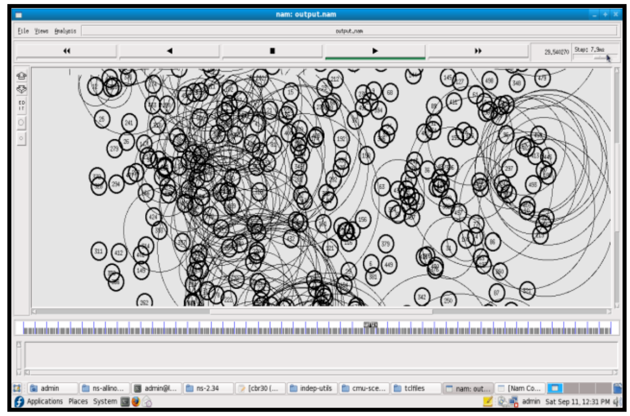

Figure 3. A Scenario with data transmission with network size 700 sensor nodes

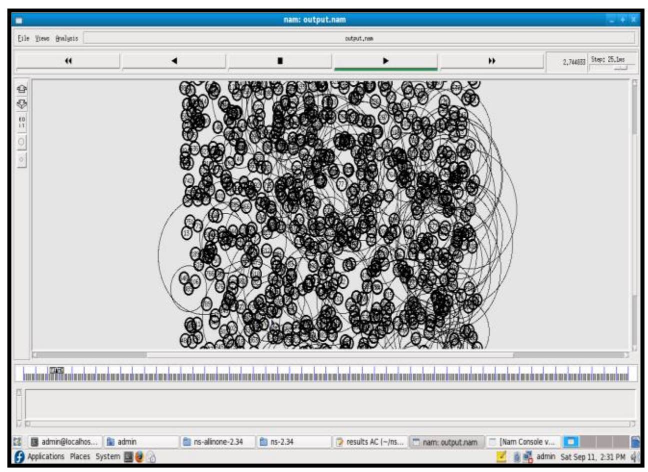

Figure 4. A Scenario with data transmission with network size 1000 sensor nodes .

C. Simulation Results

The simulation results show the effectiveness of the proposed protocol. In this paper two main parameters are analyzed. They are Throughput of the network and Packet drop.

I) Throughput

When throughput decreases the overall performance of the network degrades to large extend. Thus overall throughput of the network has to be increased.

Fig. 5 demonstrates the number of packets received per second sat the sink for various transmission rates. It shows different threshold values for various transmission rates (100,200,300,400,500).For about 80 seconds of simulation time it shows that the threshold reaches to 85 percentage on implementing HRCT whereas it reaches only to 60 percentage without implementing HRCT. Thus the throughput of the network is increased which is actually the desired goal of our protocol.

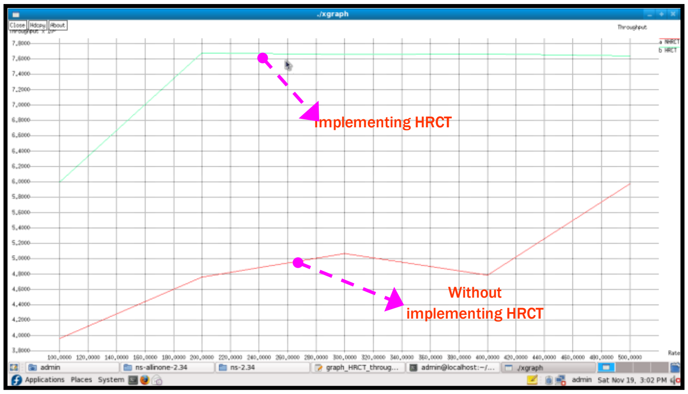

Figure 5. Transmission rate Vs. Throughput

II) Packet Drop

Fig. 6 demonstrates the number of packets dropped during the transmission from different sources to the sink. It shows different drop rate for various transmission rates (100,200,300,400,500). For about 80 seconds of simulation time it shows that the packet drop reduces to 25 percentage on implementing HRCT. Thus the packet drop is reduced , increasing the overall performance of the network.

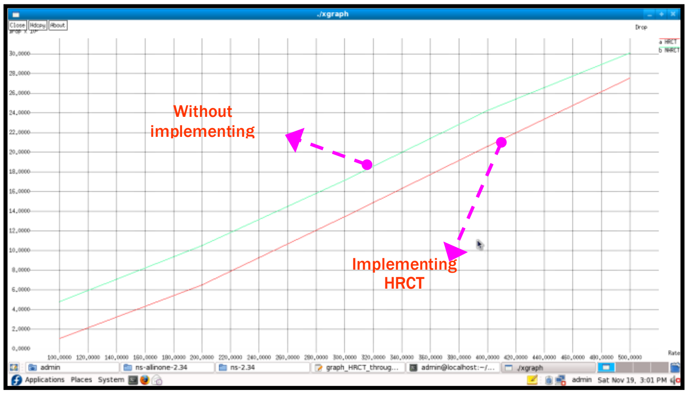

Figure 6. Transmission rate Vs. Packet Drop

V. CONCLUSION AND FUTURE WORK

This paper presents the congestion due to concurrent transmission in wireless sensor network. An effective and efficient protocol is developed to detect and control congestion. Throughput is calculated by varying sensor rate. In future HRCT will be implemented using Fuzzy Controller. The efficiency of the proposed protocol is evaluated by analyzing network parameters.

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