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Study of Various Congestion Control Protocols in Wireless Sensor Networks

Sagar Motdhare[1], Parag Puranik[2], Ujjwala Malkhandale[3]

[123]Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur

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Abstract - *A foremost problem with wireless sensor networks is that, they communicate through radio and air is the broadcast medium by default. Almost all of the link protocols for the wireless transmissions are also broadcast inherently. Because of this, congestion is very realistic concern in sensor networks. The fact that the cost of retransmission of a lost frame is very high for the energy constrained sensor node exacerbates the problem of congestion. Thus, there must be effective means to detect congestion and control it once detected. The congestion in sensor network has to be treated more of a network problem.*

Key Words: **Congestion Control, wireless sensor networks, energy efficiency**.

1.INTRODUCTION

Wireless Sensor Networks (WSNs) are a new class of networking technology that is increasingly becoming popular today. Huge strides taken in sensing technology, low power microcontrollers and communication radio have spurred the mass production of relatively inexpensive sensor nodes. Such large scale sensor networks far reimburse use of conventional networks in situations where terrain, climate and other environmental constraints obstruct the deployment and setting up of regular networks. Because of the tremendous scale at which such nodes can be deployed, they are extremely robust in terms of individual node failures which make them all the more favorable in such extreme situations. There has been an explosion in the use of sensor networks for environmental measurement and study. A series of applications have been built using sensor networks, from environmental monitoring to radiation recognition to lots of tracking applications. [8]

The sinks send queries or commands to the sensor nodes in the region while the sensor nodes collaborate to accomplish the sensing task and send the sensed data to the sink or sinks. The sinks also serve as a getaway to the outside network. The architecture of a WSN can be of two types: *Flat architecture and Hierarchical architecture.*[7][8]

Applications of WSNs in the areas of environment and habitat monitoring require the sensor nodes to periodically collect and route data towards a sink. Also, it is known that each sensor node can only be equipped with a limited amount of storage, so if at any given routing node the data collection rate dominates the data forwarding rate congestion starts to build up at this node A major problem with sensor networks is that, they communicate through radio and air is the broadcast medium by default. Almost all of the link protocols for the wireless transmissions are also broadcast intrinsically. Because of this, congestion is very sensible concern in sensor networks. There must be successful means to detect congestion and control it once detected. The congestion in sensor network has to be treated more of a network problem.

The phenomenon of congestion can be observed in different types of wired and wireless networks even in the presence of robust routing algorithms. Congestion in wireless sensor networks (WSN) mainly occurs because of two reasons -- when multiple nodes want to transmit data through the same channel at a time or when the routing node fails to forward the received data to the next routing nodes because of the out-of-sight problem. [8]

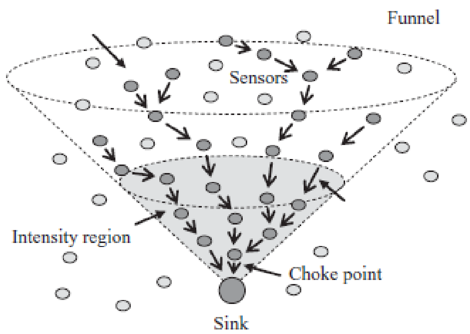

Fig-1: Funneling Effect in WSN

Such type of congestion and data loss normally occurs at the nodes located in the vicinity of a static sink. Data loss at these nodes occurs due to the fact that at any given point of time a sink can only communicate with one or a limited number of nodes.

In WSN, congestion has d direct impact on energy efficiency and application QOS. For example, congestion can cause buffer overflow that may lead to large queuing delay and higher packet loss. It also wastes the limited energy of a node and degrades link utilization.

In many scenarios, nodes will have to rely on a limited supply of energy (using batteries). Replacing these energy sources in the field is usually not practicable and hence a WSN must operate at least for a given mission time of as long as possible. Hence, the lifetime of a WSN becomes a very important figure of merit. To support long lifetime, energy efficiency operation is a key technique.

In this paper, we study various existing congestion control protocols designed for WSN as well as the problems using these protocols.

2. RELATED WORK

This section summarizes the currently available techniques for congestion avoidance and removal in a sensor network.

2.1 Congestion Control

There are mainly two reasons that result in congestion in a WSN. The first is the packet arrival rate exceeding the packet service rate. This is more likely to occur at the sensor nodes closer to the sink because they usually carry more combined upstream traffic. The second reason is contention, interference, and the bit error rate on a link, which can result in congestion on the link. In a WSN, congestion has a direct impact on energy efficiency and application QoS. For example, congestion can cause buffer overflow that may lead to larger queuing delay and higher packet loss. Not only can packet loss degrade reliability and application QoS, but also waste the limited energy of a node. Congestion can also degrade link utilization. Moreover, if a contention - based link protocol, for example, Carrier Sense Multiple Access (CSMA), is used to share the radio resources, it can result in transmission collision and link - level congestion, which will in turn increase packet service time and waste energy. Therefore, congestion must be efficiently controlled, either avoided or mitigated. Typically, there are three mechanisms that can deal with this problem: congestion detection, congestion notification, and congestion mitigation and avoidance. [7]

2.2 Loss Recovery

In wireless environments, both congestion and bit errors can cause packet loss, which would degrade end - to – end reliability and QoS, and further decrease energy efficiency. Other factors that result in packet loss include node malfunction, incorrect or outdated routing information, and energy depletion. In order to address this problem, one can increase the source sending rate or introduce retransmission - based loss recovery. Loss recovery is more active and energy efficient, and can be performed at both the link layer and the transport layer. At the link layer, loss recovery is performed on a hop - by – hop basis, while at the transport it is usually done on an end - to - end basis. In what follows, we introduce a loss recovery approach that consists of two phases: loss detection and notification, and retransmission recovery. [7]

2.3 Protocols for Congestion Control

Several congestion control protocols have been proposed for upstream convergent traffic in WSNs. They differ in congestion detection, congestion notification, or rate - adjustment mechanisms

Fusion. Fusion is a hop - by - hop congestion control protocol for upstream traffic in WSNs. In fusion, congestion detection is based on queue length and uses implicit congestion notification by means of setting a CN bit in the header of each outgoing packet. Due to the broadcast nature of the wireless channel, the neighboring nodes of a congested node can overhear such CN bits. Once getting the CN bit, a neighboring node stops forwarding packets to the congested node so as to eliminate congestion quickly. However, this kind of rate adjustment is non - smooth, which may affect link utilization and fairness more or less.[1]

Congestion Detection and Avoidance. CODA detects congestion based on current buffer occupancy and wireless channel load. It uses a particular suppression message to unambiguously notify whether there is congestion or not to the upstream nodes. After receiving such a suppression message, the upstream nodes will multiplicatively reduce their sending rates. On the other hand, the upstream neighboring nodes will linearly increase their sending rate if they do not receive any suppression message over a period of time. It may result in decreased reliability, especially under scenarios with sparse sources, and/or high data rates. The suppression message and ACK control message used in CODA consumes additional energy and bandwidth.[2]

Priority-Based Congestion Control Protocol. Priority – Based Congestion Control Protocol (PCCP) is a transport protocol recently proposed for WSNs. The node priority in PCCP is assumed to be application dependent and could be configured and updated by the sink. First, as a hop - by – hop congestion control protocol, it jointly uses packet inter arrival time and packet service time to estimate current local congestion degree in each intermediate sensor node. The combined use of the packet inter arrival and the packet service time not only precisely calculates congestion degree, but effectively helps differentiate the reason of packet loss occurrence in wireless environments because the packet inter arrival time (or service time) may become small (or large) if congestion is going to occur. Second, PCCP uses implicit congestion notification and avoids the overhead caused by control messages. Third, PCCP introduces a flexible priority - based rate control based on the measured congestion degree. This flexible rate control allows the nodes with more traffic to increase their sending rate when some nodes have smaller traffic than allowed so as to keep high throughput, and/or allocates more bandwidth to the nodes with a higher priority so as to guarantee priority - related fairness. In contrast, in order to guarantee that the sink gets the same number of packets from each node, CCF employs a work - conserving fair packet scheduling algorithm, which, however, could cause low throughput when some nodes have small traffic even if others have more.[3]

Siphon. Siphon is a traffic redirecting protocol, which manages upstream traffic overload with the novel introduction of multi radio virtual sinks (VS). The virtual sinks are supposed to be installed with at least two radio interfaces: One is a low - power mote radio and the other is a long - rage radio, for example, IEEE 802.11. The primary mote radio is used to connect sensor nodes, while the secondary powerful radio can be used to connect other virtual sinks or even the physical sink that provides a gateway to the Internet. When congestion occurs, Siphon triggers traffic redirection from sensor nodes to the virtual sinks, which in Turn forward the traffic using the long - range radio to other virtual sinks or even the physical sink. As a result, congestion can be mitigated quickly. The virtual sinks actually provide effective shortcuts for data delivery under traffic congestion.[4][6]

Trickle. Trickle is a controlled broadcasting protocol designed for propagating and maintaining code updates in WSNs and therefore operates in the direction of downstream. Trickle uses a local "Polite Gossip" to exchange code data among neighboring nodes. With Polite Gossip, each node tries to broadcast a summary of its data periodically so that all sensor nodes can get the same updates. In each period, each node can "politely" suppress its own broadcasting if the number of the same metadata, which this node receives from neighboring nodes, exceeds a threshold. On the other hand, if the nodes receive a new code or metadata, they can shorten the broadcast period, which thus leads to earlier broadcast of the new code. Trickle independently runs in each node and introduces no additional control overhead.[5]

3. OPEN PROBLEMS

The congestion control protocols discussed above consider either congestion control, reliability guarantee, or both. Some of them use end - to - end control while the others use hop - by - hop control. Some of them guarantee event reliability while the others provide packet reliability. However, the existing protocols for WSNs have two primary limitations. First, sensor nodes may have different importance in specific applications. For example, they can be equipped with different kinds of sensors and deployed in different geographical locations. Therefore, sensor nodes can generate sensory data with different characteristics and have different importance with respect to reliability and bandwidth requirements. Congestion control protocols guarantee simple fairness, which means that the sink needs to get the same throughput from all nodes. In addition, most reliability protocols use a single and identical loss - recovery algorithm for all nodes and applications. However, sensor nodes and applications may consist of diversified features and priorities, which require flexible loss recovery in order to optimize energy efficiency. Second, the existing transport protocols for WSNs assume that single – path routing is used at the network layer. Scenarios with multipath routing are not considered. It is not clear whether these protocols can be directly applied to WSNs employing multipath routing. For example, when multipath routing is utilized, a problem with congestion control protocols is how a sensor node adjusts its own sending rate and the sending rate of its child nodes in a fair and scalable manner. This is because with multipath routing a node may have multiple parents and multiple paths to the sink. The problem could be even more complicated if some nodes have multiple paths, while the others do not.[7]

4. CONCLUSION

This paper presented various congestion control protocols in a WSN to set up congestion free and energy efficient routing paths, leading to increased lifetime of the WSN. The use of these protocols can create a congestion free WSN environment which can reduce the impact of congestion on energy efficiency and application QOS.[7]

5. FUTURE SCOPE

In WSN, congestion has a direct impact on energy efficiency and application QOS. Moreover it leads to cause buffer overflow, packet loss and degrades link utilization. Thus, congestion and lifetime in a sensor networks has to be treated as a network problem Congestion in WSN basically occurs at nodes which are located in the vicinity of networks with static sink, which ultimately results in data loss. Existing Congestion Avoidance and Congestion Control Techniques leads to data loss as they do not directly apply to the multi hopping environment. If multiple sinks are employed around the field, then the network architecture will not be cost effective. Thus, a new approach employing MOBILE SINK can be proposed to avoid Congestion in WSN. [8]

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