Multi-constrained QoS Geographic Routing for Heterogeneous Traffic in Sensor Networks

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***Abstract*— Sensor nodes report the sensed data packets to the sink and depending on the application these packets may have diverse attributes: time-critical (TC) and non time-critical (NTC). In such a heterogeneous traffic environment, designing a data dissemination framework that can achieve both the reliability and delay guarantee while preserving the energy efficiency, namely multi-constraint QoS (MCQoS), is a challenging problem. This paper proposes a new *aggregate routing* model and a localized algorithm (DARA) that implements the model. DARA is designed for multi-sink multipath location aware network architecture. Delay-differentiated multi-speed packet forwarding and in-node packet scheduling mechanisms are also incorporated with DARA. The simulation results demonstrate that DARA effectively improves the reliability, delay guarantee and energy efficiency.**

I. Introduction

In heterogeneous traffic environment, the time-critical (TC) packets are correspond to suddenly happen important events while the non time-critical (NTC) packets carry periodic environmental parameters like temperature, airflow etc. Events like radiation leakage or moving object tracking produce TC packets that must be reached at the sink within a certain time limit. The sudden surge of such TC traffic from hundreds of sensor nodes makes the reliable and timely event perception much difficult for many reasons [1][2][3].

We define reliability (R) as the ratio of the number of unique packets received by the sink to the number of packets sent from the source nodes; and, given an application delay requirement D, the delay guaranteed service means that the time delay, δ, experiences by any packet to reach its destination from the source is less than D. A routing scheme is said to be energy efficient if it ensures both low average energy consumption over time and almost homogeneous energy dissipation rates for all sensors.

Recently, there have been several pioneering studies on achieving multi-constrained QoS in sensor networks [2][3][4]. However, these works either do not consider the reliability [2] or energy [3] or have abstract and/or restrictive assumptions on the underlying routing structure [4], which limits their scope of applicability. This paper defines an *aggregate routing function* based on three metrics: progress speed, residual energy and expected sojourn time of a packet. A distributed aggregate routing algorithm (DARA) is then presented that finds a forwarding node with the maximum aggregated weight. Probabilistic analysis is carried out for the reliability and delay guarantee. Reliability is increased by sending duplicate packets from source nodes.

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II. Multi-constraint QoS: Challenging Issues

A. Multi-constrained Hard-QoS vs. Soft-QoS provisioning

Due to seemingly contradictory relationship amongst the service parameters it is not possible to find a solution that minimizes all the parameters (hard-QoS) [1]. For instance, the use of shortest route from source to sink is most desirable to providing delay guaranteed service, but this approach puts additional burden on a set of nodes in terms of energy utilization. Adopting link layer ARQ mechanism at each hop with higher retry count values may increase the reliability [3], but doing so increases the energy consumption as well as per node packet delay. Therefore, we look for some tradeoffs among the constraints to achieve soft-QoS provisioning.

B. Single-sink Multipath vs. Multi-sink Multipath Routing

Single-sink multipath routing [3][4] is not applicable for provisioning MCQoS as the data packets converge somewhere near the sink, which increases traffic contention and average packet delay, as in Fig. 1a. Therefore, we advocate that the use of multi-sink multipath routing (Fig. 1b) is more suitable as it splits the large burst of data into several smaller bursts flowing through spatially separated nodes.

C. Pitfalls in Existing Works

MMSPEED [3] is a novel packet delivery mechanism, where routing is driven by two parameters - the geographic progress speed of a packet from node i to j towards the final destination k, $Speed_{i,j}^{k}$, and the end-to-end total reaching probability (TRP). In MMSPEED, node i forwards a packet to its downstream node j whose $Speed_{i,j}^{k}$ value is higher and TRP is greater than some threshold. But, unfortunately the calculation of $Speed_{i,j}^{k}$ does not consider the residual energy (e_r) and expected sojourn time at target node j. Hence, the routing function of MMSPEED does not reflect the real dynamics of sensor network, where achieving energy efficiency and minimizing per node packet delay are the main hurdles of MCQoS routing.

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