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Congestion Detection and Mitigation Protocols for Wireless Sensor Networks

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ABSTRACT

Congestion control is tremendously important area within wireless sensor networks (WSN). With the appearance of new network applications, the non-stop increasing traffic is starting to experience unexpected situation of network congestion. Congestion in wireless sensor network affects the nonstop flow of data, loss of information, delay and reduces the energy of nodes due to overhead of retransmission. Therefore, congestion needs to be control in wireless sensor network in order to extend system lifetime, improve fairness and quality of service and to attain high energy efficiency. This paper revives different routing protocols used in wireless sensor networks to mitigate and control congestion and to provide consistency for different applications and prolong the life of the wireless sensor network.

Keywords : WSN (Wireless sensors networks), Congestion, Congestion Control.

I. INTRODUCTION

Wireless sensor networks (WSN)[1] consists of various wireless devices mount with various types of sensors, shown in Fig.1 to assemble information such as temperature, pressure, humidity, sound, vibration and wind speed from the surroundings. Wireless sensor network widely applied to environment such as environmental monitoring, target tracking, habitat monitoring, healthcare, telecommunication monitoring, military surveillance and factory monitoring. When the event is occurring for which the system is installed the sensors activate and begin to send the data to the base station.

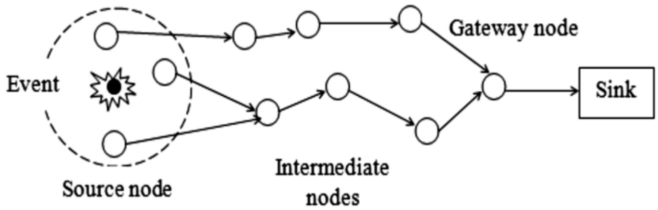

Figure 1: Wireless Sensor network

If the event is occurring frequently or with high value or many sensors capture the same event occurring they will send more packets to the base station as a result congestion starts from that point and spreads along its links as shown in Fig 2. Data crossing that sub-network (area of congestion) would suffers from prolonged delays (buffer waiting) eventually leading to timeouts (loss rate).

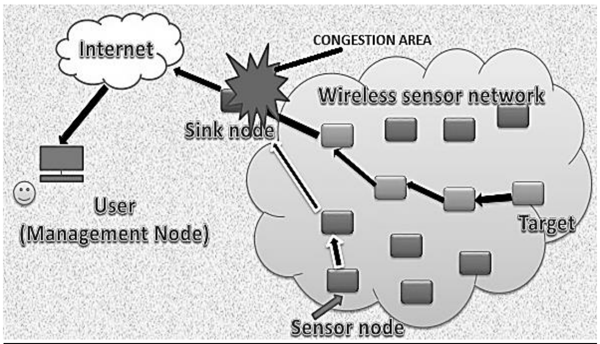

Figure 2 : Congestion Scenario in WSN

Initially the researchers are interested in the design of routing scheme to enable data transfer in WSN. But later on they realized that there must be such a mechanism to address the situation when there is chance of congestion or congestion has occurred. In this paper we give an overview of the congestion control and detection protocols/Techniques in Wireless Sensor Networks. We have to first avoid the congestion so that the congestion did not occur and if the congestion occurs then we will try to mitigate the congestion using different techniques.

In Section “A” we have discussed FUSION which is congestion detection and avoidance mechanism uses hop by hop congestion detection like CODA [3] but the difference is that it uses implicit notification or congestion notification bit in the header of packet. It also include prioritized MAC scheme to ensure fairness i.e. unlike CSMA[2] which gives equal chance to every node to transmit their data but in this technique the high priority nodes which have more data then we assign extra time to drain their buffer. In Section “B” we have discuss the CODA (Congestion detection and avoidance) technique which uses the buffer overflow and channel sensing for congestion detection. Once the congestion is detected we use the back pressure and close loop method to inform the other nodes that the congestion is occurred and also to inform them to limit their sending data rate. In section “C” we have discuss anther protocol for congestion detection and avoidance named CCF(Congestion control and Fairness) protocol which states that every node is able to control the rate of its downstream nodes This allows the root node to reduce the generation rates of all downstream nodes. By reducing the transmission rates of all downstream nodes when this node's queue is full or about to become full, it allows the queue to empty. CCF guarantees simple fairness so that each node receives the same throughput. In Section "D" we have discussed another congestion control protocol which is priority based congestion control protocol for wireless sensor network. The node priority index is brought in to show the importance of every one node. In Section “E” we have discussed another congestion control protocol named ECODA (Enhanced Congestion Detection and Avoidance) protocol which is the superior version of CODA which uses dual buffer thresholds to detect congestion and a queue scheduler that arrange the packets for transmission and to drop the packets with low priority when the buffer is about to full or accedes the upper limit of the buffer. On node level it uses the back pressure method and bottle neck data sending rate control for congestion mitigation. ECODA cares of the high priority packets in the manner if the congestion has occurring the flexible queue scheduler select the low precedence packets for dropping to defeat the congestion.

II. METHODS AND MATERIAL

A.Related Work

FUSION MECHANISIM

FUSION IS DESIGN TO PROVIDE UPSTREAM CONGESTION CONTROL MECHANISM IT CONSISTS OF THREE CONGESTION MITIGATION TECHNIQUES APPLY IN DIFFERENT LAYERS, THAT IS

i. Hop-by-hop flow control

Using hop by hop flow control a sensor node present congestion detection and congestion mitigation congestion is discover through both queue occupancy and channel sampling techniques. The hop by hop flow control scheme in FUSION is similar to backpressure scheme in CODA[9]. The only difference in fusion is that each sensor node sets a congestion bit in the header of every outgoing packet instead of using backpressure messages.

ii. Rate limiting of source traffic in the traffic in the transit sensor nodes to provide fairness.

When a sensor node overhear a packet from its parent node (the node closer to the sink) with the congestion bit is set, it stops forwarding data toward the sink, Rate limiting is a defensive scheme to avoid congestion.

iii. Prioritized MAC(Medium Access Control)

FUSION also includes a prioritized MAC scheme to guarantee that congested nodes receive prioritized access to the channel. In traditional CSMA mechanism each node has the same opportunity to send the data over the channel but in WSN the parent’s nodes that are closed to the sink may gather more traffic and can overflows if it does not have more chances to send out its packets. To avoid this problem FUSION uses a random back-off time for each node is introduced which it related to its local congestion state so that the congested nodes may drain its buffer faster.

CODA (Congestion Detection and Avoidance)

CODA is an energy conserving and efficient control technique that is designed to solve congestion in the upstream direction i.e., the sensor to sink direction.

It involves three mechanism which is following:

B. Congestion Detection

Accurate and efficient congestion detection plays an important role in the congestion control of wireless networks. The detection method in CODA is the receiver based congestion detection. CODA uses a combination of the present and past channel loading conditions, and the current buffer occupancy, to infer accurate detection of congestion at each receiver with low cost. Sensor networks must know the state of the channel since the transmission medium is shared and may be congested with traffic between other nodes in the neighborhood. Listening to the channel to measure local loading incurs high energy costs if performed continually. Therefore, CODA uses a sampling scheme that activates local channel monitoring at the appropriate time to minimize cost while forming a accurate estimate.

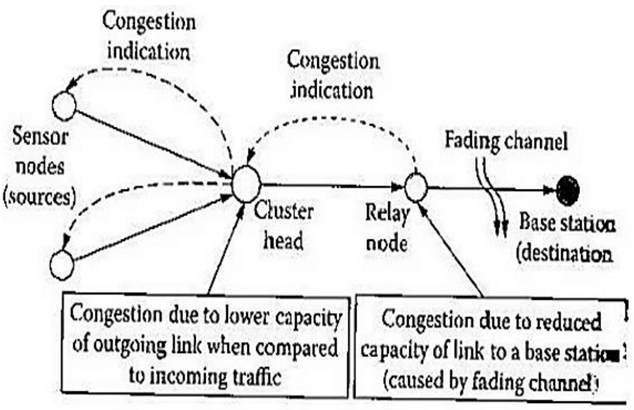

Figure 3: Congestion detection and notification in CODA

i. Open-loop, hop-by-hop backpressure

Once congestion is detected node broadcast backpressure message and this message circulate towards the source as shown in Fig. 3. In CODA, a node broadcasts backpressure mechanism as long as it detects congestion. The node detecting congestion will report its upstream neighbors to reduce rate of data flow. A node that receives a backpressure message will adjust its sending rate by Adaptive Increase Multiplicative Decrease, the AIMD rate adjustment technique or by dropping packets based on the local congestion plan. When an upstream node (towards the source) receives the backpressure message, it decides whether it has to further propagate the backpressure upstream based on the local network situation.

ii. Closed-loop, multisource regulation

The cost of closed loop flow control is high compared to open loop flow control because it required feedback signaling. CODA runs Closed-loop congestion control mechanism on the sink to regulate multiple sources in the case of continual congestion. Essentially when the transmission rate of a source surpass maximum theoretical throughput (Smax) the source informs the sink by setting a bit in every packet that it transmits to the sink as long as the transmission rate remains higher than Smax. in response sink starts sending ACKs to the source until the sink detects congestion. When the sink detects congestion, it stops sending ACKs until the congestion is alleviated, to implicitly notify to drop its rate.

Disadvantages of CODA

1. Unidirectional control from sensors to sink.
2. Decreased reliability.
3. The delay and response time increases under heavy closed loop congestion

CCF(Congestion Control and Fairness)

In this section we propose a distributed and scalable algorithm that purges congestion within a sensor network, and that ensures the fair delivery of packets to a central node, or base station. We say that fairness is achieved when equal number of packets is received from each node. Congestion control and fairness [4] for many-to-one routing method is a distributed and scalable algorithm which eradicates the congestion in a wireless sensor network. CCF provides hop-by-hop upstream congestion control that not only eliminates congestion but also ensure fair delivery of packets to the base station [6] in CCF fairness is achieved when an equal number of packets are received from each node to the base station or sink by maintaining a separate queue for each their preceding hop node. CCF detects congestion based on packet service time and control congestion based on hope-by-hope manner. In CCF the congestion of any node can be evaluated by the number of available child nodes (downstream nodes) the average rate at which the packets can be sent by it. When the congestion is experienced it informs the downstream nodes to reduce their data rate and vice versa by implicit notification like closed loop hop-by-hop backpressure in CODA [5] .

Limitations:

i. CCF uses only packet service time to detect congestion and therefore it cannot detect either under utilization nodes or links.
ii. CCF does not provide any reliability mechanism i.e. preserve equal resource for each sensor node.

PCCP (Priority Based Congestion Control Protocol):

In Priority based Congestion Control [7] node priority index is introduced to reflect the importance of each node. PCCP is a more rapid and more energy well-organized congestion control algorithm than CCF. PCCP maintains a priority index which is used as an indicator of the importance of each node. The packet inter arrival time and the packet service time are used together to find out the degree of congestion.

Intelligent congestion detection (ICD)
Implicit congestion notification (ICN)
Priority based rates adjustment (PRA)

C. Intelligent congestion detection (ICD):

Not like in TCP in which congestion is detected at the endpoints in PCCP congestion is locally detected in the intermediary nodes, based on the mean packet inter-arrival time (t_a) which is the mean of the time between two successively arriving packets and the packet service time (t_s) [8] which is the time between the MAC layer and the successful broadcast of the last bit ICD can be define as

$$d(i) = t_s / t_a$$

The congestion degree helps in estimating the current congestion level at each intermediate node.

D. Implicit Congestion Notification (ICN)

PCCP uses the technique of ICN to attached congestion information in the header of the data packets. The congestion information is stored in the header of the packets that are forwarded when trigged by either of the following two events.

- When the threshold is exceeded by the number of packets forwarded by a node.
- When a congestion notification is heard by a node from its parent node.

At every node "i" PCCP attached t_a, t_s and overall priority value.

E. Priority based rates adjustment (PRA)

The additive increase and multiplicative decrease (AIMD) used in conventional transport control protocols such as TCP is not of much help in adjusting the transmission rate as the congestion notification bit holding limited information. Therefore it is important for the nodes to be notified as to precisely how much to increase or decrease the rate the congestion degree. The priority index and the global priority values help in providing more information for exact rate adjustment.

ECODA (Enhanced Congestion Detection and Avoidance)

ECODA is an energy efficient congestion control scheme for sensor networks. In this method, the given method is followed.

i. Dual Buffer threshold Congestion detection:

The dual buffer thresholds and weighted buffer difference are used to detect the congestion. The Fig shows the details of buffer state such as “accept state ”, “filter state” and “reject state)”. The different buffer states are pretend different channel loading which is used to accept or reject packets in different states.

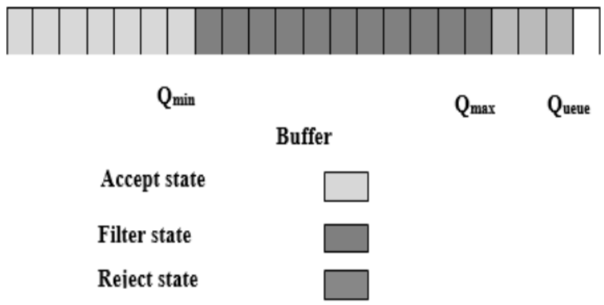

Figure 4: Dual Buffer threshold Congestion

The packet at each node has to send for buffer monitoring and attached its weighted buffer changing rate (WR) and weighted queue length (WQ) with outgoing packets. The corresponding congestion level bit in the outgoing packet header is set if a node’s buffer occupancy exceeds a certain threshold.

The ECODA [10] care of high priority packets, if the node data is most essential among its neighbors then if congestion take place, other nodes should lower down their data sending rate to mitigate node's congestion so that the high priority packets may reach to the station in time.

Two thresholds Q_{min} and Q_{max} are used to show different buffer states. Different buffer states imitate different channel loading, corresponding strategy is adopted to accept or reject packets in different states.

ii. Flexible queue scheduler and weighted fairness:

The Flexible Queue Scheduler is used to drop a low priority packet rather than the high priority packet when a high priority packet arrives if the queue in a sensor node is nearly full and dominated with low priority packets. At the same time, the high priority packet may be dropped due to queue overflow with tail-dropping.

For managing packets with different strategy, two thresholds are used such as Qmin and Qmax .
The scheduler works based on the following steps:

a. If ($0 \leq N \leq Qmin$) :

All incoming packets are buffered, because queue utilization is low.

b. If ($Qmin \leq N \leq Qmax$) :

Some packets with low priority are dropped or overwritten by succeeding packets with high priority.

c. If ($Qmax \leq N \leq Q$):

Some packets with high dynamic priority is dropped or overwritten, then the expected average buffer length increases at a rate of two variables that can be tuned to achieve best possible system performance.

iii. A bottleneck-node-based source sending rate control scheme

Both transient (temporary) and persistent (continiual) congestion handle by ECODA. It makes use of hop-by-hop backpressure mechanism to handle transient congestion. It uses bottleneck node based source sending rate control and multipath load balancing to handle persistent congestion. This mechanism does not required explicit ACK from sink; every node determines routing path status from sink and sender find better path to forward data. Bottleneck node identified and source data sending rate adjust more accurately using this mechanism.

III. CONCLUSION

In this paper we have reviewed different wireless sensor routing protocols / algorithm for congestion control, reliability and packet loss. There are several protocols for congestion control in wireless sensor network. This paper present an overview of several congestion control techniques like FUSION, CODA, CCF, PCCP and ECODA. Also the comparative analysis of congestion control techniques is presented using several parameters like throughput, delay and energy consumption which shows among the these techniques Enhanced Congestion Detection and Avoidance (ECODA) is best for congestion control as it attain high throughput, less delay & less consumption of energy compare to other techniques [12-20].

Comparision Table of congestion control protocols

Protocol Name	Congestion Detection	Congestion Notification	Rate adjustment
FUSION	Queue length	Implicit	Hop-by-Hop rate adjustment
CODA	Queue length and channel state	Explicit	Rate adjustment similar to AIMD
CCF	Packet service time	Implicit	Hop-by-Hop rate adjustment
PCCP	Packet interval time and service time	Implicit	Hop-by-Hop rate adjustment
ECODA	Dual buffer threshold and weighted buffer difference	Implicit	Hop-by-Hop rate adjustment

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