Poster Abstract:
Exploring Diversity: Evaluating the Cost of Frequency Diversity in Communication and Routing

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ABSTRACT

As the number of wireless devices increase, the frequency spectrum becomes further congested. Deployments of wireless devices in harsh radio environments (i.e. an industrial plant) also motivates the study of alternate communication protocols that offer enough diversity to overcome interference. This work explores the use of frequency diversity to address this problem and examines its effectiveness in various environmental settings. We also examine the interplay between frequency agility at the MAC layer and route diversity in the network layer and look to understand the cost-tradeoffs in the diversity of choices offered by each layer.

Categories and Subject Descriptors

C.2.2 [**Computer-Communication Networks**]: Network Protocols

General Terms

Design, Performance, Experimentation

Keywords

Link, Routing, Wireless, Sensor Network, Mote

1. INTRODUCTION

Wireless communication protocols must deal with a wide variety of operating conditions in a dynamic environment. In order to improve performance and robustness, communication stacks allow the system to change states as the environment changes. Fundamentally, each layer of the stack provides a diversity of choices. As changes in the environment are perceived by the stack, the choices are combined across layers to offer continued service and optimal performance.

Various techniques in radio design, medium access control, and routing give a system a variety of options. For example, a multichannel medium access control (MAC) protocol maintains a list of channels to communicate over, while a node using a tree-based routing protocol may maintain a list of multiple parents. Each choice can be measured with respect to a set of metrics and ranked accordingly. This ranking allows the system to make smarter choices when several options are available. It may also be stored for later use if the preferred choice(s) becomes unavailable.

There are inherent costs associated with the discovery and maintenance of the set of choices. For example, a multichannel MAC will need to scan each channel to obtain an initial ranking, maintain channel statistics related to the state of the channel, and incur an added overhead in negotiating with local neighbors for a communication channel. Even if the MAC does not use a negotiation strategy (by instead using a global schedule), it will need to pay the cost for performing periodic network time synchronization. Moreover, the added complexity of a distributed scheme, with a diverse set of choices, can be very difficult to debug.

At what point is too much diversity detrimental? How can we design a protocol so that we reap the benefits of extra choices while maintaining a reasonable maintenance cost? In this study, we examine diversity at various layers and look closely at the interaction amongst layers. Specifically assess the opportunity for using frequency agility in various environments and see how it affects robustness and cost of pair wise communication. We also examine how the network is affected holistically.

Some of our initial data indicate that the introduction of a multichannel MAC introduces a *need* for other wireless devices to also hop frequencies. Channels that would otherwise be silent are now periodically noisy with transient bursts of packets. This observation suggests a different protocol design for frequency agility – network-wide agreement on a single channel and distributed consensus for switching to a new channel if the performance on the current one degrades. We examine these types of protocol decisions in our work.

2. INITIAL WORK AND RESULTS

Currently we have data collected from a set of sixteen MicaZ motes each monitoring the received signal strength (RSSI) on a unique 802.15.4 channel for a period of 24 hours; Each of the sixteen motes being within the same collision domain. Several 802.11 access points are physically mounted among the motes on the ceiling of an office environment with no physical obstructions.

Figure 1 shows the 802.11b and 802.15.4 spectrum usage. Our data verifies that the clearest channels for communication in an 802.15.4 network are indeed 15, 20, 25, and 26; as indicated by the figure. In such an environment this sug-

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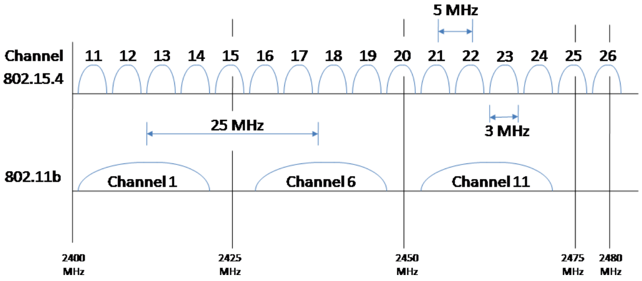

Figure 1: 802.11b and 802.15.4 spectrum usage.

gests that the added cost of scanning and ranking the other twelve channels may not be beneficial, as the top four candidate channels do not change over time. Furthermore, our data shows that the measured RSSI has the smallest variance on each of those four channels. Although this is the condition in our office environment, it may not hold for environments where the main source of loss is due to multipath effects.

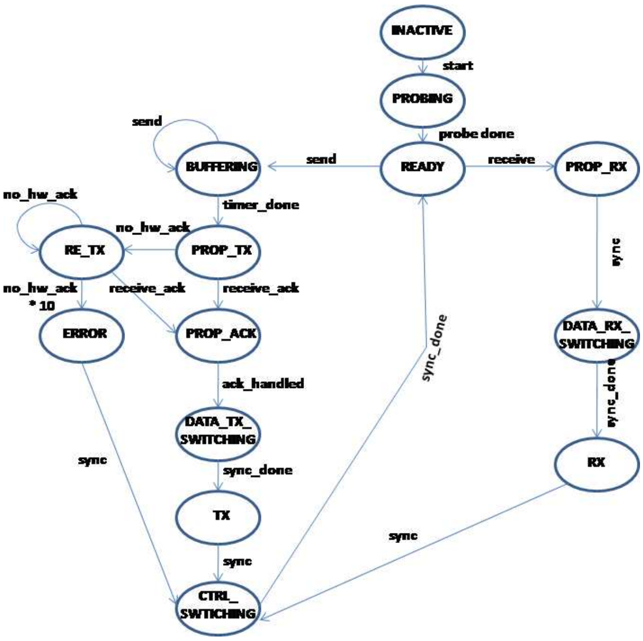

Figure 2: This multichannel MAC (state machine above) uses a single control channel for pairwise negotiation of a preferred channel. The probing phase uses the channel-probe component which scans and ranks the noise floor on each channel. Since the control channel is the point of rendezvous, low-power listening can trivially be integrated into the design.

We have also written an implementation of a simple multichannel MAC that uses a single control channel to negotiate the transmission of a burst of packets. The state machine diagram for our implementation is shown in figure 2. It is made up of a set of discreet components which can be composed in various ways to change the implementation behavior of the multichannel MAC protocol. The main system components are the channel prober, the channel state manager, and the MAC-state management component. The send interface also makes use of message futures [4] in order to reduce the amortized cost of packet transmissions.

On startup, each node scans each of the sixteen available channels and ranks them according to the average of five RSSI samples for each channel. The basic algorithm consists of the negotiation of a burst on the control channel. When the send interface is invoked a burst of packets is gathered locally and the control packet is populated with the burst size, and top three preferred channels. The receiver, who is listening on the control channel, accepts the control packet and picks the best channel among the three choices and sends an acknowledgement control packet to the sender. The receiver then switches to the data channel and waits for the burst. After the burst is done, both the sender and receiver switch back to the control channel.

3. DISCUSSION AND FUTURE WORK

For future work we will set up various experiments in our office setting and various other environments. Specifically we look to make use of the channel prober to examine how multihop paths rank their top channels and whether a single channel, or small set of channels, may effectively satisfy the needs for robust, efficient routing in sensor networks. We also intend to use our findings to explore the design space and release and open-source implementation written for TinyOS.

4. RELATED WORK

Multichannel MACs have been examined extensively in the literature and in sensor networks there are two recent publications [2, 3]. The need for frequency agility in an industrial environment has also been examined [5]. However, there has been no such study that looks at the interaction of frequency agility with and multihop routing. Furthermore, although the theoretical cost analysis has been looked at [1], it has not been examined in the context of sensor networks in a realistic environmental setting. Our study looks to address these issues and also offer an implementation of a multichannel MAC that uses of our findings.

5. REFERENCES

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