Using Energy-Efficient Overlays to Reduce Packet Error Rates in Wireless Ad-Hoc Networks

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***Abstract*— In this paper we present new energy-efficient techniques to lower the packet-level error rates of application-layer connections in wireless ad-hoc networks. In our scheme, each application-layer connection is implemented at the physical level by an overlay network. Data packets submitted at the connection source are checksummed and replicated, flowing breadth-first across the overlay network towards the destination. The destination delivers the first error-free copy of each packet, in order, to the application layer, dropping packets that are corrupt or duplicate. Specifically in this paper, we consider overlays consisting of multiple parallel node-disjoint multi-hop paths. We compare this overlay scheme with the traditional scheme in which the source transmits to the destination along a single minimum-hop path. We show that even when the two schemes are constrained by *identical power consumption bounds*, an overlay scheme that uses multiple multi-hop paths provides significantly lower packet-level error rates in many common situations. We describe the relationship between packet error rate, the number of paths, and the lengths of each path, and show that the qualitative nature of the relationship changes significantly, depending on available power budget.**

I. Introduction

Power allocation is of vital importance in wireless ad-hoc networks. Ongoing advances in applications of wireless computing/communication devices drive the energy requirements of these systems ever upwards. Clearly *the capacity of the batteries* which power most mobile devices creates a hard constraint on the operational time of a mobile computing system. Not surprisingly, this makes the design of energy efficient mobile ad-hoc networks an important area of current research.

Lowering energy consumption indiscriminately, however, can have undesirable side effects, most notably, it can raise the bit error (and hence packet-level error) rate of connections. Since many applications require very specific *Quality of Services* (QoS), such a degradation could yield the network inoperable.

In this paper, we consider the problem of how to balance the need for efficient energy allocation with the objective of low packet-level error rates.

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II. Related Work

Approaches for efficient power management in wireless networks, have been investigated [4], [16], [18] at the various protocol layers. For example:

(1) *Physical layer*: Using directional antennae, applying knowledge of spatial neighborhood as a hint in setting transmission power,
(2) *Data-link layer*: Avoiding unnecessary retransmissions, avoiding collisions in channel access whenever possible, allocating contiguous slots for transmission and reception whenever possible,
(3) *Network layer*: Considering route-relay load, considering battery life in route selection, reducing frequency of control messages, optimizing size of control headers, route reconfiguration, and
(4) *Transport layer*: Avoiding repeated retransmissions, handling packet loss in a localized manner, using power-efficient error control schemes.

Topology control and management is one of the techniques used for efficient power usage [8]. This approach consists of determining the transmission power of each node so as to maintain network connectivity while consuming the minimum possible power. Instead of transmitting using the maximum possible power, nodes in a wireless multi-hop network collaboratively determine their transmission power and define the topology of the wireless network by the neighbor relation under certain criteria. This is in contrast to the traditional network in which each node transmits using its maximum transmission power and the topology is built implicitly by routing protocols without considering the power issue.

Another approach for minimizing the power usage in wireless network is to reduce the amount of communication between nodes at the expense of extra computation. Most work focused on developing approaches that reduce the volume of

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