AN INVESTIGATION OF CONGESTION CONTROL ALGORITHM IN WIRELESS SENSOR NETWORKS

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Abstract – The Performance of Wireless Sensor Networks (WSNs) can be affected when the network is deployed under different topologies. Without Proper Congestion control mechanisms, the network become highly complex. Congestion occurs due to buffer overflow and channel contention. Congestion causes packet losses, which in turn decreases network performance and throughput. It is important to design protocols to control congestion. It is also important to control traffic rather than forwarding path. In this paper, we investigate various congestion control algorithms and evaluate their characteristics.


I. INTRODUCTION

In Wireless Sensor Networks (WSNs), the packet loss occurs due to congestion. Congestion happens when the offered load is more than the available capacity of the network. There are two ways to face congestion. 1. Reducing the offered load (Traffic control method) and 2. Increasing Capacity (Resource control method). Traffic control methods can be considered to be more effective when transient overload situation exists, while resource control methods can also be considered to be more effective when persistent high load demands exists.

II. CONGESTION CONTROL

Congestion control involves controlling the network traffic in a telecommunications network, to prevent the congestive collapse by trying to avoid the unfair allocation of any of the processing or capabilities of the networks and making the proper resource reducing steps by reducing the rate of packets sent.

A. Goals of Congestion Control

Goals[1] that are taken for the evaluation process of a congestion control algorithm are as follows:
   i. To accomplish a high bandwidth utilization.
   ii. To congregate to fairness quickly and efficiently.
   iii. To reduce the amplitude of oscillations.
   iv. To sustain a high responsiveness.
   v. To coexist fairly and be compatible with long established widely used protocols.

III. CONGESTION CONTROL IN WIRELESS SENSOR NETWORKS

Congestion Control Mechanisms are composed from 3 sub-mechanisms: Congestion Detection which is the mechanism used to safely detect if the problem has occurred or is going to happen, the Feedback Mechanism, with which the sensor node, or the sink, gives feedback to the network to take some action according to the problem and the Control Scheme, which defines the actions taken. Congestion in WSNs[2] may appear in different types depending on how the packets are lost:

Type H1 Congestion - In a particular area, many nodes within range of one another attempt to transmit simultaneously, resulting in losses due to interference and thereby reducing the throughput of all nodes in the area. We note that explicit local synchronization among neighboring nodes can reduce this type of
loss, but cannot eliminate it completely because non-neighboring nodes can still interfere with transmission.

Type H2 Congestion - Within a particular node, the queue, or buffer used to hold packets to be transmitted overflows. This is the conventional definition of congestion, widely used in wired networks. This is also the main cause of packet losses. Type H2 assumes the existence of an effective MAC protocol which is able to transmit packets from different sources without collisions.

Type W1 Congestion - Hotspot near the source (transient) - Source Congestion. Densely deployed sensors generating data events during crisis state will create persistent hotspots very close to the sources (e.g., within one or two hops. In this scenario, localized, fast time scale mechanisms capable of providing backpressure from the points of congestion back to the sources would be effective. Also local de–synchronization of sources would be effective too.

Type W2 Congestion - Hotspot near the sink (Persistent) – Sink Congestion. Even sparsely deployed sensors that generate data at low data rates can potentially create transient hotspots anywhere in the sensor field, but more likely farther from the sources and near the sink.

Fast time scale resolution of localized hotspots using a combination of localized backpressure and packet dropping techniques would be more effective, in this case. Source nodes may not be involved in the backpressure because of the transient nature of the problem in this situation. Also an effective way of alleviating sink congestion is to deploy multiple sinks that are uniformly scattered across the sensor field, and then balance the traffic between these sinks.

IV. CONGESTION CONTROL ALGORITHMS IN WIRELESS SENSOR NETWORKS

DAIPaS (Dynamic Alternate Path Selection)[3] is a congestion control and avoidance algorithm that attempts to choose an alternative path in case of congestion taking into account a number of basic performance parameters. DAIPaS also takes into consideration the node’s congestion situation in terms of buffer occupancy and channel interference. On the other hand, congestion control and reliable data transfer protocols based on their alternate path decision on a congestion threshold or the path’s cost. DAIPaS also counts the node’s remaining power. DAIPaS is completely dynamic and distributed algorithm.

TARA (Topology Aware Resource Adaptation) protocol[4] focuses on the adaptation of network’s extra resources in case of congestion, alleviating intersection hot spots. TARA copes with buffer occupancy as well as channel loading. In TARA, congestion alleviation is performed with the assistance of two important nodes. These are the distributor and merger nodes. Thus, in case of congestion and creation of hot spots, traffic is deflected from the hot spot through the distributor node along th detour path and reaches the merge node, where the flows are merged. As long as congestion has been alleviated the network stops using the detour path. For quick adaptation the distributor node keeps in its memory which neighbor is on the original path.

CADA (Congestion Avoidance Detection Alleviation). In this algorithm[3] node’s congestion level is measured by an aggregation of buffer occupancy and channel utilization. It actually counts the growing rate of buffer’s occupancy and when exceeds a certain limit, node is consider congested. On the other hand, if packet delivery ratio decreases drastically while the local channel loading reaches the maximum achievable channel utilization, it infers that there is channel congestion. For Congestion mitigation CADA employs both resource control and rate control depending on the case of congestion. Simulation results prove that CADA present better results concerning throughput, energy consumption, end to end delay and average hop delay in comparison with TARA and “no congestion control” algorithm.

GRAB (GRAdient Broadcast) [3]addresses the problem of robust packets forwarding from source to sink in WSNs using multipath routing. GRAB is divided in three main parts. The first one is source selection. To limit the number of forwarded packets a single node is selected in each area of
stimuli, as the source that will forward the event packets. Source is selected as the node with the stronger signal and is called the Center of Stimuli (CoS). Following, the sink builds and maintains a cost field. The cost at a node is the minimum cost needed to forward a packet from this node to the sink. When a node is ready to forward a packet, it broadcasts this packet, having its cost included in the packet. Nodes, whose cost is equal or higher than the forwarding node’s cost, drop the packet. The rest broadcast the packet in the same way like the source. This procedure is repeated until the packet reaches the sink. Finally, to control the number of possible selected paths, the source assigns a credit to each packet it transmits. The sum of credit and source costs is the total budget that can be used to send a packet to the sink along a path. In this manner, the network mesh is wider near the source and becomes narrower near the sink.

**HTAP (Hierarchical Tree Alternate Path)** is a scalable and distributed framework for minimizing congestion and assuring reliable data transmissions in event based networks. As such, it does not employ rate limiting actions, but tries to maintain a high level of packet rate while minimizing packet losses. It is based on the creation of alternative paths from the source to sink, using the plethora of a network’s unused nodes, in order to safely transmit the observed data. The creation of alternative paths involves several nodes which are not in the initial shortest path from the source to the sink. The use of these nodes leads to a balanced energy consumption, avoiding the creation of “holes” in the network and prolonging network lifetime.

**Directed Diffusion** is a data centric protocol, because all communication is for named data. All nodes in a directed diffusion-based network are application-aware. This enables diffusion to achieve energy savings by selecting empirically good paths (small delay) by caching and processing data in network (e.g., data aggregation). Directed diffusion consists of four (4) basic elements: interests, data messages, gradients, and re-inforcements. An interest message is a query from a sink node to the network, which indicates what the application wants. It carries a description of a sensing task that is supported by a sensor network. Data in sensor networks is the collected or processed information of an event (e.g. physical phenomenon), it is named (addressed) using attribute-value pairs and a sensing task is diffused throughout the sensor network as an interest for named data. This dissemination sets up gradients within the network designed to “draw” events (i.e., data matching the interest). A gradient is a direction state created in each node that receives an interest. This direction is set toward the neighboring node from which the interest was received. Events start flowing towards the sinks of interests along multiple gradient paths. To improve performance and reliability, the empirically “good paths” (e.g small delay) are reinforced by the sink and their data rate increases. On the other hand, unreliable paths (e.g high delay) are negatively reinforced and pruned off.

**Drop Tail Algorithm** F. Postiglione et al., discussed that the drop Tail (DT) algorithm has a great accuracy, simplest and most commonly used algorithm in the current networks, which drops packets from the tail of the full queue buffer. The main advantages of this algorithm are simplicity, suitability to heterogeneity and its decentralized nature. However, this algorithm also has some serious disadvantages, such as lack of fairness, no protection against the misbehaving or non-responsive flows (i.e., flows where the sending rate is not reduced after receiving the congestion signals from gateway routers) and no relative Quality of Service (QoS). QoS is of particular concern for the continuous transmission of high-bandwidth video and multimedia information. This type of transmitting the content is difficult in the present Internet and network with DT.

**Random Early Detection Algorithm** B. Braden et al., discussed that the Random Early Detection Algorithm (RED) had been proposed to be mainly used in the implementation of AQM (Active Queue Management). On the arrival of each packet, the average queue size is calculated by using the Exponential Weighted Moving Average (EWMA) [7]. The computation of the average queue size is compared with the minimum and the maximum threshold to establish the next action.
Choke Algorithm Konstantinos Psounis et al., proposed CHOKe algorithm [8], whenever the arrival of a new packet takes place at the congested gateway router, a packet is drawn at random from the FIFO buffer, and the drawn packet is then compared with the arriving packet. If both belong to the same flow in the network then both are dropped, else the packet that was chosen randomly is kept integral and the new incoming packet is admitted into the buffer with a probability depending on the level of congestion. This computation of the probability is the same as in RED. It is a simple and stateless algorithm where no special data structure is required. However, this algorithm is not present well when the number of flows is huge when compared to the buffer space.

Blue Algorithms Rong Pan et al., discussed the basic idea behind the RED queue management system is to make early detection of the incipient congestion and to feed back this congestion notification and allowing them to decrease their sending rates accordingly. The RED queue length gives very less information about the number of contending connections in a shared link of the network. BLUE and Stochastic Fair Blue Algorithms (SFB) were designed to overcome the drawbacks of the problems caused by the RED techniques, the TCP flows are protected by using packet loss and link idle events against non-responsive flows. SFB is highly scalable and enforces fairness using an enormously miniature amount of state information and a small amount of buffer space. The FIFO queuing algorithm identifies and limits the non-responsive flows based on secretarial similar to BLUE [8].

Random Exponential Marking Algorithm According to Debanjan Saha the Random Exponential Marking Algorithm (REM) [9] is a new technique for congestion control, which aims to achieve a high utilization of link capacity, scalability, negligible loss and delay. The main limitations of this algorithm are: it does not give incentive to cooperative sources and a properly calculated and fixed value of \( \phi \) must be known globally.

Fair Queuing Algorithms Alan Demers et al., proposed the Fair Queuing [10] and Stochastic Fair Queuing Algorithms [10] are mainly used in the multimedia integrated services networks for their fairness and delay bounding in the flow. The frame-based class of FQ is called Weighted Round Robin [11], where a router queue scheduling method is used in which queues are serviced in round robin fashion in fraction to a weight assigned for each flow or queue.

Virtual Queue Algorithm The Virtual Queue Algorithm (VQ) is a radical technique proposed by Gibben and Kelly [11]. In this scheme, a virtual queue is maintained in link with the same arrival rate as the real queue. However, the capacity of the virtual queue is smaller than the capacity of a real queue. When the packets are dropped virtual, then all packets already enqueued in the real queue and all new incoming packets are marked until the virtual queue becomes empty again.

Adaptive Virtual Queue Algorithm R.J. Gibben et al., discussed in the Adaptive Virtual Queue algorithm [11] the capacity of the link and the desired utilization maintains a virtual queue at the link. The capacity and buffer size of the virtual queue is the same as that of the real queue. At the arrival of each packet, the virtual queue capacity is updated. The adaptation of virtual queue algorithm does not suitably follow the varying traffic pattern at flow in the network, and it is also FIFO based methodology.

V. 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.
REFERENCES