FIPD: Fuzzy Based Intelligent Packet Dropping Technique for Congestion Due to Buffer Overflow in Wireless Sensor Network

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***Abstract* – Congestion plays a vital role in degrading the performance of the network. Under idle condition, network traffic is less whereas when an event is detected, the network traffic becomes high thus leading to congestion in the network. To ensure the reliability of the network an efficient protocol is proposed to detect and control congestion. Though there are various sources for congestion, the significant source for congestion is Buffer Overflow . We have proposed a new algorithm to detect and control congestion in a Wireless Sensor Network using Fuzzy Logic Controller. The congestion is detected by calculating the back logged packets in the queue. Depending on Buffer Occupancy(B_O) , level of congestion is analyzed . In order to control congestion , an effective congestion control algorithm called Fuzzy Based Intelligent Packet Dropping(FIPD) is proposed. Congestion is controlled by dropping the packets based on priority assigned to the data packets i.e Intelligent Packet Dropping. This technique is implemented successfully in NS-2 simulator.**

Keywords – Wireless Sensor Networks, Congestion detection, Buffer Overflow , Buffer Occupancy, Fuzzy based congestion Control

I. INTRODUCTION

Wireless Sensor Networks (WSNs) has an emerging applications in various fields like military, health, environment, agriculture etc.,. The wireless sensor network generate various types of traffic depending on the events. When no event is detected then the data transmitted is less where there is no congestion. When an event is detected , the data transmitted is more which leads to congestion. There are various sources for congestion: i) Buffer Overflow ii) Concurrent Transmission iii) Many to One nature iv) Packet Collision v) Reporting Rate. 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]. The effects of congestion are: (i) 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.

The motivation behind congestion detection comes from the role of the structure and applications of WSNs. For example in an environmental monitoring system, hundreds of sensors can be placed over a flat area (thereby forming a *flat* WSN) which supports low-rate periodic sensing[1]. Applications requiring high data-rate can easily cause congestion problem. The structure of wireless sensor network with data transmission from source nodes to sink is shown in the fig.1.

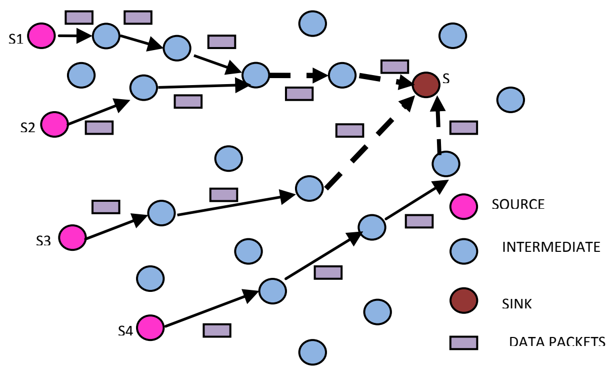

Fig. 1: Structure of Wireless Sensor Networks

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 this work, Buffer Occupancy (B_O) is used to detect congestion. When the Buffer Occupancy exceeds the threshold value it intimates, that, congestion has occurred. To control congestion Fuzzy Based Intelligent Packet Dropping Technique (FIPD) is implemented.

In this paper, an effective and efficient congestion control protocol is proposed to prevent the network from entering the congestion collapse state.

II. Related Work

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 is 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 [20] a congestion control mechanism has been proposed for WSN. An efficient congestion detection technique addressing both node and link level congestion has been proposed.

Upon various paper cited it is very clear that no technique has been implemented using Fuzzy Logic Controller (FLC) to control congestion.

III. System Overview

In this section, a new technique called Fuzzy Based Intelligent Packet Dropping technique (FIPD) has been implemented to control congestion due to buffer overflow. When an event is detected the number of active sources increases. When the number of active sources increases, the data packets generated are more ,which increases the inter-arrival time. Thus packets are accumulated in the buffer. Evaluating the buffer at the node in the network during the data transmission will infer the occurrence of congestion. In Fig. 2, a node with 'N' buffer size with data packets serviced in First In First Out pattern is shown. As the accumulation of packets increases it leads to packet drop, which in-turn leads to congestion in the network. Thus an efficient and accurate algorithm has been proposed to detect and control congestion.

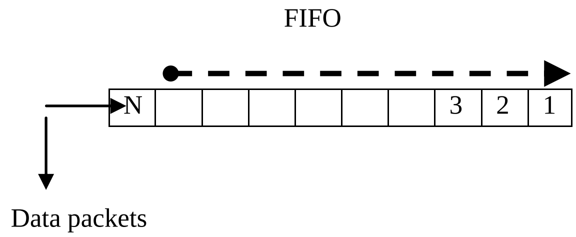

Fig 2: Buffer at each node.

In FIPD, the congestion is controlled by using Fuzzy Logic Controller. Congestion detection is done by calculating the Buffer Occupancy. Buffer Occupancy is calculated using backlogged packets in the queue. If the measured Buffer Occupancy is greater than threshold, it intimates that the congestion has been occurred , else there is no congestion in the network. Once the congestion is detected, it is controlled using FIPD. Fig. 3 shows the architecture of the proposed technique.

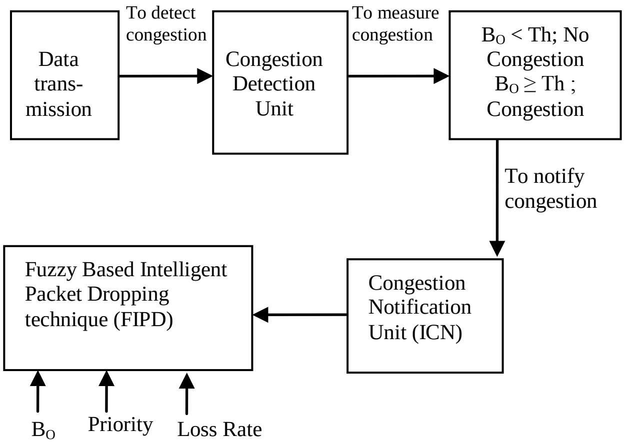

Fig. 3: Architecture of proposed technique

A. *Congestion Detection Unit*

This section, describes about the congestion detection technique. To detect the congestion a new metric called Buffer Occupancy (B_O)is used. Buffer Occupancy is calculated using the ratio between Total number of data packets transmitted per sec to Total number of data packets received per sec.

Buffer Occupancy (B_O) = P_T/ P_R

Where P_T = Total number of data packets transmitted/sec

P_R = Total number of data packets received/sec

After calculating the Buffer Occupancy (B_O), the calculated value is compared with threshold value. When Buffer Occupancy ,value is greater than or equal to threshold value, then it infers congestion has occurred. When Buffer Occupancy value is less than threshold value, then it infers there is no congestion.

$B_O <$ Th; No Congestion

Packet departure is faster than arrival.

$B_O \geq$ Th ; Congestion

Packet departure is slower than arrival.

When packet departure is faster than arrival then there is no backlogged packets, thus there is no congestion. But when packet departure is slower than arrival then it increases the backlogged packets which lead to congestion.

B. *Congestion Notification Unit*

When the congestion is detected, the notification signal is sent to intermediate nodes. There are two types of congestion notification signal. They are Implicit Congestion Notification (ICN) and Explicit Congestion Notification (ECN). In ICN, the notification signal is sent along with the data packet. In ECN, the notification signal is sent as separate packet. In the proposed work Implicit Congestion Notification is used to send notification signal to all nodes in the network. The signal is send along with the data packets to nearby nodes.ICN is an effective technique than ECN, because in ECN the notification is sent as separate packet. So this makes heavy traffic in the network which leads to congestion.

IV. Fuzzy Logic Controller

In WSNs, fuzzy logic is used for improving decision-making, reduce resource consumption, and increase performance of the network. Some of the areas it has been applied to are cluster-head election [10], [11], security [12], [13], data aggregation [14], routing [15], [16], MAC protocols [17], and QoS [18], [19]. However, not much work has been done on using fuzzy logic for congestion control. The proposed work is mainly focuses on Fuzzy Logic Controller to control congestion.

A. *Overview of Fuzzy Logic*

The structure of Fuzzy Logic Controller is shown in the fig.3. A Fuzzy system basically consists of three parts: fuzzifier, inference scheme, and defuzzifier. [4] The fuzzifier maps each crisp input value to the corresponding fuzzy sets and thus assigns it a truth value or degree of membership for each fuzzy set. The fuzzified values are processed by the inference scheme, which consists of a rule base and various methods for inferring the rules. The rule base is simply a series of IF-THEN rules that relate the input fuzzy variables with the output fuzzy variables using linguistic variables, each of which is described by a fuzzy set, and fuzzy implication operators AND, OR *etc*. All the rules in the rule-base are processed in a parallel manner by the fuzzy inference scheme. Any rule that fires contributes to the final fuzzy solution space. The inference rules govern the manner in which the consequent fuzzy sets are copied to the final fuzzy solution space.

The defuzzifier performs defuzzification on the fuzzy solution space. That is, it finds a single crisp output value from the solution fuzzy space.

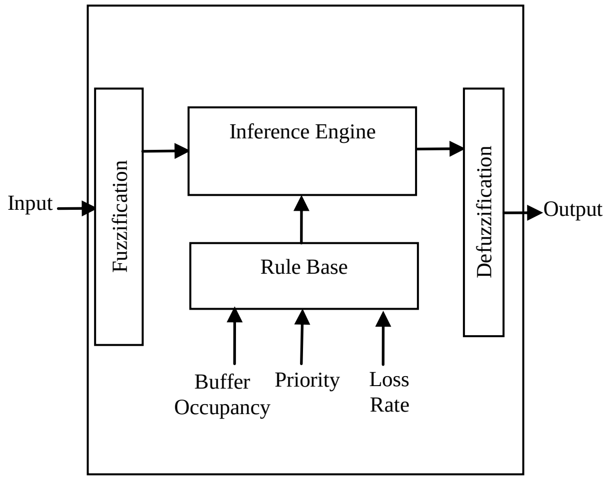

Fig. 4: Structure of Fuzzy Logic Controller.

B. *Fuzzy Based Intelligent Packet Dropping Technique Unit*

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This section, describes about the proposed congestion control technique for wireless sensor networks. The proposed technique is called Fuzzy Based Intelligent Packet Dropping (FIPD) technique. In FIPD the congestion is controlled using Fuzzy Logic Controler.

The main objective of our fuzzy routine is to drop the packets based on priority, so that the performance of the network is improved. The performance of the network can be improved by improving the delivery ratio and reducing the delay in the network. Thus, the fuzzy rule base has been turned so as to not only increase the delivery ratio but also to reduce delay in the network. The fuzzy rule base has been shown in the Table I. The fuzzy rules are framed by using three input linguistic variables namely Buffer Occupancy, Priority and Loss Rate. The values for linguistic variables are Low (L), Medium (M) and High (H). Therefore the rule base consists of 27 rules. In this, there is a single output fuzzy variable, namely Rate, which is the defuzzified value that adjusts the transmission rate of the sensor nodes. The value for fuzzy output variable is Increased High (IH), Increased Minimum (IM), Decreased High (DH) and Decreased Minimum (DM).

In FIPD the congestion is controlled by using the Fuzzy Rule Base. Once the node receives the congestion notification signal it drops the packet based on priority.

Table- I

Fuzzy Rule Base

Rule	Incoming Data Rate	Node Degree	Loss Rate	Rate
1.	L	L	L	I
2.	L	L	M	I
3.	L	L	H	DM
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
27.	H	H	H	DH

114

C. *Algorithm Description*

- *Setup initial nodes in the given area*
- *Assign nodes with capability of sensing data when an event is set*
- *Set the maximum size of the buffer as 50 & current as 0*

while
Packets are being transmitted in the Network and received at nodes
do
check for buffer size
if
Current buffer size exceeds Queue Threshold
then
Congestion has Occurred
Fuzzy based congestion control technique is implemented
else
No Congestion
end if
end while

V. SIMULATION STUDY

A. *Simulation settings*

A summary of simulation parameters is given in Table II. A Wireless Sensor Networks (WSNs) which consists of 200 sensor nodes in 1500m x 1500m area is created. The data packets are transmitted and received by the nodes using Destination Sequenced Distance Vector (DSDV) routing protocol. When an event is detected the sensor nodes transmits more number of data packets. When more number of nodes try to seize the same node, congestion will occur due overflow of buffer. Once the congestion is detected the each intermediate sensor node adjusts drops the data packets based on priority in order to control congestion. To detect and control congestion an effective and efficient technique is implemented in NS2 Simulator. The network performance is evaluated by calculating delay and packet delivery ratio.

B. *Simulation Scenario*

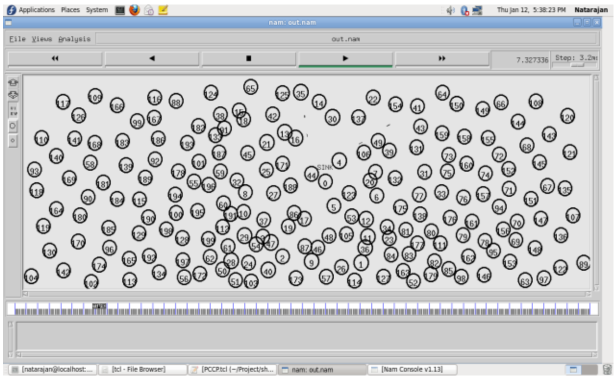

Fig.5: A scenario with data transmission in network with 200 sensor nodes.

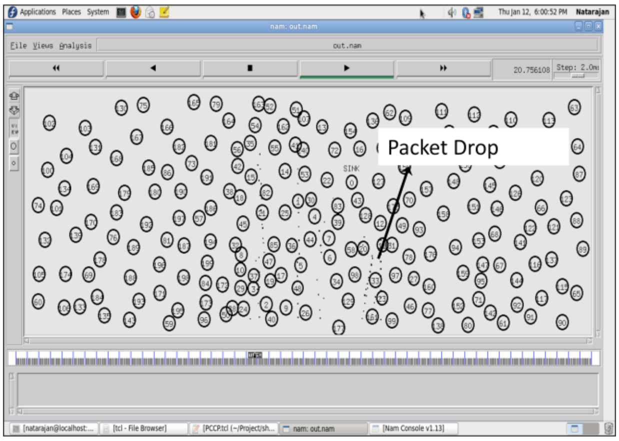

Fig.6: A scenario with packet drop in network with 200 sensor nodes.

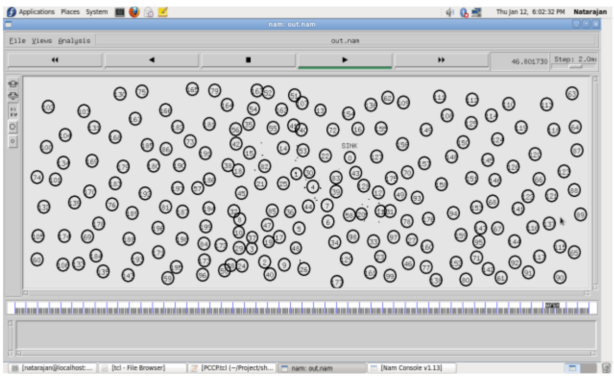

Fig.7: A scenario with congestion control in network with 200 sensor nodes.

Fig. 5 shows the scenario with transmission of data packets in the network of 200 sensor nodes. Fig. 6 shows the scenario with packet drop due to buffer overflow in the network. After controlling the congestion the network with 200 sensor nodes is shown in the fig.7.

C. *Simulation Results*

In this paper two main parameters are analysed, they are Packet delivery ratio and Delay. The simulation result shows the effectiveness of the proposed technique. Fig. 7 shows the simulation result for Packet Delivery ratio. Here the proposed technique FIPD (Fuzzy Based Intelligent Packet Dropping Technique) is compared with HRCT (Hop-by-Hop Rate Control Technique). On implementing the FIPD the delivery ratio of the network is increased when compared with HRCT. The simulation result shows that the delivery ratio of FHRCT is 100%, but for HRCT is 91% for less number of active sources.

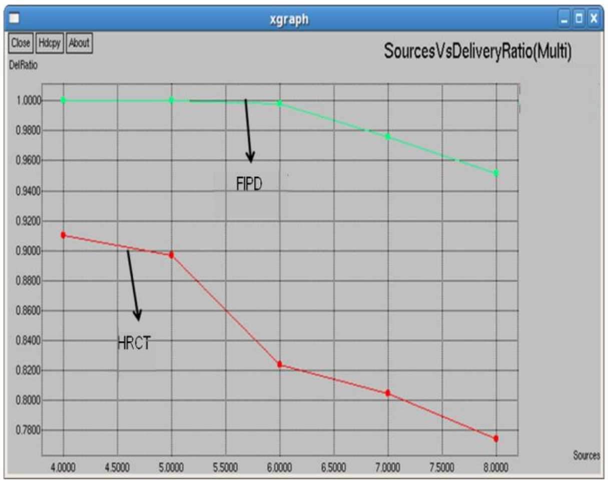

Fig.8: Number of Active Source Vs Packet Delivery Ratio.

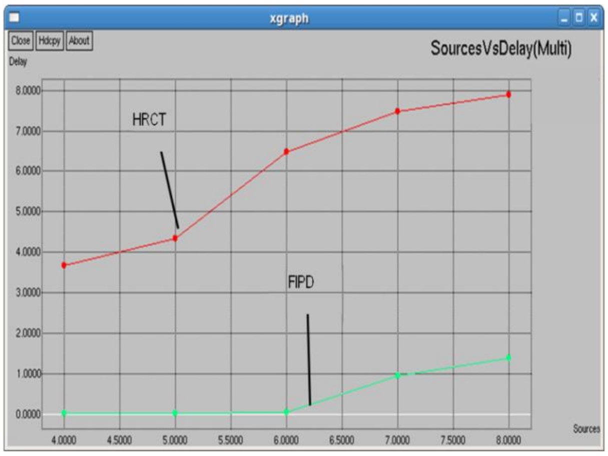

Fig.9: Number of Active Sources Vs Delay.

Another main parameter analysed here is delay. When delay increases, overall performance of the network is decreased to an extent. This paper focuses on improving the overall performance of the network by reducing the delay. In Fig. 8 FIPD technique is compared with HRCT. On the implementation of FIPD the overall delay is reduced when compared with HRCT.

VI. CONCLUSION AND FUTURE WORK

An efficient congestion control algorithm namely FIPD has been successfully developed for congestion control. The performance of this technique is compared with HRCT in terms of delay and packet delivery ratio. It is found that proposed technique provides better results than the conventional methods. In future the FIPD technique will be implemented to analyse the network throughput.

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