Multigrid Techniques for Movement Planning in MANETs with Cooperative Mobility

Bilal Khan
Dept. of Mathematics and Computer Science,
John Jay College of Criminal Justice
899 Tenth Avenue
City University of New York, NY., 10019
bilal@bilalkhan.org

Ghassen Ben Brahim and Ala Al-Fuqaha
Dept. of Computer Science, Western Michigan University
Kalamazoo, MI., 49009
gbenbrah@cs.wmich.edu,
alfuqaha@cs.wmich.edu

ABSTRACT

Rapid-deployment mobile ad-hoc networks (MANETs) are frequently characterized by common over-arching mission objectives which predicate a cooperativeness on the part of constituent nodes. In this article we present a new strategy to improve MANET communications based on node cooperation with respect to mobility. We present our model for cooperative mobility, and use this cost-benefit framework to explore the impact of cooperation in MANETs where nodes are—to varying extents—willing to be moved for the common good. We develop an effective centralized algorithm for mobility planning based on multigrid techniques. Our simulation results are compelling and demonstrate that the communication infrastructure—specifically, connection bit error rate— can be significantly improved by leveraging this proposed scheme.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design; C.4 [**Computer Systems Organization**]: Performance of Systems

General Terms

Algorithm, Design, Performance

Keywords

wireless ad-hoc networks, bit error rate, cooperative, Quality of Service.

1. INTRODUCTION

Mobile wireless ad-hoc networks (MANETs) are an important infrastructure building block, enabling rapid deployment of a flexible communication infrastructure, e.g. in military and public safety operations. In the military setting, for example, MANETs facilitate communication between mobile infantry units, command and control, field intelligence, aerial surveillance, etc. They can be built using Radio Frequency (RF) communication links both between and within infantry formations, ground armored vehicles (e.g., tanks), airborne units (e.g., fighters, bombers), and naval/amphibious platforms (e.g., destroyers, troop carriers).

These technical challenges facing MANETs stem from their intrinsic limitations, specifically (i) bandwidth scarcity and high bit error rates of wireless RF channels, and (ii) limited battery capacities which mandate energy-awareness to extend the network lifetime. These limitations have hindered the development of truly scalable QoS-aware routing, and to cope with them much effort has been undertaken to leverage the power of *cooperation* between MANET nodes.

While prior work on the question of how cooperation can benefit communication (e.g. see [6], [5], [3], [4], [8], [7] and others) has principally considered the node's willingness to forward messages as it's cooperative contribution, we explore the ramifications of treating a node's physical mobility as a contributable resource. The assumption, while not applicable in the consumer MANET setting, is quite reasonable in in MANETs where participants have a common (e.g. mission) objective; these rapid deployment settings are precisely the ones where MANETs are most compelling anyway.

2. COOPERATIVE MOBILITY MODEL

The model of networking has evolved significantly over time. Classical networking presumed that link structure is essentially static and predetermined, with users at fixed locations. The cellular network paradigm, in contrast, allowed each user to roam and extend the classical network by making wireless connections to nearby base station nodes. In the purely mobile ad-hoc (MANET) setting, the classical network disappeared altogether; links are formed entirely by dynamic peer-to-peer wireless connections between users. Arising from historical context of consumer MANETs, users are envisioned in this model as being entirely autonomous with respect to their mobility. What we propose here is a significant modification of the conventional mobile ad-hoc network model.

We consider networks where mobility is a resource that can be used to ameliorate communication infrastructure. Our work begins with the model of Basu et al. [1], but rather than considering networks consisting of robots and non-robots, we consider the more general setting of *hetero-*

IWCMC'07, August 12–16, 2007, Honolulu, Hawaii, USA.

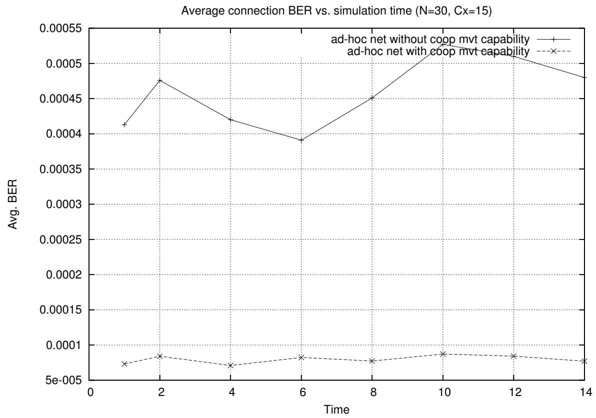

Figure 6: Using the multigrid scheme to reduce the average BER

tice that for a higher node movement budget corresponds a better improvement in the overall percentage BER improvement. For example, for a connection set size, corresponds a 35% improvement when using 50 units of budget compared to the case where each node has only 20 units. Considering the *slope* of the curves in the top graph, we conclude that the average percentage BER improvement decreases as the connection set size increases.

The bottom graph of Figure 7, illustrates the impact increasing the movement budget on the percentage of the connections that do not meet the BER requirement by the time the optimization terminates. By looking at the *slopes*, we conclude that this percentage increases as the connection set size increases. For example, 13% of the connections did not meet the BER requirement when the connection set size equals to 17. By considering the *difference* between both curves of the bottom graph, we conclude the percentage of connections that did not meet the BER requirement is much less in the case of higher movement budget available per node. For example, for 17 connections, increasing the movement budget from 20 to 50 units results in a 50% improvement in the percentage of connections not meeting the BER requirement.

5. CONCLUSION AND FUTURE WORK

In this paper, we consider how cooperation between nodes can improve communication in mobile ad-hoc networks. We propose a new cooperative mobility model based on location management scheme under budget constraints aiming to the improvement of the QoS of a connection set. The main contribution of this paper is the design and implementation of an effective multigrid scheme for computing dynamic node placements. Simulation experiments indicate conclusively that the resulting approach is scalable and succeeds at efficiently moving cooperative nodes in a manner which optimizes connection bit error rates.

Several extensions to this work are presently being considered. First, we seek to quantify the impact of the grid refinement schedule on the quality of the solutions derived. In addition, we will design distributed implementations of this scheme, under the presumption of effective clock synchronization protocols.

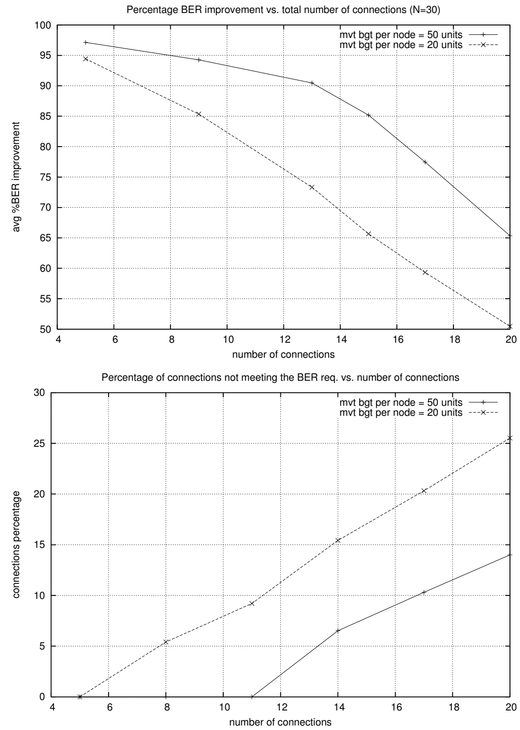

Figure 7: The benefit of increasing the mobility budget

6. REFERENCES

[1] P. basu and J. Redi. Movement Control Algorithms for Realization for Fault-Tolerant Ad-Hoc Robot Networks. IEEE Network, July 2004.

[2] A. Brandt. Multi-level adaptive solutions to boundary-value problems. volume 31, pages 333–390, 1977.

[3] S. Buchegger and J. Y. L. Boudec. Cooperative routing in mobile ad-hoc networks: Current efforts against malice and selfishness. of Mobile Internet Workshop. Informatik 2002., Dortmund, Germany, October 2002.

[4] M. Gerharz, C. de Waal, P. Martini, and P. James. A cooperative nearest neighbors topology control algorithm for wireless ad hoc networks. IEEE, 2003.

[5] A. Khoshnevis and A. Sabharwal. Network channel estimation in cooperative wireless networks. Canadian Workshop on Information Theory, Waterloo, Ontario, May 2003.

[6] N. Li, J. C. Hou, and L. Sha. Design and Analysis of an MST-Based Topology Control Algorithm. IEEE INFOCOM, 2003.

[7] A. Nosratinia, T. E. Hunter, and A. Hedayat. Cooperative Communication in Wireless Networks. IEEE Communication Magazine, October 2004.

[8] C. Politis, T. Oda, N. Ericsson, S. Dixit, A. Schieder, H. Lach, M. Smirnov, S. Uskela, and R. Tafazolli. Cooperative Networks for the Future Wireless World. IEEE Communication Magazine, September 2004.

[9] V. E. H. William L. Briggs and S. F. McCormick. *A Multigrid Tutorial, Second Edition*. SIAM, 2000.