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ROBUSTNESS AND OPTIMALITY OF JOINT CONGESTION CONTROL AND MULTI-PATH ROUTING IN SENSOR NETWORKS

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ABSTRACT

This paper is a contribution to the analysis on the robustness and optimality of joint congestion control and multi-path routing (JCC-MR) in sensor network. In congestion control, source nodes adapt their sending rates to network congestion, and network capacity adapts the routing to the measured traffic. This raises the question of whether the joint system of congestion control and routing is robust and optimal. We prove that both robustness and optimality of the joint system is achievable for deterministic traffic, and also for elastic traffic if the link capacity does not exceed. Simulation results demonstrate that the joint system converges quickly, provides with higher throughput and improves the spatial balance of energy.

Keywords- Sensor Network, Congestion Control, Multi-path Routing, Network Utility Maximization, Distributed Algorithm.

1. INTRODUCTION

In this paper, we consider the problem of congestion control (CC) and multi-path routing (MR) over a multi-hop wireless sensor network. Separately, both the CC and MR algorithms got special research interest over the past few years (see, e.g., [1][2][3][4][5]) with many fascinating and complex issues, involving, e.g., mobility, power control, link quality estimation, MAC, routing etc. Each of these works minimizes the resource utilization of the network to achieve the desired goal, since WSN is highly resource critical. A few of them are summarized below.

CODA [1] detects incipient congestion based on the channel loading and queue occupancy length and thereafter broadcasts a rate suppression message as a backpressure signal. Therefore, rate of upstream sensors are controlled in hop-by-hop basis. Interference-aware Fair Rate Control (IFRC) [2] detects incipient congestion at a node by monitoring the average queue length, communicates congestion state to exactly the set of potential interferers using a low-overhead congestion sharing mechanism, and converges to a fair and efficient rate allocation. Congestion is shared among the multiple forwarding nodes. An aggregate fairness model and a localized algorithm (AFA) that implements the model is proposed in [3]. AFA is designed to work with any underlying routing protocol. It allows the packets from a data source to follow an arbitrary set of forwarding paths to the base stations. AFA estimates the no. of flows coming from each upstream and allocates bandwidth proportional to that number, and thereby automatically adjusts each sensor's forwarding rate to avoid packet drops due to downstream congestion.

Multi-path routing in sensor network has its concomitant gain in achieving high reliability, security and traffic balancing (see, e.g., [4][5][6]). MMSPEED [4] is a novel packet delivery mechanism, where multi-path routing is done to increase the end-to-end total reaching probability (TRP). MCMP routing [5] uses link delay and reliability as routing decision parameters in single-sink