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Review

Congestion control mechanisms in wireless sensor networks: A survey

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ABSTRACT

Congestion control is deemed to be one of the most significant challenges in Wireless Sensor Networks (WSNs) which is attributed to resource constraint specification and the number of deployed nodes. In WSNs, congestion is caused by the following factors: packet collision, node buffer overflow, transmission channel contention, transmission rate, many-to-one data transmission scheme and dynamic time variation transmission channel. Indeed, congestion has a significant impact on Quality of Services (QoS) parameters such as packet delivery ratio (PDR), end-to-end delay and energy consumption in wireless nodes. This paper presents a comprehensive survey of major congestion control mechanisms used in WSNs and classifies the available methods into four categories i.e. traffic control protocols, resource control protocols, queue assisted protocols and priority-aware protocols. This review paper compares the important techniques with each other in terms of congestion detection, congestion notification and congestion mitigation as well as directions for future researches and works.

Contents

1. Introduction

In recent years, advances in micro-electromechanical systems (MEMS), wireless networks and very large-scale integrated circuit (VLSI) design have enhanced the importance of WSNs as a remarkable technology for mission-critical tasks (Akyildiz et al., 2002; Yick et al., 2008). These networks play a vital role in many fields and applications such as habitat and environment monitoring (Biagioni and Bridges, 2002; Cerpa et al., 2001), target tracking (Brooks et al., 2003; Kung and Vlah, 2003), structural health monitoring (Schwiebert et al., 2001) and critical infrastructure

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protection (Chen et al., 2011). In WSNs, sensor nodes have limited resources with regard to computation, storage, communication bandwidth and, most importantly of all, energy supply. These specifications and inherent constrains have affected QoS parameters such as packet delivery ratio, end-to-end delay, bandwidth utilization and average node energy consumption in WSNs (Akyildiz et al., 2002; Yick et al., 2008). Hence, researchers should consider these resource specifications and constraints in different applications so as to improve the above-mentioned QoS parameters.

Due to the event-driven nature of WSNs, resource constraints, many-to-one communications, number of deployed sensors and the high traffic of sensor nodes lead to the creation of congestion in these networks. In WSNs, network congestion occurs when the offered traffic load exceeds the available capacity at any point in the network (Flora, 2011). Indeed, it can be mentioned that congestion is one of the highly critical challenges in WSNs and it has a profound impact on QoS parameters and the energy efficiency of sensor nodes. Moreover, congestion increases packet loss and degrades the throughput or wireless channels. Thus, in order to handle such challenges and problems in WSNs, researchers should consider and control the factor of congestion (Fig. 1).

As Fig. 2 illustrates, congestion in WSNs is created at two levels: *node-level congestion* (or buffer overflow) and *link-level congestion*. In *node-level congestion*, when packet arrival rate is higher than packet service rate, congestion is caused. This type of congestion occurs mostly in those sensor nodes which are closer to the sink. Node-level congestion increases packet loss and power waste in WSNs. Consequently, this type of congestion has a direct impact on network availability and network lifetime. Factors such as competition, collision and bit error result in *link-level congestion*. Thus, in this kind of congestion, packet delivery rate in sink node is reduced. Therefore, for enhancing throughput and packet delivery rate at sink node, collision should be prevented by using an appropriate medium access control based congestion control algorithms.

Firstly, congestion should be detected in sensor nodes known as congestion detection phase. Secondly, as congestion occurs, upstream sensor nodes should be notified of congestion referred to as notification phase. Finally, congestion should be mitigated and appropriate data rate should be selected, known as rate adjustment or congestion mitigation phase. Thus, the process of congestion control includes three phases: congestion detection, congestion notification and congestion mitigation. Several congestion detection techniques have been proposed for WSNs i.e. occupied queue length, packet service time, packet interval and packet service time, packet drop at the sink node, queue length

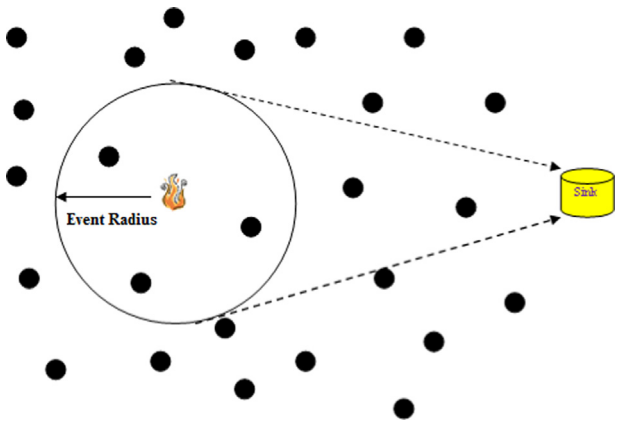

Fig. 1. Many-to-one data transmission scheme in WSNs.

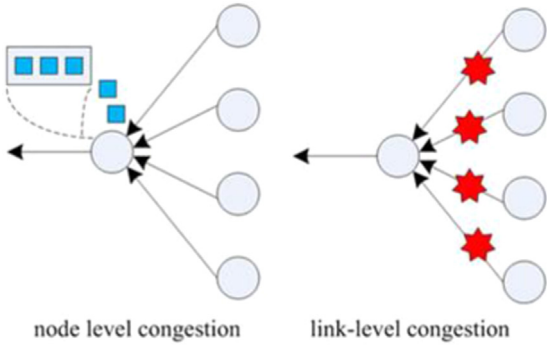

Fig. 2. Common congestion positions in WSNs.

and channel state and dual buffer thresholds and weighted buffer difference.

This review paper is intended to highlight a critical issue and problem in WSNs; in other words, congestion control algorithms for WSNs have been examined and outlined and their pros and cons of have been briefly discussed. In fact, numerous congestion control techniques have been proposed for WSNs. However, the investigation of the proposed techniques indicates that congestion has an undeniably significant impact on the performance and efficiency of WSNs. Consequently, it should be noted that the optimization and improvement of performance is a challenging task for WSNs. This issue has triggered a variety of research and study on the design and implementation of appropriate and efficient techniques on congestion control. Indeed, handling and controlling congestion in WSNs is considered to be a remarkable research gap which has attracted researchers' attention.

The major contributions of this review paper are as follows: this review paper overviews the related literature and pinpoints the most important and updated congestion control mechanisms which have been proposed for WSNs. This review paper characterizes and highlights the different approaches to designing and improving congestion control by focusing on their strategies, merits and demerits. Furthermore, this paper collects, classifies, analyzes, and compares the major congestion control protocols for WSNs.

This review paper has focused on the following issues: congestion detection, congestion notification, congestion control, control pattern and generic or cross-layer congestion control mechanisms. Ultimately, this paper discusses the major challenges in congestion control protocols for WSNs and recommends directions for further research on the design and implementation of appropriate new congestion control techniques.

The rest of the paper is organized as follows: Section 2 reviews the related works on congestion control. Section 3 provides an overview on related issues in WSNs and presents a brief review of each protocol and classifies the most popular congestion control algorithms based on the strategies used for congestion detection, notification and mitigation. Section 4 compares different congestion control protocols in WSNs with respect to their strategies and common evaluation parameters. Section 5 presents a discussion for this review paper. Section 6 concludes this paper and recommends directions for further research.

2. Related works

Despite the bulk of protocols proposed for congestion control, it remains an unresolved and thorny issue. Some significant survey and review studies related to the above-mentioned research problem are mentioned below.