Congestion Control in Wireless Sensor Networks- An overview of Current Trends

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Abstract: In WSN congestion occurs when traffic load exceeds the capacity available at any point in a network. Congestion acts an important role in degrading the performance of the network or failure of the network. So it is essential to detect and control the congestion in the entire WSN. Thus one can improve the performance of the network. Different factors are involved in the congestion; the main factor is buffer over flow, packet loss, lowers network throughput and energy wastage. To address this challenge this is essential for a distributed algorithm that mitigate congestion and allocate appropriate source rate to a sink node for wireless sensor network. This paper gives some ideas how to control and manage the congestion in a wireless sensor network.

Keywords: Wireless Sensor Networks, Congestion Control, Congestion Detection and Mitigation

I. INTRODUCTION

The WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical environmental conditions, such as temperature, sound, vibration, pressure motion or pollutants, at different locations [1]. WSN has significantly different communication constraints. The devices in such type of network are deployed in a huge numbers; they need the ability to assist each other to communicate data to a centralized collection point which is called a sink or a base station. The smallest devices are composed of a sensing unit, a radio, a processor integration of the sensor and having a power unit. The devices are capable of monitoring of a wide variety conditions such that temperature, humidity, soil makeup, pressure, vehicular movement, lighting conditions and noise levels, etc.

A typical example of pervasive computing applications is WSN, which has a broad range of applications such as military reconnaissance, environment monitoring, disaster relief and agriculture. The foremost aim of this type of network is to improve its life time and energy efficiency, load balancing packet transfer from sink to network as sensor of network is to conserve battery power. In WSN the powered mainly consumed for three purposes: data transmission, signal processing and hardware operation. With the rapid development and increasingly mature technology of MEMS (Micro Electro Mechanism System), wireless communications and modern networks merge into wireless sensor networks (WSN) [2]. It has created various innovative sensor network applications in near future. Today’s sensor nodes are capable of sensing more than one parameter with the aid of multiple sensor boards mounted on a single radio board [3]. It is more efficient, reliable and cost effective to use multi sensing unit instead of multiple nodes with multiple functionality.

Congestion is a problem in wireless sensor networks. Some techniques are used to reduce the congestion in WSN. Fusion’s Techniques mitigate congestion, queue occupancy detects congestion, hop-by-hop flow control improves the efficiency of the network and source rate limiting as will improves the fairness. Fusion improves efficiency by 3 times and eliminates starvation [4]. Different types of data generated by the sensors have various priorities. Hence it is necessary to ensure desired transmission rate for each type of data based on the given priority to meet the demands of the base stations. In such a network, the sensor nodes could in fact generate simple periodic events to unpredictable bursts of messages. Congestion occurs even more likely when concurrent data transmissions over different ratio links interact with each other or when the reporting rate to the base station increases. When the number of nodes in the entire network increases the congestion might occur frequently [5]. A typical model of Wireless sensor network is shown in Figure 1 [6].

The rest of the paper is organized as follows. In Section II, causes of congestion are discussed. In Section III, types of
Congestion are elaborated followed by congestion control mechanism in Section IV. Finally, the paper in Concluded in section V.

![Wireless Sensor Network Model](image)

**Figure 1:** Wireless Sensor Network Model.

II. CAUSES OF CONGESTION

When the data traffic of source nodes nearby sink grows, the offered lead exceeds capacity available and the network becomes congested. The congestion has buffer overflow, channel contention, interference, packet collisions and many to one flow nature. When the number of packets is more than the available space of buffer the buffer over flow occurs. Contention occurs between the different flow and different packets of a flow. Interference occurs along multiple path of a network among the nodes nearby due to simultaneous transmission [7]. Packet collisions lead to packet drops. Many to one nature of data communication between many sources and sinks result in bottleneck around sink [15-33]. Congestion results to degrade the channel quality, packets loss per unit time.

III. TYPES OF CONGESTION IN WSNs.

Congestion can be classified into two major categories.

1. Location based.
   a. **Location based congestion** includes, Source congestion and sink congestion.
   b. **Source congestion:** The event occurred is detected by all the sensor nodes in the special, these nodes are source nodes for next transmission. If the node’s radi ranges is greater the sensing range will also be greater. If the sources fall in each other’s radio range, the can communicate with each other. If all the source nodes, start sending packets to the same time to the sink at high rates, then a hot spot zone will be formed around the sources ant within this hot sport a large number of packet will be dropped.

2. **Sink congestion:** When the sensors observe an event at a high date rete, sink nodes and the nodes around them will sense a high traffic volume. If a hot spot occurs around the sink, the packet will be lost inside the congested area near the sink, and dropping of a packet around the sink needs recovery of packets by some means.

3. **Forwarder Congestion:** The date sensed must be reached to the destination by source and sink nodes. Data in a sensor network has multiple paths and these paths are interconnected with each other. The area surrounded the intersection will possible become a hot spot for congestion.

   a. **Causes of Packet loss:**
   It has mainly two types (Buffer over flow and link collision)

   1. **Buffer over flow** (Node level congestion). When the packet arrival rate exceeds the packet service rate this type of congestion occurs. In most cases this is occur in sensor nodes near to sink node.

   2. **Link collision** (Channel congestion/ Link level congestion): For WSNs where wireless channels are shared by several nodes using CSMA like Protocols [34-42], collision could occur when multiple active sensor nodes try to seize the channel at the same time. Link level congestion increases packet service time, and decreases both link utilization and overall throughput and wastes energy at the sensor nodes [8].
IV. CONGESTION CONTROL MECHANISM

Two main types of congestion in a WSN are buffer congestions and channel collision. Channel Collision can be overcome using Data Link Layers’ mechanisms: CSMA (Carrier Sense Multiple Access), FDMS (Frequent Division Multiple Access). Through these mechanisms the medium can be shared with frequent division FDMA, time division TDNA and sampling medium on the existence of the transmission of some other node CSMA.[10]

V. SCHEMES OF CONGESTION CONTROL

Congestion control can be divided into two main categories: (1) Centralized Congestion Control Schemes, (2) Distributed Congestion Control Schemes.

a. Centralized Congestion Schemes:

This scheme is consist of routing protocols with congestion control. In this scheme a centralized approach is used as all the actions for controlling the congestion is undertaken by base station / sink node. All the activities such as congestion detection and avoidance are taken by the sink. Decision is always taken by the centralized node, the sink node applies the command and the decision is taken according to the centralized scheme. The sink/ base station periodically collects data from the sensor nodes, detects the possibility of congestion, and accordingly sends messages to the involved sensor to mitigate the congestion. Table 1 has a summarized detailed discussion on some centralized congestion control schemes [11].

Table 1. Comparison of the existing centralized routing protocols with the congestion control.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Protocol</th>
<th>Operational Strategy</th>
<th>Congestion Detection Criteria</th>
<th>Priority Criteria</th>
<th>Packet Drop Priority</th>
<th>MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Directed diffusion</td>
<td>Routing with aggregation, distributed in nature</td>
<td>Buffer Overflow</td>
<td>No</td>
<td>No</td>
<td>CSMA</td>
</tr>
<tr>
<td>2</td>
<td>ESRT</td>
<td>Routing with congestion support, centralized in nature</td>
<td>Buffer Overflow</td>
<td>No</td>
<td>No</td>
<td>CSMA</td>
</tr>
<tr>
<td>3</td>
<td>PSFQ</td>
<td>Routing with congestion support, centralized in nature</td>
<td>Buffer Overflow</td>
<td>No</td>
<td>No</td>
<td>CSMA</td>
</tr>
<tr>
<td>4</td>
<td>RCRT</td>
<td>Centralized congestion detection, rate adaptation, and rate allocation</td>
<td>Buffer Overflow</td>
<td>No</td>
<td>No</td>
<td>CSMA</td>
</tr>
<tr>
<td>5</td>
<td>I2MR</td>
<td>Routing aided by congestion control</td>
<td>Buffer Occupancy, and exponential weighted</td>
<td>NO</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
b. Distributed Congestion Control Schemes.

The congestion in this case is distributed in nature. The congestion control is dispersed over the entire sensor field. The scattered deployment nature of sensor nodes results in the distribution of congestion control algorithm into various routines and sub routines across the wireless sensor network. These routines are executed by certain events in the sensor fields called stimulus and accordingly produce response. The result of one routine/subroutine may act as a stimulus to another subroutine. Table 2 summarizes the congestion detection criterion in Distributed congestion Control Scheme. [12]

Table 2: Mutual Comparison of existing distributed congestion control protocols.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Protocols</th>
<th>Operational strategy</th>
<th>Congestion detection criteria</th>
<th>Priority Criteria</th>
<th>Packet Drop Priority</th>
<th>MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CODA</td>
<td>Congestion Control</td>
<td>Single Buffer Occupancy</td>
<td>No</td>
<td>No</td>
<td>CSMA(VC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>congestion detection criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ECODA</td>
<td>Congestion Control</td>
<td>Dual Buffer Occupancy</td>
<td>Yes</td>
<td>Yes</td>
<td>CSMA with AIMD</td>
</tr>
<tr>
<td>3</td>
<td>ECODA</td>
<td>Congestion Control</td>
<td>Buffer Occupancy, Incoming Flows</td>
<td>Probabilistic Algorithm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DAIPaS</td>
<td>Congestion Control</td>
<td>Buffer Occupancy Channel Interference</td>
<td>NO</td>
<td>NO</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>ADCC</td>
<td>Congestion Control</td>
<td>Transient Buffer Monitoring Using EWMA</td>
<td>NO</td>
<td>NO</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td>LPCC</td>
<td>Congestion Control</td>
<td>Transient Buffer Monitoring using EWMA</td>
<td>NO</td>
<td>NO</td>
<td>NA</td>
</tr>
<tr>
<td>7</td>
<td>PCCP</td>
<td>Congestion Control</td>
<td>Buffer monitoring, Packet inter arrival time and service reflecting congestion</td>
<td>NO</td>
<td>No</td>
<td>NA</td>
</tr>
<tr>
<td>8</td>
<td>DPCC</td>
<td>Congestion control</td>
<td>Buffer occupancy and traffic flow</td>
<td>NO</td>
<td>NO</td>
<td>CSMA, Back off interval</td>
</tr>
<tr>
<td>9</td>
<td>LACAS</td>
<td>Congestion control</td>
<td>Learning automata Pre defined rules</td>
<td>Pre defined rules</td>
<td>No</td>
<td>NA</td>
</tr>
<tr>
<td>10</td>
<td>Fusion</td>
<td>Flow control, rate limiting, Buffer and rate</td>
<td>NA</td>
<td>NA</td>
<td>CSMA with RTS/CTS</td>
<td></td>
</tr>
</tbody>
</table>
VI. CONGESTION CONTROL MECHANISMS IN WSNS.

It has mainly three phases (Detection, Notification & Rate adjustment)

a) Congestion Detection:

In WSN congestion can be detected by several ways like, buffer occupancy, channel sampling and packet service rate and scheduling rate.

b) Congestion Notification:

When the congestion is detected the entire network is informed about it in one of the ways below:
   a. Explicit congestion notification
   b. Implicit congestion notification

c) Congestion control approaches:

( Resource management and Traffic control)

Resource Management: To mitigate the congestion the network resource management tries to extend network resources. In wireless networks, power control and multiple radio interfaces can be used to increase bandwidth and weaken congestion.

Traffic Management: Have two methods for traffic control in WSN.

A. The hop-by-hop congestion control: It has faster response, it is usually difficult to adjust the packet forwarding rate at intermediate nodes mainly because packet forwarding rate is dependent of MAC protocol and could be variable.

B. The end-to-end congestion control: It imposes exactly the rate of adjustment at each source node and simplify the design at intermediate nodes, it results in slow response and relies highly on the round trip time (RTT) [14].

VII. CONCLUSION

WSNs experiences congestion, so it is required solution to control congestion. A lot of research and solutions are published to overcome the congestion problem. We made a survey on congestion control mechanisms for WSNs and underlined some suitable techniques and assumption to mitigate the congestion problem in the wireless sensor networks.

REFERENCES


[27] Khan, F., Jan, SR, Tahir, M., & Khan,


