Balancing Power: Tradeoffs between Connection Lifetime and Control Traffic in MANETS

Zeki Bilgin
Department of Computer Science
The Graduate Center, CUNY
New York, 10016
zbilgin@gc.cuny.edu

Bilal Khan
Department of Math.& Computer Science
John Jay College, CUNY
New York, 10016
bkhan@jjay.cuny.edu

ABSTRACT

We present new power distribution schemes on an active route in wireless ad hoc networks, with the objective of maximizing connection lifetime against node mobility. Through experiments with each of the proposed power distribution schemes, we obtain a description of the relationship between control traffic overhead and their expected gains in connection lifetime, as well as an understanding of the influence of various system parameters (e.g. connection size, node density, and power budget size) on this relationship.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design–*wireless communication*

General Terms

Algorithms, Performance

Keywords

Ad-hoc, mobility, connection lifetime, power control

1. INTRODUCTION

Link breakage due to node mobility is a severe problem in wireless ad hoc networking. Such disconnections on active routes generally increase traffic overhead in the network layer, and cause packet losses in the link layer. In this study, we exploit the transmission power control in order to prevent link disconnections, and thus maximize of connection(path) lifetime against node mobility. We take connection lifetime to be the time during which its constituent links are operational. A link ceases to be operational when the autonomous movement of one of the link's endpoints causes it to fall out of transmission range of the other endpoint.

We presume that energy supplies at the nodes are renewable. Notice that we are not trying to increase spatial reuse nor energy efficiency. Specifically, we assume that each connection in a network has a certain ***power consumption budget*** which can be distributed among the nodes on the connection [2, 3]. We describe new power budget distribution schemes which seek to increase connection robustness in mobile environments.

The budgeted power model was initially introduced by Khan in [2]. Later, in [5], the authors designed a decentralized power budget redistribution protocol that minimizes end-to-end connection BER. Then, in [1] the authors developed analogous protocols to maximize the expected connection lifetime. In this paper, we refine our prior results on maximizing connection lifetime by considering *both the time and traffic required in operating the control protocols themselves.*

2. PROBLEM DEFINITION

Consider a single connection between a source node $\boldsymbol{s}$ and a destination node $\boldsymbol{t}$, and assume that a transmission power budget $\boldsymbol{P}$ has been specified for this connection. The questions arise: (i) How should P be distributed among intermediate nodes of the connection if the objective is to maximize the expected value of the connection lifetime? (ii) How does such a power distribution scheme perform relative to a scheme which simply allocates power in a uniform static manner among the constituent nodes? In answering these questions, we normalize the proposed schemes with respect to the control traffic utilized by the power distribution schemes themselves.

Model. We consider a wireless ad-hoc network $G = (V, E)$ consisting of $|V|$ mobile nodes each assigned a unique ID i in $\{1, \ldots, |V|\}$ and equipped with omni-directional antennas that can dynamically adjust their transmission power [2, 3, 5]. If node i transmits with power $P_t(i)$, the power of the signal received by node j is given by $P_{rcv}(j) = \frac{P_t(i)}{c \times d_{ij}^{\alpha}}$, where d_{ij} is the distance between nodes i and j, and α, c are both constants, and usually $2 \leq \alpha \leq 4$ (See [4]). In order to correctly decode the signal at the receiver side, it is required that $P_{rcv}(j) \geqslant \beta_0 \times N_0$, where β_0 is the required signal to noise ratio (SNR) and N_0 is the strength of the ambient noise. We denote the minimum signal power at which node i is able to decode the received signal as $P_{min} = \beta_0 \times N_0$.

3. POWER DISTRIBUTION SCHEMES

We describe schemes that continuously redistribute the power budget assigned to a connection among its constituent mobile nodes, so as to postpone link disconnections and maximize connection's expected lifetime. The proposed schemes are implemented on top of any routing protocol that can

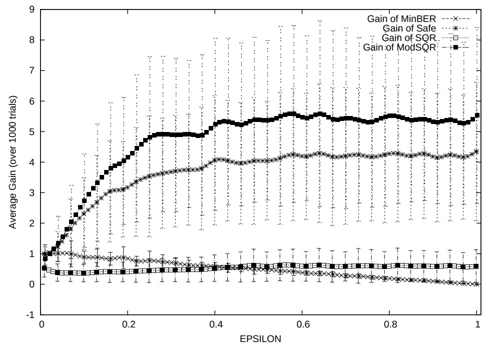

Figure 9: The Influence of Control Traffic on Gain in Soft TDM Mode

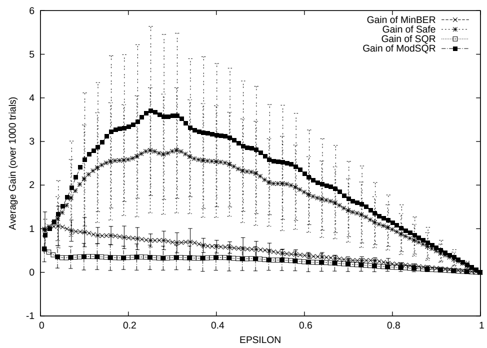

Figure 10: The Influence of Control Traffic on Gain in Hard TDM Mode

while keeping other variables fixed: power budget (P) was fixed at 10.0W, the number of nodes (N) was fixed at 10 , and the mean node density was one node every 100m.

Figure 9 shows the effect of *Epsilon* on the gain in Soft TDM mode. *ModSqr* and *Safe* show similar response herein, but *ModSqr*'s gain is higher than *Safe*'s gain since *Safe* has higher control traffic (and hence longer convergence times) than *ModSqr*. Note that the correlation between *ModSqr* and *Safe* was (0.97), showing that the former genuinely outperforms the latter, in spite of the fact that the two curves lie within each other's error bars. Both curves initially rise linearly up to around ε=0.25, then remain flat. When the ε is too small, there are few control time slots and the schemes run and converge slower than the side effects of node mobility, resulting in lower performance. Once the percentage of control time slots reaches a reasonable value (at about ε=0.25) the schemes obtain maximum gain level and increasing ε beyond this yields nothing in terms of the gain. Assigning too large an ε is both useless and *harmless* due to fact that the schemes is already converged and the nodes are allowed to handle data packets in the absence of control packets respectively in Soft TDM. In the same figure, the gain of *MinBER* decreases linearly as ε increases, and when ε=1.0 its gain becomes zero; this is understandable since in *minBER* the nodes always have control messages to send and will thus swamp out data if given the opportunity. The correlation between *minBER* and *Sqr* was low (0.13), indicating that the two schemes are incomparable, since their curves lie within each other's error bars. Figure 10 considers the effect of varying ε in Hard TDM mode. The correlation between *ModSqr* and *Safe* was (0.99). According to the figure, there are tradeoffs for *ModSqr* and *Safe* schemes such that they reach their maximum gain values when ε=1/4. As ε increases to 1.0 the gains of the all schemes decrease linearly and approach 0, since in Hard TDM control slots will swamp out data slots if ε is set too high.

6. CONCLUSION

The *Sqr* scheme equalizes received power levels at all nodes, and so is theoretically optimal in settings where the power distribution protocols operate instantaneously. In practice, however, it is seen to perform poorly when convergence time take into consideration. This realization motivated the design of the *Safe* scheme, which seeks to equalize the safe distances of nodes–that is, the distance that any node can move without breaking the connection. While the *Safe* scheme computes an optimal solution, it is crippled by its high communication complexity (and hence slow convergence in TDM implementations); this motivated the development of the *ModSqr* scheme, which captures the gains of *Safe* without incurring the high communication costs. We have implemented all schemes with two different lower layer assumptions: (i) *Soft TDM mode*, that is, there are control time slots for control traffic, and these time slots can be used on behalf of data traffic if there is no control packet to be forwarded at the nodes. (ii) *Hard TDM mode*, that is, there are again control time slots assigned for control traffic, but this time the nodes are not allowed to handle data packets if there is no control packets in the control time slots.The investigations demonstrate that taking control traffic overhead and convergence time of protocols play a critical role in the analysis of the proposed schemes.

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