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Procedia Computer Science 37 (2014) 181 – 188

Procedia Computer Science

The 5th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2014)

Interference-Aware Congestion Control Protocol for Wireless Sensor Networks

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Abstract

This paper deals with congestion and interference control in wireless sensor networks (WSN), which is essential for improving the throughput and saving the scarce energy in networks where nodes have different capacities and traffic patterns. A scheme called *IACC* (*Interference-Aware Congestion Control*) is proposed. It allows maximizing link capacity utilization for each node by controlling congestion and interference. This is achieved through fair maximum rate control of interfering nodes in inter and intra paths of hot spots. The proposed protocol has been evaluated by simulation, where the results rival the effectiveness of our scheme in terms of energy saving and throughput. In particular, the results demonstrate the protocol scalability and considerable reduction of packet loss that allow to achieve as high packet delivery ratio as 80% for large networks.

Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.

Keywords: Wireless sensor networks; transport protocols; congestion control; fairness; interference; link capacity.

1. Introduction

In a wireless sensor network, sensors gather information about the environment and notify the base-station. Applications may require the notification to be continuous, periodic, or on event occurrence [1]. In some event-based (resp. continuous) applications, nodes may transmit significant volumes of data towards the sink upon event occurrence (resp. permanently), e.g., video tracking, surveillance applications. As sensors share the same wireless channel, contention on the available bandwidth is inevitable. In a real environment, the packet collision caused by links interference or packets loss due to congestion on inter-paths and intra-path nodes dramatically affects the application throughput and causes high energy consumption. Congestion control consists of two parts: i) the congestion and interference detection, and ii) a rate control mechanism establishment, which adjusts the reporting rate. Different

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Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.
doi:10.1016/j.procs.2014.08.028

metrics are used in literature for detecting congestion, such as buffer length, packet inter arrival time, packet service time, channel load, etc [1].

The existing approaches, in their mitigating or avoiding forms, underuse the throughput that the network capacity can offer to the application. The mechanisms based on rate regulation between nodes use AIMD (Additive increase multiplicative decrease) methods to balance the offered capacity, but ignore nodes interference, the principal cause of loss. On the other hand, scheduling based methods do not take into account physical-link-capacity differences between nodes. In this paper, we propose a scheduling scheme that takes into account dynamic link interference and capacity. It provides efficient and fair rate partitioning over congested links. The proposed protocol identifies the hot spot points by measuring locally, at every node, the interfering neighbor links that cannot be simultaneously active in the whole schedule. Finally, the rate of each link and the number of slots given to each node is determined by taking into account the depth of the node and its link capacity.

The paper is organized as follows. Section 2 presents the related works on congestion control and avoidance. In Section 3, the problem is formulated with a thorough network model. The proposed protocol *IACC* (Interference-Aware Congestion Control) is presented in Section 4. Section 5 shows the simulation results. Finally, Section 6 concludes the paper.

2. Related Work

ESRT [2] (Event-to-Sink Reliable Transport) is a centralized rate allocation control protocol where the sink controls nodes rate in event driven-applications. Nodes are assumed to be located at one hop from the sink. ESRT defines event reliability as the number of data packets required for reliable event detection from the whole set of nodes, while minimizing energy consumption. Each node sends at a fixed rate until receiving rate update instruction from the sink. The sink uses the perceived goodput and congestion level (based on the buffer length) to update rates. This method ensures fairness, but not efficiency of throughput.

CODA [3] (Congestion Detection and Avoidance) is a mitigation rate control protocol, where each node detects congestion using both channel and buffer loads. The node controls its rate in an AIMD manner. CODA considers two strategies: i) open-loop back pressure for transient congestion, where the concerned node broadcasts the message to its neighbours that further propagate these messages to upstream nodes, depending on their buffer occupancy, and ii) an end-to-end acknowledgement-based approach (also named closed-loop for persistent congestion). However, CODA does not focus on per-source fairness.

In CCF [4], each node uses packet transmission duration to estimate the channel capacity. It then divides this capacity between its sub-tree nodes. A major drawback of CCF is that the remaining capacity from no-sending nodes goes unused.

In ARC [5], rate adjustment is done through an AIMD, which is proportional to the number of descendant nodes. The congestion is passively detected when a node finds that its parent does not forward its traffic. ARC tries avoiding interference by introducing a jitter before sending. This allows desynchronizing neighbours.
QCRA [6] attempts to determine optimal and fair sources transmission rate at the sink using information about topology, link loss rates, and communication pattern. Its heuristic results to a coarse-grained TDMA schedule between neighbours using CSMA. Loss rate is used to assign nodes' sending rates. QCRA decisions are periodic with epochs at the order of few tens of minutes.

MCCP [7] uses successive data and schedule intervals. During data interval, nodes send data using a schedule received from their next hop nodes. As one packet can be sent at a slot, slot length represents the reporting rate. With short length slots, the rate is increased. During the schedule intervals, nodes generate the schedule for the next data interval. Packet delivery time and buffer size are used to attribute time slots. But slot attribution in this scheme does not specify any contention avoidance.