Available online at www.sciencedirect.com
ScienceDirect
Ad Hoc Networks 5 (2007) 462–485
Ad Hoc Networks
www.elsevier.com/locate/adhoc

Sink-to-sensors congestion control

Ramanuja Vedantham [a,*], Raghupathy Sivakumar [a], Seung-Jong Park [b]

[a] School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, United States
[b] Department of Computer Science and CCT, Louisiana State University, Baton Rouge, United States

Received 17 June 2005; received in revised form 5 December 2005; accepted 15 February 2006
Available online 31 March 2006

Abstract

The problem of congestion in sensor networks is significantly different from that of conventional ad-hoc networks and has not been studied to any great extent thus far. In this paper, we focus on providing congestion control from the sink to the sensors in a sensor field. We identify the different reasons for congestion from the sink to the sensors and show the uniqueness of the problem in sensor network environments. We propose a generic framework that addresses congestion from the sink to the sensors in a sensor network. Through *ns2* based simulations, we evaluate the proposed approach and compare its performance with three baseline approaches.

Keywords: Sensor networks; Sink-to-sensors; Congestion control; Simulations

1. Introduction

Wireless Sensor Networks (WSNs) have gained tremendous importance in recent years because of its potential use in a wide variety of applications. This, along with the unique characteristics of these networks [1], has spurred a significant amount of research for coming with network protocols specifically tailored for sensor networks. In this paper, we propose one such approach to address congestion in sensor networks from sink-to-sensors (*downstream*).

The need for congestion control in sensor network is clearly motivated by the nature of the application that it is used for. Consider the example of an object tracking military application, where there are image sensors deployed in a sensor field and the goal is to detect the presence of an enemy in the sensor field. For this application, it is necessary that the sink is able to transmit a *query and the data associated with the query*, such as photos of the all the enemies being targeted, which would make the message size associated with these queries substantially large. This message corresponding to each query needs to be delivered reliably to the sensors in the least possible time. While one might be inclined to think that transmitting at a higher (data) rate may accomplish this, we show in Section 2 that this is not advisable as it results in more number of collisions leading to several packets in the message being lost. This translates to poor usage of network and node resources per packet delivered, which are a premium for

* Corresponding author. Tel.: +1 404 312 1024.
E-mail addresses: ramv@ece.gatech.edu, ramanuja79@gmail.com (R. Vedantham), siva@ece.gatech.edu (R. Sivakumar), sjpark@bit.csc.lsu.edu (S.-J. Park).

1570-8705/$ - see front matter
doi:10.1016/j.adhoc.2006.02.002

sensor networks. The problems due to congestion are only exacerbated in the presence of reverse path traffic, which accounts for the bulk of traffic in WSNs. Thus, congestion control mechanisms are vital and necessary because of the following important considerations:

- Efficient usage of available network bandwidth and energy resources at each sensor node.
- Fast and reliable message delivery with minimal collisions.

There have been a few works that have addressed congestion control in sensor networks from sensors-to-sink (*upstream*) [2,3]. However, such works are not applicable in the downstream direction because of the differences in the nature of communication paradigm and the availability of node resources. For example, in downstream communication in WSNs, when all nodes are receivers of a particular message the buffering of different packets in a message is not an issue as the nodes will anyway store all the packets in a message, while this is not true in the upstream direction. Hence, the receiving rate can be much higher than the sending rate without worrying about buffer overflow. Our work is orthogonal to these upstream approaches and can coexist and compliment them for providing congestion control in the downstream direction. While some works employ some variation of rate control [4,5] as a means for providing downstream reliability, they do not guarantee optimum usage of available network bandwidth in determining the transmission rate and therefore do not address congestion to any reasonable degree. Efficient flooding approaches [6–8] have been thought of a means to improve the successful delivery rate of messages and possibly address congestion. However, they still cannot guarantee any strict semantics to regulate the congestion as they only address global congestion without any consideration for any local congestion in a subregion of the network.

In this work, we clearly motivate the need for *explicit* downstream congestion control. We then propose an adaptive, explicit rate control approach, called *CONgestion control from SInk to SEnsors* (CONSISE), that adjusts the downstream sending rate at each of the sensor nodes to utilize the available network bandwidth depending on the congestion level in the local environment. The proposed approach is highly scalable and easily implementable and can provide large performance benefits and efficient usage of resources with minimal overheads.

To describe briefly, in CONSISE, a node upon reception of a packet from an upstream node[1] will piggy-back meta-level information regarding its current sending rate along with its node identifier. Each downstream node upon reception of a packet updates the information regarding the number of packets it has received from a particular node. At the expiry of a periodic timer, a node determines its sending rate as well as gives explicit feedback to the upstream node. The sending rate is determined based on the explicit feedbacks received from downstream nodes while the feedback rate is computed based on the meta-level information collected during the epoch. The realization of CONSISE's design is done in such a way as to address and leverage the specific characteristics of the sensor network environments, as we elaborate in later sections.

The rest of the paper is organized as follows: Section 2 defines the scope of the paper, motivates the problem of downstream congestion control and identifies the challenges. Section 3 enumerates the key design elements proposed in CONSISE to address the research challenges. Section 4 presents the proposed approach for achieving downstream congestion control in sensor networks. Section 5 evaluates the performance of the proposed scheme with two baseline approaches that provide limited congestion control, and a basic scheme that does not provide any congestion control. Section 6 discusses related work in the context of providing congestion control in sensor networks. Section 7 discusses some of the practical issues and considerations in the proposed approach and Section 8 concludes the paper.

2. Problem definition

In this paper, we propose a mechanism for performing congestion control in the following context:

- *Network model:* We consider a multi-hop WSN with either one sink or several sinks coordinating the sensors in the field.
- *Downstream congestion control:* Although a strong case can be made for mechanisms to address congestion in both the upstream and the downstream directions in mission critical

[1] A node closer to the sink than the current node.