Congestion in Wireless Sensor Networks and Mechanisms for Controling Congestion

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Abstract - The unique characteristics of WSN such as coherent nature of traffic to base station that occurs through its many-to-one topology and collision in physical channel are main reasons of congestion in wireless sensor networks. Also when sensor nodes inject sensory data into network the congestion is possible. Congestion affects the continuous flow of data, loss of information, delay in the arrival of data to the destination and unwanted consumption of significant amount of the very limited amount of energy in the nodes**.** Therefore Congestion in wireless sensor networks (WSN) needs to be controlled in order to prolong system lifetime improve fairness, high energy-efficiency, and improve quality of service (QoS). This paper has mainly described the characteristic and the content of congestion control in wireless sensor network and surveys the research related to the Congestion control protocols for WSNs.

Keywords - Wireless Sensor Networks, WSNs, Congestion control, protocols**.**

1. Introduction

Wireless sensor networks (WSNs) are generally composed of one or more sinks and tens or thousands of sensor nodes scattered in a physical space. With integration of information sensing, computation, and wireless communication, the sensor nodes can sense physical information, process crude information, and report required information to the sink. These sensors are small, with limited processing and computing resources [1]. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. The common task of sensor node is to collect the information from the scene of event and send the data to a sink node. Figure 1 shows the typical wireless sensor network that consist of multiple number of sensor nodes and one sink where data is collected are deployed in the sensing field. WSNs can be used in many applications such as habitat monitoring, security surveillance, target tracking, medical application and etc. Wireless sensor network (WSN) is a high degree of cross-disciplinary, highly integrated knowledge on network communication, and is a forefront research hot spot in the world [2].

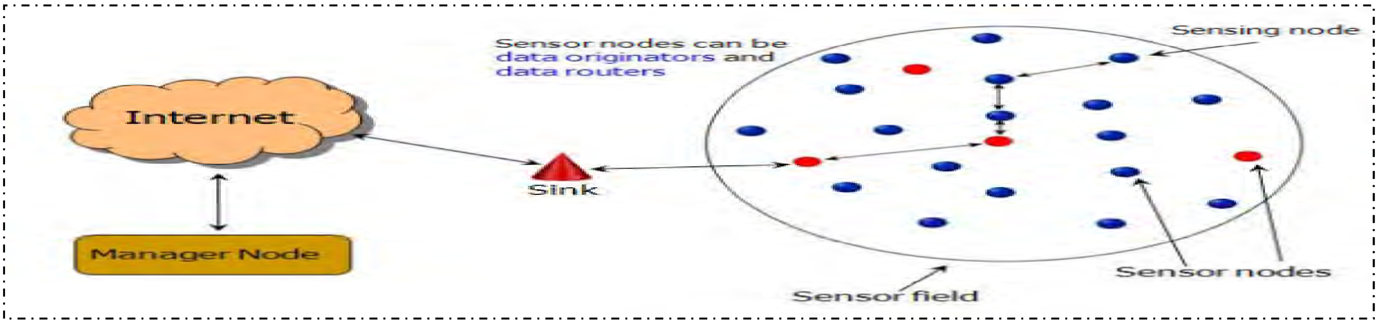


Fig1: wireless sensor network

2. Congestion In Wireless Sensor Networks

Many wireless sensor network applications require that the readings or observations collected by sensors be stored at some central location. Congestion can occur while collecting the data and sending it towards the central location over the wireless sensor network. Congestion happens mainly in the sensors-to-sink direction when packets are transported in a many-to-one manner. Congestion in WSNs has negative impacts on network performance and application objective, i.e., indiscriminate packet loss, increased packet delay, wasted node energy and severe fidelity degradation. The purpose of WSN congestion control is to improve the network throughput, reduce the time of data transmitted delay. Under this circumstances, node energy, communications bandwidth, network computing capacity and other resources is generally limited. It is possible to improve the network performance through the protocols design, route algorithm choose, data integration and load balancing, and so on. [3].

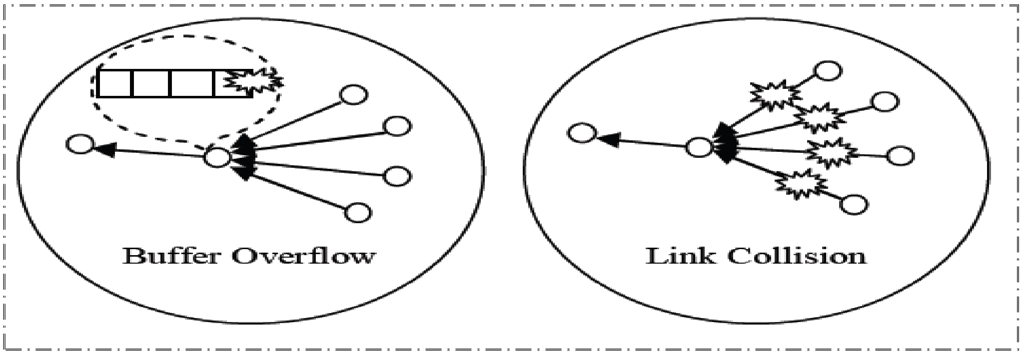
3. Congestion types in Wireless Sensor Networks

- Node-level congestion:

The 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[4].

- Link-level congestion:

In a particular area, severe collisions could occur when multiple active sensor nodes within range of one another attempt to transmit at the same time.. Packets that leave the buffer might fail to reach the next hop as a result of collision. This type of congestion decreases both link utilization and overall throughput, while increasing both packet delay and energy waste [5] [6].



1- Node-level congestion 2 - Link-level congestion

Fig2: Congestion types in WSNS

4. Overview Of Congestion Control Protocols In Wireless Sensor Networks

There have been several attempts to solve the problem of congestion control. In a review of related works in the context of wireless sensor networks congestion control is presented.

Congestion Avoidance and Detection (CODA)

CODA [7] is energy efficient congestion control mechanism designed for WSNs. CODA, detects the congestion by observing the buffer size of sensor nodes and the load of the wireless channel. If these two characteristic exceed from a pre-defined threshold, a sensor node informs its neighbour to decrease the transmission rate. Before transmitting a packet, a sensor node divides the channel to fixed periods. If it found the channel busier than pre-defined times, it adjusts a control bit to inform the base station of the congestion.

Congestion Control and Fairness (CCF)

CCF [8]detects congestion based on packet service time at MAC layer and control congestion based on hop-by-hop manner with simple fairness. CCF uses packets service time to deduce the available service rate and detect the congestion in each intermediate node. When the congestion is experienced, it informs the downstream nodes to reduce their data transmission rate and vice versa.

Adaptive Rate Control (ARC)

ARC [9] monitors the injection of packets into the traffic stream as well as route-through traffic. Each node estimates the number of upstream nodes and the bandwidth is split proportionally between route-through and locally generated traffic, with preference given to the former. The resulting bandwidth allocated to each node is thus approximately fair. Also, reduction in transmission rate of route-through traffic has a backpressure effect on upstream nodes, which in turn can reduce their transmission rates.

SenTCP

SenTCP [10] is an open-loop hop-by-hop congestion control protocol with two special features: 1) It jointly uses average local packet service time and average local packet inter-arrival time in order to estimate current local congestion degree in each intermediate sensor node. The use of packet arrival time and service time not only precisely calculates congestion degree, but effectively helps to differentiate the reason of packet loss occurrence in wireless environments, since arrival time (or service time) may become small (or large) if congestion occurs. 2) It uses hop-by-hop congestion control. In SenTCP, each intermediate sensor node will issues feedback signal backward and hop-by-hop. The feedback signal, which carries local congestion degree and the buffer occupancy ratio, is used for the neighboring sensor nodes to adjust their sending rate in the transport layer. The use of hop-by-hop feedback control can remove congestion quickly and reduce packet dropping, which in turn conserves energy. SenTCP realizes higher throughput and good energy-efficiency since it obviously reduces packet dropping; however, SenTCP copes with only congestion and guarantees no reliability.

Fairness Aware Congestion Control (FACC)

FACC [11] is a congestion control mechanism, which controls the congestion and achieves fair bandwidth allocation for each flow of data. FACC detects the congestion based on packet drop rate at the sink node. In FACC nodes are divided in to two categories near sink node and near source node based on their location in WSNs. When a packet is lost, then the near sink nodes send a Warning Message (WM) to the near source node. After receiving WM the near source nodes send a Control Message(CM) to the source node. The source nodes adjust their sending rate based on the current traffic on the channel and the current sending rate. After receiving CM, flow rate would be adjusted based on newly calculated sending rate.

Fusion

In Fusion [12] hop by hop flow control mechanism is used for congestion detection as well as congestion mitigation. Congestion is detected through queue occupancy and channel sampling technique at each intermediate node. Congestion notification (CN) bit will set in the header of every outgoing packet when the node detects congestion. Once the CN bit is set, neighboring node can overhear it and stop forwarding packet to the congested node.

Priority Based Congestion Control Protocol (PCCP)

PCCP[13] [14] is a congestion control mechanism based on node priority index that is introduced to reflect the importance of each sensor node. Nodes are assigned a priority based on the function they perform and its location. Nodes near the sink have a higher priority. The congestion is detected based

on the ratio of sending rate to the packet arrival rate. If the sending rate is lower, it implies that congestion has occurred. The congestion information is piggybacked in data packet header along with the priority index. Nodes adjust their sending rate depending on the congestion at the node itself. PCCP tries to reduce packet loss in congestion state while achieving the weighted fairness transmission for single-path and multipath routing.

Trickle

Trickle[15], an algorithm for propagating and maintaining code updates in wireless sensor networks **.** Trickle's basic primitive is simple: every so often, a mote transmits code metadata if it has not heard a few other motes transmit the same thing. This allows Trickle to scale to thousand-fold variations in network density, quickly propagate updates, distribute transmission load evenly, be robust to transient disconnections, handle network repopulations, and impose a maintenance overhead on the order of a few packets per hour per mote. Trickle sends all messages to the local broadcast address. There are two possible results to a Trickle broadcast: either every mote that hears the message is up to date, or a recipient detects the need for an update. Detection can be the result of either an out-of-date mote hearing someone has new code, or an updated mote hearing someone has old code. As long as every mote communicates somehow - either receives or transmits - the need for an update will be detected. For example, if mote *A* broadcasts that it has code φ, but *B* has code φ+1, then *B* knows that *A* needs an update. Similarly, if *B* broadcasts that it has φ+1, *A* knows that it needs an update. If *B* broadcasts updates, then all of its neighbors can receive them without having to advertise their need. Some of these recipients might not even have heard *A*'s transmission. Trickle uses "polite gossip" to exchange code metadata with nearby network neighbors. It breaks time into intervals, and at a random point in each interval, it considers broadcasting its code metadata. If Trickle has already heard several other motes gossip the same metadata in this interval, it politely stays quiet: repeating what someone else has said is rude.

Siphon

Siphon [16] aims at controlling congestion as well as handling funneling effect. Funneling effect is where events generated under various work load moves quickly towards one or more sink nodes, which increases traffic at sink which leads to packet loss. Virtual sinks are randomly distributed across the sensor network which takes the traffic load off the already loaded sensor node. In siphon initially VS discovery is done. Virtual sink discovery is initiated by the physical sink by as explained in . Node initiated congestion detection is based on past and present channel condition and buffer occupancy as in CODA [7]. After congestion detection traffic is redirected from overloaded physical sink to virtual sinks. It is done by setting redirection bit in network layer header.

Prioritized Heterogeneous Traffic-oriented Congestion Control Protocol (PHTCCP)

PHTCCP [17] is an efficient congestion control protocol for handling diverse data with different priorities within a single node motivates**.** PHTCCP module works interacting with the MAC layer to

perform congestion control function. In this protocol , we focus on efficient mechanism so that congestion could be controlled by ensuring adjustment transmission rates for different type of data that generated by the sensors have various priorities. We assume that the sink node assigns individual priority for each type of sensed data and each node has n number of equal sized priority queues for n types of sensed data Heterogeneous applications can reflect the number of queues in a node. In congestion detection method, congestion level at each sensor node presented by packet service ratio.

$r(i) = R_s^i / R_{sch}^i$, R_s^i is the ratio of average packet service rate and R_{sch}^i is the packet scheduling rate in each sensor node.

Learning Automata-Based Congestion Avoidance Algorithm in Sensor Networks (LACAS)

In LACAS [18] the problem of congestion control in sensor nodes are dealt with utilizing an adaptive approach based on learning automata. This protocol causes the rate of processing (rate of entry of data) in nodes to be equivalent to the rate of transmission in them so that the congestion occurrence gradually decreases. An automaton is placed in each node which has the ability of learning. In fact it

can be considered as a small piece of code that interacts with environment and makes decisions based on the characteristics of it.

5. Conclusion

In recent years there has been a growing interest in Wireless Sensor Networks (WSN). The impact of wireless sensor networks on our day to day life can be preferably compared to what Internet has done

to us. Both the factors of congestion control and reliability helps in reducing packet loss, which results in an energy efficient operation of the network, which is a key factor in increasing the lifetime of the sensor network. Another factor to be taken into account by the transport protocols is the limited resources of the node devices. Although these congestion control techniques are promising there are still there are many challenges to solve in wireless sensor network to handle congestion control efficiently. And more research efforts are needed to continue to improve congestion control in WSNs.

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