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A Survey on Congestion Control in Wireless Sensor Networks

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ABSTRACT

In Recent years, wireless sensor network plays a vital role in various fields. A Wireless Sensor Network is deployed with large number of sensor nodes. These sensor nodes acquire real time information and transmit the information. When large number of sensor nodes are active in transmitting the information there is a possibility of congestion in the data packets. Congestion occurs due to buffer overflow, channel contention, Packet collision, Reporting rate, Many to One nature, dynamically time varying wireless channel condition. Congestion causes packet loss which in turn decreases network performance and throughput. It necessitates a congestion control algorithm for lossless data packet transmission. Many congestion control algorithms are available in literature. This paper reviews various existing techniques for detecting and controlling congestion. The techniques include Congestion Detection and Avoidance, Traffic Adaptive MAC, Event to Sink Reliable Transport, Congestion Control and Fairness. In addition, different performance metrics for measuring congestion was also surveyed. In this paper a comparison between the performances of the various congestion control techniques is also provided.
Keywords: Wireless Sensor Networks, Congestion, Congestion Detection and Control.

1. INTRODUCTION

Wireless sensor network (WSN) consists of spatially distributed autonomous sensors nodes to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units. These nodes collects and transmits the information. Under light load the data traffic in the network is light. When an event has been detected, the load becomes heavy and the data traffic also increases. This might lead to congestion.

The most predicament issues that happen in WSN is Congestion**.** There are many sources for congestion. They are buffer overflow, concurrent transmission, packet collision and many to one nature. Congestion causes packet loss, which in turn reduces throughput and energy efficiency. Therefore congestion in WSN's needs to be controlled for high energy-efficiency, to prolong system lifetime, improve fairness, and improve quality of service (QoS) in terms of throughput (or link utilization) and packet loss ratio along with the packet delay. A WSN consists of one or more sinks and perhaps tens or thousands of sensor nodes scattered in an area. Congestion restraint generally follows two steps: congestion detection and congestion control.

Accurate and efficient congestion detection plays an vital role in congestion control in sensor networks. Congestion detection is the methodology in which that abnormality in the normal traffic is been made out. i.e when a packet is been transferred from one node to other predicament events can happen. Congestion Is controlled by various techniques like Congestion Detection and Avoidance, Event to Sink Reliable Transport, Congestion Control and Fairness

In this paper, we make highlight on different congestion detection and control technique in Wireless Sensor Network. In section 2, the different methods for congestion detection in wireless sensor network has been discussed. Section 3 deals with congestion controlling techniques that increases efficiency and throughput in WSN. Section 4 deals with a detailed study of pros and cons of different technique. Section 5 and Section 6 are conclusion and references.

2. CONGESTION DETECTION FOR WIRELESS SENSOR NETWORK

The major issue in wireless sensor network is congestion. So an accurate and efficient congestion detection plays an important role in WSN. There are various detection techniques which has low cost in terms of energy and computation complexity. Those techniques are discussed below:

Energy efficient congestion detection method like CODA deals with various degrees of congestion depending on the sensing application [1]. Congestion detection protocols can be implemented by two main schema i) Open-loop hop-by-hop backpressure technique, ii) Closed-loop multi-source regulation technique. In Open-loop hop-by-hop backpressure technique, backpressure is generated as long as congestion is detected when an upstream node (toward the source) receives a backpressure message it decides whether or not to further propagate the backpressure upstream based on its own local network conditions. In closed loop multi-source regulation technique, when the source event rate is less than some fraction of the maximum theoretical throughput of the channel, the source regulates itself. However a source is more likely to contribute to congestion and therefore closed-loop congestion control is triggered, the source only enters sink regulation if this threshold is exceeded. At this point a source requires constant, slow time-scale feedback (e.g., ACK) from the sink to maintain its rate. The reception of ACKs at sources are served as a self-clocking mechanism allowing sources to maintain their current event rates. In contrast, it fails to receive ACKs which forces a source to reduce its own rate.

In Hop-by-hop Backpressure [2] if the sink is congested, backpressure spatially spreads the congestion and helps alleviate congestion quickly. In addition, hop-by-bop control supports in-network data processing. Once congestion is detected, the receiver will broadcast a suppression message to its neighbors. Hop-by-hop control signals are propagated upstream toward the source. It needs at least one round-trip-time (RTT) to detect congestion. The hop-by-hop backpressure can immediately response to the congestion at the intermediate node without incurring the round trip delay that reduces feedback's effectiveness.

Queue Occupancy [3] is a simple way to detect congestion relies on monitoring a sensor's queue size: if the fraction of space available in the output queue falls below a high water mark á. the congestion bit of outgoing packets is set. Otherwise the congestion bit is cleared.

In Receiver-based Congestion Detection [1], it 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 side. Once congestion is detected, nodes signal their upstream neighbors via a backpressure mechanism.

In Event to Sink Reliable Transport [4], a sensor sets a congestion notification bit in the packet header if its buffer is full. The sink periodically computes a new reporting rate based on a reliability measurement, the received congestion notification bits and the previous reporting rate. In Congestion Control and Fairness [5], it uses packet service time to deduce the available service rate and detects congestion. Each Sensor node uses rate adjustment based on its available service rate and number of child nodes. CCF provides simple fairness for all nodes with same throughput. But fairness can maintained while each node gets same priority.

Intelligence Congestion Detection [6] method is used to measure local congestion level at each intermediate node, the packet inter-arrival time (P_a) and packet service time(P_b) at MAC layer is taken into consideration. Using P_a and P_b we can derive Congestion Degree (CD)[5][8]. By taking the value of CD into consideration we can detect the occurrence of congestion.

$$CD = P_b / P_a$$

If the value of CD is greater than 1 we can ensure that there is no congestion occurred, if the value results in lesser than 1 the congestion is been detected.

Table 1
Comparison on different Congestion Control Algorithms

Techniques	*Dataflow Direction*	*Loss Recovery Control*	*Congestion Notification*
Receiver-based congestion detection	Upstream	Buffer Occupancy	Backpressure
Open-loop hop-by-hop backpressure	Upstream	Intermediate Node	Backpressure
Closed-loop multi-source regulation	NA	Source Node	ACK
Hop-by-Hop Backpressure	Upstream	Sink Node	Backpressure
Queue occupancy	NA	Queue size	Congestion bit
Event to Sink Reliable Transport	NA	Sink Node	Congestion bit
Intelligence Congestion Detection	Upstream	Intermediate node	Implicit congestion notification

3. CONGESTION CONTROL FOR WIRELESS SENSOR NETWORK

The Congestion control algorithms prevent the network from entering Congestive Collapse. Congestive Collapse is a situation where, although the network links are being heavily utilized, very little useful work is being done. This kinds of cases is being handled effectively by large number of algorithms.

In HMAC [7] it gives proportional access, i.e. a node carrying higher amount of traffic gets more access to the medium than others. Therefore, downstream nodes obtain higher access to the medium than the upstream nodes. This access pattern is controlled with local values and is made load adaptive to cope up with various application scenarios. The congestion process can be normalized when there is a synchronization between upstream node and downstream node. To implement this we have to check whether sufficient buffer space is available at the downstream node. The method that promotes this strategy is Weighted Round Robin Forwarding [7](WRRF).

In this method it avoids the packet to drop due to congestion by not allowing upstream nodes to transmit if there is not available buffer. This is been achieved by giving priority using the above method. The downstream node allows all the packets to be transmitted by the upstream nodes but all are not transmitted at the same time. For the first round some packets will be transmitted and likewise the process continues until all the packet is been sent. This provides efficient method for controlling congestion.

In priority Based Rate Adjustment technique (PRA)[5], when a notification for congestion is been made the rate is been limited accordingly. (i.e) when a congestion happens congestion notification bit which is used in AIMD gets information about how much decrease or increase in the rate for transmitting the packet has to be given so as to overcome the congestion.

Short Term Congestion Control [3] is a method in which node experiences congestion, its immediate child node split the real time traffic on to its alternate parent (route) in a proportion to their weight factor w_i. This weight factor w_i is solely depends on the end-to-end path delay from the alternative parent (route) node to the sink. This approach will eventually carry the newly created real time data flows at a slower rate along the primary route, allowing the congested node to be relieved and thus alleviate congestion.

In Long Term Congestion Control [3] when a back pressure message reaches the source node it initiates long-term congestion control. Source node sends proportionate real time traffic as the similar way of short-term congestion control along its alternate routes (parents) based on their weight factor w_i. Moreover, source node dynamically adjusts to the changing conditions and selects the best node (parent) as its primary route to send further packets. As a result subsequently both the real time and non-real time data flows will follow the changed or updated primary route.

In Priority based Congestion Control [5] node priority index is introduced to reflect the importance of each node. It uses inter arrival time along with packet service time for detecting Congestion Degree and uses hop-by-hop control technique. It consists of key components such as intelligence control detection, implicit congestion notification and priority based rate adjustment technique. Once a packet is sent it calculates the degree of congestion using the Congestion Degree formula [5][8]. This algorithm makes a notification about the occurrence of congestion. Thus occurrence of congestion will be announced to near by nodes. By getting the notification each nodes will adjust rate of transmission so as to control congestion.

In Pump Slowly Fetch Quickly, PSFQ [9] it takes a different approach and supports a simple, robust and scalable transport that is customizable to meet the needs of different reliable data applications. It is used to distribute data from a source node by pacing data at a relatively slow speed (“pump slowly”), but allowing nodes that experience data loss to fetch (i.e., recover) any missing segments from immediate neighbors very aggressively (local recovery, “fetch quickly”). In this case there is a possibility of getting packet to be lost. This can be made out by using a Negative ACK towards the source. Thus how the protocol provides control for congestion.

In Topology Aware Resource Adaptation (TARA) [10] the capacity of a given topology is defined by the maximum throughput (i.e. packet delivery rate) that can be observed by the sink(s). If there are no interferences between links, the capacity of a topology would be the same as the maximum throughput achievable by unlimited unidirectional transmissions in an one-hop topology. The interference between links makes the overall throughput much smaller than the one-hop capacity.

Light weight buffer management [11] is an effective approach that prevent data packets from overflowing the buffer space of the intermediate sensors. This approach automatically adapt the sensors’ forwarding rates to nearly optimal without causing congestion. It gives how to implement buffer-based congestion control with different MAC protocols. In particular, for CSMA with implicit ACK.

4. CONCLUSION

Congestion control in wireless sensor network is a new area of research, with a limited, but rapidly growing set of results. In this paper, we presented a comprehensive survey of congestion control technique in wireless sensor network. They have the common objective of trying to extend the lifetime of the wireless sensor networks.

Overall the congestion control techniques have been classified into categories like node level congestion control and link level congestion control. We have highlighted different strategy as well as pros and cons of different protocols.

Although these congestion control technique promising there are still many challenges that need to be solved in the wireless sensor network in this regard.

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