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A Review on Congestion Control Techniques in Wireless Sensor Networks

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Abstract: IEEE 802.15.4 high density Wireless sensor network consist of large number of nodes, when any event occurs these sensor node becomes active in transmitting, it increases data traffic. Due to large volume of data transmission and restricted bandwidth congestion occurs. This leads packets to get delay, they even may get drop, throughput is reduced energy consumption is increased. A congestion control scheme in wireless sensor network based on IEEE 802.15.4 standard is necessary to regulate traffic level at an acceptable value. Congestion may occur in wireless sensor network based on IEEE 802.15.4 standard when data packets arrive at node and there is no space in the buffer. Congestion may also occur when all sensors send the data at the same time. This causes throughput reduction, packet loss and packet delay and wastage of limited energy. This seminar presents a survey of traffic control and resource control mechanisms to control congestion in wireless sensor networks based on IEEE 802.15.4 standard. It presents their significance, limitations and makes a comparison among them on the basis of various factors which would help in the future research and investigation in this particular area.

Keywords: IEEE 802.15.4, Network Congestion, Wireless Sensor Network, Congestion Control

I. INTRODUCTION

A. Wireless Sensor Network (WSN) based on IEEE 802.15.4 standard :
Wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions such as temperature, sound, pressure and vibrations. They are constructed by nodes where each of them is connected to sensors. A sensor node will have a radio transceiver with an internal antenna, a microcontroller for interfacing and a battery for its functioning. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes.IEEE 802.15.4 is one of the available wireless standards.IEEE 802.15.4 is a proposed standard addressing the needs of low-rate wireless personal area networks LR-WPAN with a focus on enabling the wireless sensor networks.WSNs are made up of energy constrained nodes embedding limited transmission, processing and sensing capabilities. Therefore, network lifecycle becomes short and hence energy-efficient technique implementation becomes an important requirement for wireless sensor network

B. Congestion in IEEE 802.15.4 WSN :
There are several issues related to WSN. One of the crucial concerns is congestion. Congestion takes place when data packets arrive at a node and no space is present in the buffer. Congestion may occur when all the sensors send the data at the same time. Congestion occurs when unpredictable events occur. Due to the convergent nature, WSN may suffer from congestion. Congestion leads to missing packets, packet delay, throughput reduction and energy losses which can hardly be afforded in a WSN. In fact, the objective of WSN would be blurred if there is a loss of important data packets.

C. Reasons for Congestion :
Congestion occurs due to several reasons that are briefly discussed below. Nodes that are nearer to the base stations need to transmit more data packets, hence their traffic burden will be more. This situation may lead to serious packet collisions, network congestion and packet loss. Congestion can also occur due to the packet loss, which takes place during collision. For the unpredictable bursts of messages, simple periodic events can be generated in this type of network. Congestion becomes more accountable due to interaction of concurrent data transmissions over varying radio links or due to increase in the reporting rate to the base station.

Efficient mechanisms that guarantee the balanced transmission rates for different types of data are required to provide congestion control. From a multi-hop network, the sensor forwards the data generated by the nodes at a constant rate to a single sink. Due to the increase in the offered load, the loss rates can increase rapidly. Lack of buffer space at a sensor node causes error in the wireless channel. Due to this, the losses are separated. The buffer drops are reduced by the channel losses. Finally, the offered load increases rapidly. There is an opportunity for scarcity of resources due to high reporting rates by numerous events. This occurs though the event is few bytes long and leads to congestion and packet or event drops. As the data traffic becomes heavier in sensor node, packets might be put into the nodes buffer and have to wait for access to the medium that is shared by a number of communication entities. In such cases, congestion can happen in the network. If network congestion becomes more severe, some packets will be dropped due to limited buffer size. This will potentially result in loss of packets, decrease in throughput and waste of energy.

D. Types of Congestion :
Two types of congestion could occur in WSNs. They are node level congestion and link level congestion
Node Level Congestion: The first type is node-level congestion that is common in conventional networks. It is caused by buffer overflow in the node and can result in packet loss, and increased queuing delay. Packet loss in turn can lead to retransmission and therefore consumes additional energy.
For WSNs where wireless channels are shared by several nodes using Carrier Sense Multiple Access (CSMA) protocols, collisions could occur when multiple active sensor nodes try to seize the channel at the same time. This can be referred to as link level congestion.
Link Level Congestion: Link-level congestion increases packet service time, and decreases both link utilization and overall throughput, and wastes energy at the sensor nodes. Both node-level and link-level congestions have direct impact on energy efficiency and QoS.

II. TECHNIQUES FOR CONGESTION CONTROL

Congestion control is a method used for monitoring the process of regulating the total amount of data entering the network to keep traffic levels at an acceptable value. Congestion control has to consider network capacity and application requirements. A number of schemes were proposed to address these challenges:

A. CODA (Congestion based Detection and Avoidance) :
CODA is an energy conserving and efficient control technique designed to solve congestion in the upstream direction. i.e. the sensor to sink direction.
It involves of two main schemes:
1) Open loop hop by hop backpressure mechanism.
2) Closed loop multisource regulation.
The detection method in CODA is the receiver based congestion detection. It considers a combination of both present and past loading conditions of the current buffer occupancy in the receiver. [1]

Disadvantages of CODA are
1) unidirectional control from sensors to sink.
2) Decreased reliability.
3) Delay and response time increases under heavy closed loop congestion.

B. ESRT (Event to Sink Reliable transport) :
This technique overcomes on of the disadvantages of CODA. ESRT is tailored to match the design requirements of WSN such as event detection and signal estimation/tracking. ESRT works based on two parameters: Event reliability and reporting frequency. Event reliability is defined as the number of data packets received at the decision interval at the sink. The end-to-end data delivery services are regulated by adjusting the sensor report frequency. If the reporting frequency is too low, the sink will not be able to collect enough information to detect the events. But if the reporting frequency is too high, it endangers the event transport reliability. ESRT adjusts the reporting frequency such that the observed event reliability is higher than the desired value to avoid congestion the congestion detection in ESRT is by local buffer level of the sensors nodes. It adds a congestion notification bit on the packets header when congestion occurs.

Disadvantages: All sensor nodes are controlled at once as a result the regions of higher node density and lower node density are given the same energy levels. Multiple event source congestion is ignored as ESRT lays more emphasis on reliability and energy conservation ESRT assumes and uses a wireless channel that operates on one hop using high power which might affect the on-going data traffic. [2]

C. CONSISE(Congestion control for Sink to Sensors) :
Technique that works downstream i.e., from the sink to sensor direction. Conventionally, congestion happens in the sensor-to-sink direction but, the reverse is also possible. The reasons are broadcast storm problem that refers to higher

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levels of collision that occurs on a series of local broadcast and reverse path traffic from sensors to sink. Congestion in the sensor-to-sink direction will not be rare if WSN is built over CSMA/CA type of MAC and flooding based routing protocol.

In CONSISE, every node maintains two parameters: a receiving rate and a sending rate. CONSISE adjusts the sending rate of each sensor node to make use of the available network bandwidth efficiently. CONSISE algorithms are run both in sensor nodes and sink periodically. Every node maintains two parameters: a receiving rate and a sending rate.[4] The working of CONSISE - at the end of each epoch an ACK is given to the upstream node (closer to the sink) depending on the traffic and then adjusting the sending rate. To receive packets as fast as possible, the downstream node selects an upstream node. After getting notified as preferred upstream node, the data is sent at higher rate without any congestion. CONSISE algorithms are run both in sensor nodes and sink periodically. [3]

D. Priority based congestion Control protocol (PCCP) :
Is an upstream congestion control protocol which measures congestion degree as the ratio of packet inter-arrival time to the packet service time.It is designed in a way that the data packets have a guaranteed weighted fairness so that sink can get different throughput from the sensor nodes but in a weighted way. PCCP is intended to improve energy-efficient and support traditional QoS in terms of latency, throughput and packet loss ratio. PCCP can be of three components:
1) Intelligent Congestion Detection (ICD).
2) Implicit Congestion Notification (ICN).
3) Priority-based rate adjustment.

ICD detects congestion based on the packet inter-arrival time and service time, ICN notifies congestion. A novel scheme is employed in each sensor nodes in order to generate both flexible fairness and throughput. [5]
Scheme is designed in such a way that:
1) The node with high priority gets higher bandwidth.
2) The nodes with same priorities gets equal Band width.

E. CCF(Congestion Control and Fairness) :
CCF, adjusts traffic rate based on packer service time along) with fair packet scheduling algorithms. Eliminates congestion with a sensor network and ensures the fair delivery of packets to the sink node. Working- each node measures the average rate r at which packets can be sent, divide the rate among the children nodes, adjust the rate if the queue is overloaded and propagate the rate downstream. It is designed to work with any MAC protocol in the data link layer and it exists in the transport layer. It controls congestion in a hop-by-hop manner and each node uses exact rate adjustment based on its available service rate and child node number. [6]

It has two major disadvantages:
1) The rate adjustment is based on packet service time which leads to low utilization as it has significant packet error rate.
2) It cannot allocate the remaining effective capacity as it uses work-conservation scheduling algorithm.

F. PSFQ(Pump Slowly and Fetch Quickly (PSFQ) :
Control protocol aims at distributing data from) sink-to-sensors i.e., it belongs to the downstream reliability guarantee. PSFQ is based on slowly injecting packets into the network pump operation and performing aggressive hop-by-hop recovery in case of packet loss fetch operation and selective status reporting reporting operation. The pump operation consists of timely controlled data forwarding. The sink broadcasts a packet with its file ID, file length, sequence number and report bit to its neighbours till at the data fragments are sent. In intermediate nodes, the packets that are received is stored in out-of-order sequence. The sectors of data are not forwarded entirely in this case, instead it requests for re transmission of the missing segment. The fetch operation happens when the sensor goes into the fetch mode to request re transmission of fragment from neighbouring nodes once loss is detected at the receiver. It sends a NACK in a reverse path to recover the missing fragment as a retransmission request containing the sequence number of the missing segment the reporting operation happens when the sink sends a feedback to the sensor upon the delivery status. This is done with the help of a simple and scalable hop-by-hop report mechanism. [7]

Disadvantages:
1) Since it uses hop-by-hop recovery, it requires more buffer space.
2) The transmission of data packets are relatively slow in operation and hence there is large delay in the system.
3) PSFQ cannot detect a loss of single packets individually as it uses NACK signals for indication and the entire block is re transmitted upon request.
4) It cannot be used in the forward direction and does not address packet loss due to congestion.

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G. SMACS(Self-organizing Medium Access Control) :
Self-organizing Medium Access Control (SMACS) is one of the SMAC TDMA-based techniques in which TDMA techniques should be included to the data link layer congestion control mechanism as nodes have to switch-off for some time, to avoid idle listening and through this avoid energy starvation of the device. This is an important case because listening and transmitting are both very energy-expensive operations in a low-power radio. However, in other cases, it can consume more energy. Hence, this technique is only suitable for low-power radio application. [8]

Disadvantages of SMACS: Consume more energy

III. COMPARISON OF CONGESTION CONTROL TECHNIQUES

After studying the various techniques, we came to conclusion that the above techniques give show the best attempts to control congestion and improve the efficiency of the system to the best possible level. We should select the best possible solutions among all others which will serve the purpose of improvement in throughput at the same time it will not affect the basic attractive features of 802.15.4 like low power consumption, high reliability and low complexity. Table I shows the comparison of various congestion control techniques that are reviewed under Section II.

TABLE I COMPARISION OF VARIOUS CONGESTION CONTROL TECHNIQUES

Technique	Metrics Used	Advantages	Disadvantages
CODA	Buffer size, end-to-end delay, response time, fairness	Suitable for event driven networks and achieve better fairness along with congestion control	Under heavy closed loop congestion, reliability is less with more delay and response time
ESRT	Buffer size	Achieve reliable event detection with minimum energy expenditure and congestion resolution	ESRT affect the on-going data traffic due to the high power single hop channel
CONSISE	Flow rate & no energy conservation	efficient use of the available network bandwidth	no energy conservation
PCCP	Congestion degree, inter-arrival time, packet service time	Improve energy-efficient and support traditional QoS	Often delay occur
CCF	Packet Service Time	High throughput and ensures the fair delivery of packets	It fails to allocate the remaining effective capacity
PSFQ	Round Trip time	Suitable for constrained devices	Not compatible with IP and needs precise time synchronization between sensor nodes
SMACS	Energy consumption, throughput	Suitable for low-power radio application	Consume more energy

IV. CONCLUSION AND FUTURE SCOPE

The above techniques give show the best attempts to control congestion and improve the efficiency of the system to the best possible level.

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These analysis leads to the following conclusion:
1. A unified protocol that can handle both reliability and congestion control is needed.
2. An integrated protocol that levers both the direction of flow, sensor-to-sink (upstream) and sink-to-sensors (downstream) would be preferred.
3. Energy efficiency over transport protocols in future needs emphasized.

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