1.0 Introduction

The sponsor of this research project has developed a wireless alarm system to be used in residential buildings. Each alarm unit in the system employs a radio transceiver for communication among the units. When a unit's alarm is triggered, the unit broadcasts an information message at a radio frequency. Any units within range of the broadcasting unit sound their alarms and repeat the message for other units to receive. The system is a multi-hop packet radio network because short, bursty messages travel from source to destination over multiple relays or hops.

In a packet radio network several terminals transmit information over a shared communication channel. If more than one terminal transmits at a given time, message collisions can prevent a receiving unit from successfully decoding the information. A multiple access strategy is needed to reduce the likelihood of this situation.

In general, existing multiple access strategies can be described as either scheduled or random[1]. In a scheduled multiple access protocol, a terminal is not permitted to transmit unless it has successfully made a transmission reservation. Although scheduled multiple access protocols prevent message collisions, the scheduling process mandates additional system overhead. The terminals in a random access protocol, on the other hand, can transmit whenever they have a message to send. Random access protocols rely on retransmission strategies to reduce the likelihood of message collisions.

Because terminals in packet radio networks transmit short, bursty messages, scheduled access strategies are not efficient. System resources are wasted when terminals are idle. To use system resources more efficiently, packet radio networks typically employ random access strategies.

There are several existing random access protocols which have been used in packet radio networks. One of the most famous is the ALOHA protocol developed by Abramson[2].

The ALOHA protocol was developed in 1970 at the University of Hawaii to allow multiple terminals to interact with a main computer. In the ALOHA protocol a terminal may transmit when it has a message to send. After transmitting, the terminal listens on a separate channel for an acknowledgment from the receiving station. If an acknowledgment is not received, the terminal retransmits the information after a random time delay.

A more efficient version of ALOHA is the slotted ALOHA protocol[3]. In slotted ALOHA time is divided into small time slots. Transmissions can only be initiated at the start of a time slot. Although slotted ALOHA offers improved channel capacity over ALOHA, neither protocol performs well under heavy traffic conditions. As the traffic load increases, transmissions keep colliding and infinite time delays are possible.

A random access strategy which offers significant improvement over both unslotted and slotted ALOHA is the Carrier Sense Multiple Access (CSMA) technique first introduced by Kleinrock and Tobagi[4]. Like the ALOHA strategy, CSMA requires a separate channel for acknowledgment.

In a CSMA system a terminal which has data to transmit senses the channel for the presence of a carrier signal. The terminal may then either transmit its packet or delay its transmission depending on the status of the channel and the particular CSMA scheme being employed. Once the packet has been transmitted, the terminal waits for an acknowledgment on a separate channel. If an acknowledgment is not received, the terminal reschedules the packet for transmission.

In general, there are three types of CSMA – nonpersistent, 1-persistent,and p-persistent. In a nonpersistent CSMA system a terminal which senses the channel idle immediately transmits its packet. However, if the channel is occupied, the terminal reschedules its transmission according to some random time delay distribution.

In a 1-persistent CSMA system, if a terminal senses the channel idle, it transmits its packet immediately. If the channel is occupied, the terminal waits until the channel becomes idle and then transmits immediately. It should be noted that message collisions are guaranteed to occur if two or more terminals have packets to send while the channel is busy. In this scenario, the terminals will begin transmitting simultaneously as soon as the channel becomes idle.

The 1-persistent CSMA technique is a specific case of a more generalized strategy called p-persistent CSMA. In p-persistent CSMA, if a terminal senses the channel idle, the probability that it will transmit a packet is p. The probability that it will delay its transmission is $(1-p)$. The p-persistent protocol is an improvement over the 1-persistent protocol, as the start of a terminal's transmissions can be randomly delayed , thereby reducing the likelihood of message collisions.

Although CSMA offers improved performance over the ALOHA protocol, there is a serious problem with the CSMA algorithm. Consider a case in which two terminals are attempting to transmit a message to a third terminal. Assume that the two transmitting terminals cannot sense one another's transmissions because there is an obstruction between them. In this scenario, there is a high probability of message collisions since both terminals will assume that the channel is idle. This situation is called the hidden terminal problem and was investigated by Tobagi and Kleinrock[5].

The multi-hop packet radio network deployed in the wireless alarm system uses a hybrid of the CSMA techniques just described. This thesis analyzes the effect of packet collisions and the hidden terminal problem on the system's performance. It develops an analytical model to determine the probability that collisions will prevent an alarm unit in a four-unit system from receiving a message. The thesis extends the model to include configurations of five and six units. The author has validated the analytical model with actual system testing.

The thesis investigates the effect of indoor radio propagation on system performance. In particular, it includes a literature survey of existing indoor models. Additionally, the author, with the assistance of several colleagues, has conducted indoor propagation measurements in three different homes in an effort to characterize the losses that can be expected within a home. The thesis discusses the results of these measurements.

The results of this project are guiding the sponsor's installation plan for the placement of the wireless alarms within the home. The results are also assisting in the design of future versions of the wireless alarm system so that the existing problems can be resolved.