# A SIMULATOR FOR EVALUATING MAC PROPOSALS

## I. Overview

1. This document describes a simulator for evaluating wireless medium access proposals. The simulator is currently (June 1991) in a state of development and testing. This is an interim report.

2. Wireless networks operate in an environment significantly different from cabled networks. They may be subject to interference from uncooperative sources as well as interference from other wireless networks and network nodes which are unaware of their existence or state.

3. Wireless radio networks are especially subject to interference from other networks due to the effects multipath fading and shadowing.

4. Infrared networks are less subject to multipath effects (because of their incoherent sources) but are subject to shadowing.

5. Any wireless network medium access protocol must provide adequate capacity in the face of interpenetrating, uncoordinated networks. Wireless networks are interpenetrating due to the nature of radio and infrared propagation. They are uncoordinated due to the ability (in the case of radio) for signals to penetrate walls.

6. The IEEE 802.11 Committee has received a number of proposals for medium access mechanisms. Claims have been made concerning the suitability of different approaches to wireless medium access. Although the subject has generated much heated discussion, most of the discussion has been individual opinion based on experiences in related but different fields.

7. There is a need for an objective method for the Committee to evaluate proposals. Simulation provides an economical and rapid method for determining the performance of specific proposals in a variety of transmission and load environments.

## II. Simulator Objectives

1. A simulator for the wireless environment must provide a capability for developing and employing a suite of standard test environments. It should be highly transportable, permitting its use on platforms from personal computers to mainframes. Its code should be available for public review to permit its validity to be questioned and improved. To help establish credibility, it should be tested against previously published results for existing medium access methods.

2. A simulator has been written in the C programming language with machine dependencies kept to a minimum and isolated into a separate module. This should assure its ready portability to a variety of computer platforms and facilitate peer review and modification.

## III. Simulator Data Base Description

1. The simulator is driven by a data base (created outside the simulator). Any number of data bases may be created to allow test suite expansion to cover as many conditions as desired. Since the data base is independent of the simulator, it may be created by means capable of producing ASCII files including a (provided) data-base-filling program. The data base contains the following information:

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2. Packet size distribution by node: Normal local area network traffic is characterized by a bimodal distribution of packet lengths. Any realistic simulation must take this into account. The simulator provides for a data base having up to 32768 levels of packet size. Each node may have a different packet size distribution if desired. This is particularly advantageous in distinguishing different traffic patterns for clients and servers. Packet sizes for each level are defined as fractions of the maximum length packet (defined later).

   The impact of packet size distribution on MAC protocols has not been widely studied. It seems that collisions involving only short packets would be less harmful to channel capacity than collisions involving long packets. This simulation will permit exploration of this issue.

3. Connectivity by node: Wireless environments are characterized by a wide variation in signal strengths received at any node from all of the other nodes. The simulator provides for a data base having 256 levels of signal strength at each node from all of the other nodes. Thus, conditions from no-signal, through interfering-signal to full signal may be simulated. Hidden nodes may be accommodated as well as interfering nodes which cannot hear other nodes. This connectivity data base allows the signal relationships to be asymmetrical so that a node which "hears" another node clearly, might not be "heard" equally well by that node.

   The ability to simulate different connectivity conditions is important to evaluating wireless MAC proposals. The "hidden node" problem has been shown to cause deterioration in the performance of CSMA protocols. However, the "capture effect" of strong signals on receivers has not been widely considered. This effect permits collisions to occur which do not interfere with reliable communication.

4. Node-to-node destination probability: A great deal of local area network traffic is characterized by communications from nodes to a server and from the server to nodes. Node-to-node communications are much rarer. The simulator permits each node-to-node link to be independently assigned a probability, allowing one or more nodes to simulate servers.

   Since the server and the nodes using the server are unlikely to be hidden from each other, the impact of hidden nodes may be reduced. By providing for user-specified destination probabilities, MAC layer performance can be realistically evaluated.

5. Node traffic generation rate: Just as there is an asymmetry in the distribution of node-to-node destinations, there may be a similar asymmetry in the rate of traffic generation by node. The simulator allows each node to have a specific traffic generation rate to be assigned.

6. Number of nodes: The number of nodes handled by the simulator can be defined by the user. Choice of this number will, in part, be limited by the capabilities of the computing platform. Too large a number can result in long simulation times.

7. Time slots per maximum length packet: Time is not explicitly used in the simulation. The state of all network nodes is recomputed at each time slot. Packet lengths are specified as fractions of the number of time slots in a maximum length packet. This permits the simulation to be scaled to any speed network. Choice of the number of time slots per maximum length packet sets the resolution of the simulation. Experimentation with this parameter allows simulation time to be minimized without degrading validity.

8. Time slots for propagation and carrier-detect delay: Carrier sense protocol performance is very dependent on channel propagation delay. Although this may be a small fraction of the packet time, the receiver's time to detect carrier may effectively add to this time. This data base entry allows these delays to be described in terms of simulation time slots required for propagation and carrier sense. Since propagation time does not normally vary

significantly (as a fraction of packet time), this parameter is not set on a node-by-node basis.

## IV. Simulator Description

1. The modelling software consists of three basic parts: the startup code, the model itself and the statistics generator.

2. The startup code reads the file containing the ASCII data base representing the test, parses it and creates a program data base. Remaining variables are initialized and the display is set-up for the statistics generator output.

3. The model will iterate through time, allowing each node to change its state at every time interval. When appropriate, the statistic generator will be called to increment its counters. The network simulation function will be a state machine, where each node contains in its data, the current state of that node and any information necessary to the function. The operator is allowed to stop the simulation at any time during the model run.

4. The model framework is simply a pair of nested loops, where the outer loop represents time, and the inner loop runs through the nodes and allows each to determine its state.

```
while (! operator_abort() )
{
    for ( node = 0; node <= last_node; node++ )
    {
        model_state(node);
    }
    update_statistics();
}
```

5. A model is created for each medium access protocol to be simulated. Each model accesses its part of the data base array to determine the node's present status and calculate the probability of taking some actions in the current time slot. The model functions are state machines, implemented as case statements. The model function will be called once for each node for each simulated time slot.

6. The statistics generator provides functions to the model for initialization, screen updating, incrementing the number of attempted transmissions, successful transmissions, collisions, etc. The screen displays a bar-graph representation of the current network status and the statistics collected to that point, allowing the operator to observe the behavior of the network simulation as it runs.

7. A separate program was developed for creating data bases for the simulator.

## V. Simulator Development Status

1. The simulator is incomplete. Nevertheless, early trials using the ALOHA and Slotted ALOHA medium access methods have validated its utility. Results of the simulation closely match theoretical predictions.

2. The data base capabilities of the simulator are not complete. In particular, the specific node-by-node capability has not yet been implemented. Currently, all nodes have identical packet sizes, destination probabilities and

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connectivity. Additional simulator capability is being added daily.

3. Simple ALOHA and Slotted ALOHA models have been designed and agreement with the results reported by Kleinrock and Tobagi (refer to "A Short Tutorial on CSMA", IEEE P802.11/91-44) is excellent. Additional models including P-Persistent CSMA are expected to be completed shortly.

4. The authors plan to use the model to evaluate modifications to the P-Persistent CSMA protocol which appear to have promise of improving performance in the presence of hidden or interfering nodes.

5. The authors will supply source code to interested parties on request. Suggestions for improvements and corrections are welcome.