A New Fuzzy-Based Cooperative Movement Model in Support of QoS in Wireless Ad-Hoc Network

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ABSTRACT

In this paper, we develop a Cooperative Mobility Model that captures new salient features of collaborative and mission-oriented MANETs. We propose new techniques to leverage two optimizations for cognitive radio networks that are specific to such contexts: *cooperative mobility* and *opportunistic channel selection*. We present a new formal model for MANETs consisting of cognitive radio capable nodes that are willing to *be moved* (at a cost). We develop an effective decentralized algorithm for mobility planning, and powerful new filtering and fuzzy based techniques for both channel estimation and channel selection. Our experiments are compelling and demonstrate that the communications infrastructure—specifically, connection bit error rates—can be significantly improved by leveraging our proposed techniques. In addition, we find that these cooperative/ opportunistic optimization spaces do not trade-off significantly with one another, and thus can be used simultaneously to build superior hybrid schemes. Our results have significant applications in high-performance mission-oriented MANETs, such as battlefield communications and domestic response & rescue missions.

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

Cognitive radio, Cooperation, Quality of Service, Ad-hoc network, filter, fuzzy logic. low bit error rate.

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1. INTRODUCTION

Mobile wireless ad-hoc networks (MANETs) are an important building block of modern networks, having found fruitful applications in both consumer and mission-oriented settings. Examples of the latter include battlefield and public safety scenarios where MANETs are considered especially well-suited because they support the rapid establishment of communications for mobile platforms over a shared wireless medium, and obviate the need to invest time and expense in developing a fixed infrastructure.

Surprisingly, while MANETs have been applied in mission-oriented rapid-deployment applications such as battlefield communications and domestic response & rescue missions, much of MANET research has not made a concerted effort to leverage the central difference between consumer MANETs and mission-oriented rapid-deployment MANETs: namely that the latter brings with them implicit common group objectives which make inter-node cooperation both logical and feasible. This willingness to cooperate provides designers of rapid-deployment mission-oriented MANETs additional opportunities for new optimizations which have not been thoroughly explored. In this paper, we will consider two such optimizations and describe the tradeoffs inherent between them.

In this work, we develop a realistic model for cooperation in mission-oriented rapid-deployment MANETs that leverages both cooperative mobility and cognitive radio (CR) paradigms. In short, we present solutions to optimizing the performance of MANETs which consist of CR-capable nodes that are sometime able to *be moved*. We evaluate the extent to which the communications infrastructure can be improved by leveraging these two paradigms, and assess the extent to which the two optimization spaces interact with one another.

The remainder of the paper is organized as follows. In Section 2, we present our model of Cooperative Mobility and algorithms for mobility planning. In Section 3, we present our proposed traffic estimation and opportunistic channel selection strategies. Our proposed channel estimation strategy utilizes a combination of Exponentially-Weighted Moving Average (EWMA) and wavelet-based filters. Channel selection employs an extensible fuzzy rule-base to determine the overall cost of a cognitive radio channel, based on its estimated average and auto-correlation metrics. In Section 4, we describe policies for cooperative mobility and opportunistic channel selection. In Sections 5 and 6, we present the experiments and interpret their outcomes. Finally, in

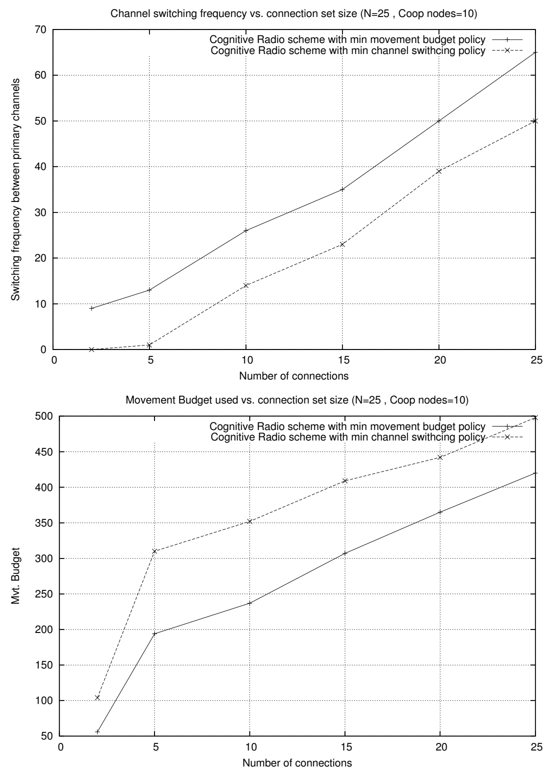

Figure 8: Opportunistic cognitive radio and cooperative mobility

ing the size of the connection set on the performance of the proposed schemes. The simulations setup consists of a network size of 25 nodes, a connection set size of 10, mobility budget per node equals to 300 units, and considering the wavelet transform and flip-flop filtering techniques to estimate the traffic over the primary channels of the cognitive radio channel. The graph of Figure 9 shows that both proposed policies of the cognitive radio based schemes outperforms the cooperative model without cognitive radio capability. Although the percentage improvement in the number of connections that did not meet the required BER decreases as the connections set size increases, the improvement remains in excess of 30% regardless of connection load.

7. CONCLUSION

Our experimental results are compelling and demonstrate that the communications infrastructure—specifically, connection bit error rates—can be significantly improved by leveraging cooperative mobility and opportunistic channel switching using our proposed techniques. The techniques thus have significant impact on practical mission-oriented MANETs, with applications to battlefield communications and response and rescue missions.

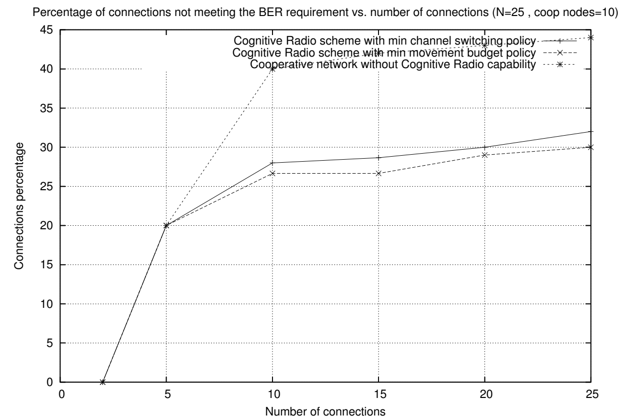

Figure 9: The performance of the proposed schemes when increasing the connection set size

The resultant algorithm improves average connection BER almost linearly as the mobility budget increases (with constant numbers of cooperative nodes). It also improves connection BER almost linearly as the number of cooperative nodes increases (with constant total mobility budgets). The wavelet transform and flip-flop filtering techniques are effective, predict the status of primary channels, enable lower average connection BER especially when coupled with our channel selection scheme. The cooperative mobility and opportunistic channel selection schemes can be hybridized without negative tradeoffs. The schemes scale and continue to provide significant BER reductions (in excess of 30%) even as network load increases.

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