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Problem 1

35 Points

Part A (10 points) Describe the two main models we use to model variations in the received signal strength. What are the spatial and temporal regimes in which each of the two models applies?

The first model is *Shadowing* that describes signal strength variations in the order of multiple signal wavelengths (\( \lambda \)) and can be modeled with a Gaussian distribution (in dB). The second model is called *multi-path fading* and models signal variations over small distances and small time intervals. Fading is usually modeled using a Rice or Rayleigh distribution.

Part B (25 points) The radio’s so-called *gray region* corresponds to a range of distances from the transmitter over which packet reception ratio (PRR) is highly variable. Explain how this high variability can be explained using the models you described above. Can node mobility actually improve PRR for links that are in the gray area?

The variability in the gray area suggests that while a node might be initially placed in a location with low PRR by moving some direction it might improve its PRR considerably. The challenge is to determine how far the node should move and how many locations it should sample. This decisions can be made given an understanding of the signal variation from the models described above.
Problem 2

30 Points

Part A (10 points) Describe why the mechanism used to generate preambles in BMAC does not work for 802.15.4 radios and what can be done for these radios.

BMAC transmits a continuous preamble however 15.4 radios are packet based. Therefore, a MAC protocol for these radios needs to transmit back to back packets. Moreover, the radio introduces a small inter-packet delay (shown in Figure 1). In turn this means that the receiver needs to keep it’s radio up for a period equal to the sum of two packet transmission times and one inter-packet interval. To see why this is true imagine that the receiver turns its radio ON just after the first few bits of the first preamble have been transmitted and therefore it will not be able to properly decode that first preamble. Then it waits for the inter-packet interval and finally decodes the second preamble.

Part B (20 points) Unlike the simplified X-MAC protocol that you implemented for your homework, the actual protocol requires a negotiation phase before the transmitter successfully delivers a packet. Specifically, after the receiver wakes up and it correctly decodes a preamble sent to its address, it sends an acknowledgment (see Figure 1). After the transmitter receives the ACK it transmits the actual data packet.

Answer the following questions: (a) What are the benefits of using packet-based preambles in XMAC? (b) How long should an XMAC receiver keep its radio on to determine if there is an outstanding packet for it? (c) How would you change the receiver’s check mechanism to reduce the time that it’s radio is on? Does this change also have an impact on how the transmitter acts?

(A) The benefit of using packet-based preambles is that the preamble carries destination information that receivers can use to determine whether the packet is intended for them. (B) Answered above. (C) Rather than having a packet-based check at the receiver, one can have a energy-based check. That is the receiver checks if there is energy on the channel by checking its CCA circuit. This means that the receiver’s check time is independent of the preamble packet. In turn this means that the transmitter can send full packets (i.e., packets that carry the actual payload the transmitter wants to deliver) rather than small preamble packets.

Figure 1: XMAC
Problem 3

35 Points
Part A (10 points)
We saw in class that one can use queue occupancy to detect the onset of congestion. What other quantity can a node measure to infer congestion in the upstream network path?

A node can measure (through overhearing) the difference between the time it transmits a packet until the last time it hears the packet transmitted by its parent. We use the last time, because the packet may collide and needs to be retransmitted.

Part B (25 points)
Using this quantity, design a congestion control algorithm that controls the nodes’ transmission rates. To make things simpler, assume that only a single end-to-end flow is active at any point in time and the algorithm has to determine that flow’s sending rate (or equivalently the inter-packet time interval).

Given the mechanism above, a node can pace the transmission of its messages such that it sends its next message after its upstream neighbor has successfully delivered the previous message. However, some links further upstream might be further congested (i.e., slower). For this reason, the slowest rate must be propagated downstream. This can be done by including the lowest rate to acknowledgments.