Minimizing Wireless Connection BER through the Dynamic Distribution of Budgeted Power

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Abstract— **We develop a new dynamic scheme which continuously redistributes a fixed power budget among the wireless nodes participating in a multi-hop wireless connection, with the objective of minimizing the end-to-end wireless connection bit error rate (BER). We compare the efficacy of our scheme with two static schemes: one that distributes power uniformly, and one that distributes it proportionally to the square of inter-hop distances. In our experiments we observed that the dynamic allocation scheme achieved superior performance, reducing BER by using its ability to distribute the power budget. We quantified the sensitivity of this performance improvement to various environmental parameters, including power budget size, geographic distance, and the number of hops.**

Index Terms— **wireless ad-hoc networks, multi-hop path, bit error rate, power budget, optimal power distribution.**

I. INTRODUCTION

New distributed computing/communication applications drive the energy requirements of wireless ad-hoc systems ever upwards, while simultaneously, the batteries which power wireless devices present a hard constraints on the operation of mobile computing systems. Recent developments in devices with tunable transmission power enable us to manage the tension of power supply and power demand using dynamic power redistribution schemes. In this paper, we present results of recent investigations along this avenue. Our objective is to optimize the bit error rate (BER) of connections—and hence the packet-level error rate (PER) experienced at the network layer. Since many applications require a minimal Quality of Service (QoS) to guarantee acceptable responsiveness, such an improvement can greatly benefit network function.

Historically, reconciling the gap between power consumption and supply involved [14] solving the following issues: (i) improving the power efficiency in the system; and (ii) preventing the system deconstruction due to unfair power usage. In our earlier work [2], [3], we proposed addressing these issues through the principle of *optimal allocation of budgeted power*; we introduced a model in which every connection request is assigned a fixed *power budget* to support its instantiation. In this paper, we present a scheme which dynamizes these approaches by enabling the redistribution of a power budget among the constituent nodes in a multi-hop connection, with the objective of minimizing the wireless connection BER.

Standard models of *wireless ad-hoc* networks typically consider infrastructure-less networks in which every node assumes the role of both a host and router, and every node is mobile. In this paper, we will not consider mobility-related issues. Although our investigation makes the simplifying assumption of a scenario in which mobility does not greatly impact power allocation decisions, the conclusions we present are nevertheless significant in the broader context of power management in wireless and ad-hoc networks.

The remainder of the paper is organized as follows. We begin in Section II with an exposition of prior related research work. Then, in Sections III and IV we define the problem and the presumed network model. In Section V, we describe the protocol by which power is redistributed dynamically, to attain minimum BER. In Section VI we describe the experimental setup, and then analyze the results of the simulation study in Section VII, by comparing the proposed protocol against other traditional power distribution schemes.

II. RELATED WORK

Approaches for efficient power management have been investigated at various protocol layers by several researchers, (e.g. see [14], [13], [4]) 1. At the *Physical layer*: Using directional antennae, applying knowledge of spatial neighborhood as a hint in setting transmission power; 2. At the *Data-link layer*: Avoiding unnecessary retransmissions, avoiding collisions in channel access whenever possible, allocating contiguous slots for transmission and reception whenever possible; 3. At the *Network layer*: Considering route-relay load, considering battery life in route selection, reducing frequency of control messages, optimizing size of control headers, route reconfiguration; 4. At the *Transport layer*: Avoiding repeated retransmissions, handling packet loss in a localized manner, using power-efficient error control schemes.

One broad category of solutions consists of energy aware routing protocols (e.g. see [13], [6], [8]). In wired networks, the emphasis has traditionally been on maximizing end-to-end throughput and minimizing delay. To maximize the lifetime of mobile hosts, however, routing algorithms must select the best path from the viewpoint of power constraints and route stability. Routes requiring lower levels of power transmission are generally preferred, but this can adversely affect end-to-end throughput. Transmission with higher power increases the probability of successful transmission, although high power strategies also result in more cross-node interference, destroy existing transmission bands, and thus cause the network to have blocked connections. In [5] and [1], Banerjee and Misra showed that energy-aware routing algorithms that are solely based on the energy spent in a single transmission are not able to find minimum energy paths for end-to-end reliable

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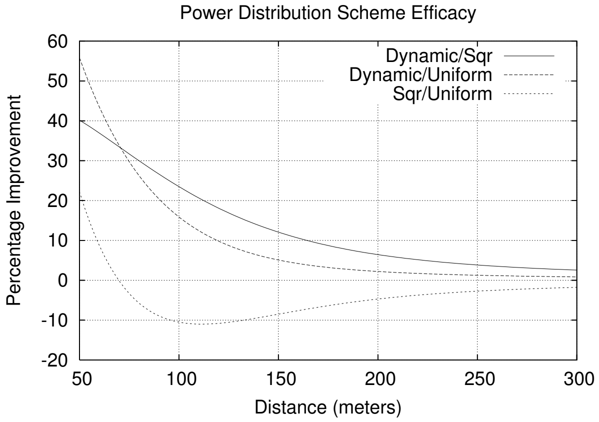

Fig. 6. Percentage improvement vs. total connection distance

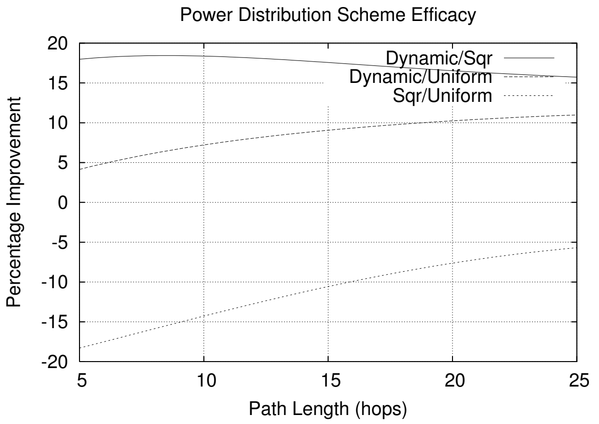

Fig. 7. Percentage improvement vs. connection length

heights of the curves, we conclude that the proposed dynamic scheme outperforms both of the other power allocation techniques in both small and large distances scenarios. As the distances become larger, the difference between power allocation schemes becomes immaterial.

Figure 7 illustrates the impact of varying the path length (in terms of the number of intermediate nodes) between the source and destination nodes while keeping constant both the distance between the connection end points and the total power budget. The connection power budget was fixed at $2200mW$, and the number of distance was fixed at $120m$–drawing upon the two experiment scenarios described earlier. Considering the *slopes* of these curves we conclude that the improvement of the the *Dynamic* scheme relative to the *Sqr* scheme lightly decreases as the number of the intermediate hops increases. However, in case of *Dynamic* versus *Sqr* and *Sqr* versus *Uniform* schemes, the improvement increases as the length of the path increases. For example, when considering a 10 hop path, *Dynamic* achieved an improvement of 7% over the *Uniform* scheme, while for a 20 hop path, the improvement was 10%. Comparing the *heights* of the curves, we conclude that the proposed dynamic scheme outperforms both of the other power allocation techniques for both short and long paths scenarios.

VIII. Conclusion and Future Work

In all the experiments, the dynamic allocation scheme achieved superior performance relative to the uniform and distance-squared proportional schemes. This improvement resulted from the dynamic scheme ability to reduce the BER by dynamically allocating the power budget among the intermediate nodes.

In all the experiments conducted, the proposed scheme was seen to converge in fewer than 10 iterations per node. The convergence rates and communication overhead was tunable by adjusting the definition of “significant change” in the protocol. Because we were not considering mobility, this cost was taken as the one-time initialization cost for the connection. In future, we intend to extend our consideration to the fully mobile setting. Because our power allocation protocol is decentralized and dynamic, it can react to node mobility by redistributing power in a manner which optimizes the BER. To evaluate the efficacy of the protocol in the mobile setting, we are presently conducting experiments to quantify the tradeoffs between convergence thresholds, control-traffic overhead, and resultant improvement in BER.

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