Propagation Model Embedded In A Wireless Network Simulator

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Abstract

A propagation model has been added to the network simulator ns to achieve more accurate physical layer simulation. The model includes the capability to predict signal strength in the face of obstacles and varied terrain.

Keywords: Propagation Model, Network Simulator, ns

Introduction

Network simulators often model only certain aspects of a network, such as the network protocols used in transmission, and they usually do not include realistic physical layer models. Similarly, physical layer simulators usually do not include the behavior of network protocols. This paper details the results of adding a sophisticated propagation model to *ns*, yielding an improved capability to model the physical layer as well as the protocols. In the next section, there is a discussion of the method of simulation. The second section explains the tests that were generated. Finally, the results of those tests are given and conclusions are presented.

Method of Simulation

The simulator used to model this wireless environment is *ns* [1], the network simulator. It is a discrete event simulator originally created at the University of California at Berkeley, and is a continually evolving research tool. Researchers at Carnegie Mellon University made many modifications to the tool to provide greater wireless capabilities, including adding such protocols as Mobile IP and the 802.11 wireless MAC protocol [2].

The modifications to *ns* include data structures that contain physical layer information, such as the position of the antenna, the carrier frequency, the bit rate, the antenna gain, the transmitting power of the device, and the receive and carrier sense thresholds. This information is used by the propagation model to determine the signal strength of an arriving packet. The parameters used are typical of a wireless LAN such as WaveLAN ™ and are listed in Table 1 below.

Table 1. The physical layer parameters used in the simulations are typical of a wireless LAN.

Transmitted Power	24.5 dBm
Carrier Frequency	915 MHz
Receive Threshold	-72 dBm
Carrier Sense Threshold	-80 dBm
Bit Rate	2 Mbps = 250KB/s
Antenna Height	1.5 meters
Antenna Gain	2 dB

A basic propagation model was also added to the simulator. It consists of free-space propagation up to a break-point distance d_o. For distances greater than d_o, the path loss is assumed to increase as r^4 [2].

Model Description

The propagation model from [2] was extended in several ways. The following capabilities were added:

I. Basic Propagation Model Enhancements

Since a wireless signal is rarely free of fluctuations, a random variable was added to the basic propagation model to permit the simulation of log-normal shadowing [3]. In addition, minor adjustments to the distance d_o were made based on [4].

II. Line-of-sight Blockage by a Moving Object

If an object moves between the transmitter and receiver, the signal can be lost owing to the blockage of the line-of-sight path. The model allows for a spherical object with specified radius and velocity to roam between the communicating nodes. Excess path loss caused by the object is estimated using knife-edge diffraction [5] from the object edge nearest the line-of-sight path. A rounding loss [5] is also added to better approximate diffraction around a sphere in contrast to a single knife-edge.

As an example, consider two nodes communicating over flat terrain. Figures 1 and 2 show results of two nodes communicating in the face of an obstacle. For these figures, a sphere of radius 3.0 meters is traveling at 10 meters/second (around 22.4 miles/hour) between a transmitter and a receiver. The transmitter and receiver nodes remain stationary at 60 meters apart.

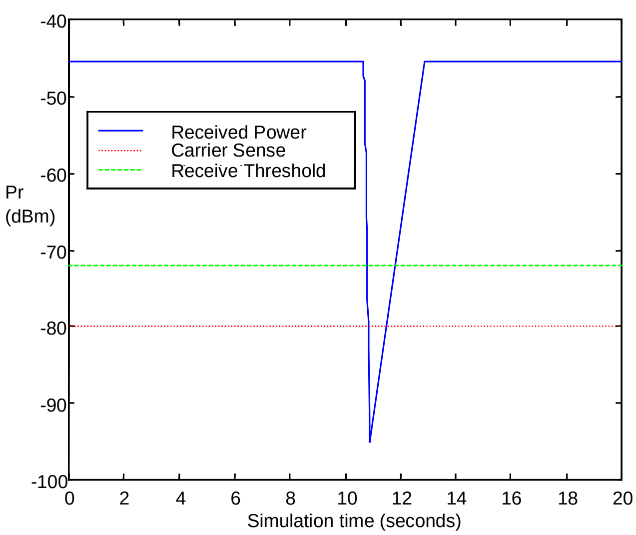

Figure 1. The received power drops sharply when the line-of-sight is blocked.

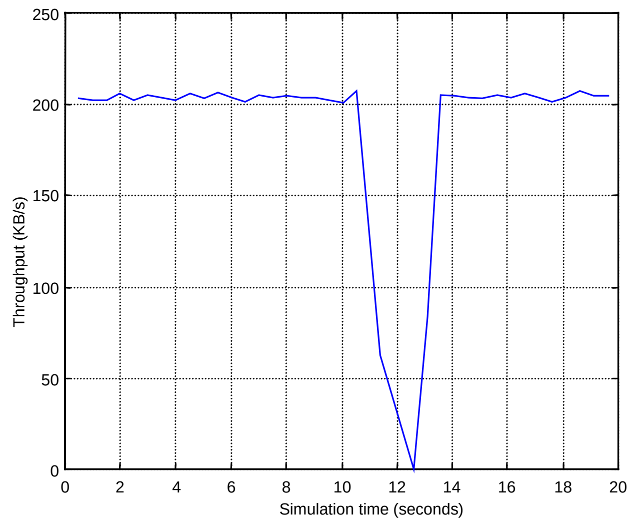

Figure 2. The throughput is severely affected when the received signal strength drops below the receive threshold due to line-of-sight blockage.

The signal strength, shown in Figure 1, juts below the receive threshold line for a few seconds. This is a result of the obstacle blocking the line of sight path between the transmitter and the receiver. Figure 2 shows the effect of this dip on the throughput. While the throughput remains constant for the most part, it drops dramatically to zero for the few seconds when the received power is below the receive threshold. Note that the throughput remains constant at about 80% of the total bit rate until the line-of-sight is lost. The 80% mark is reasonable considering overhead bits are not counted in the throughput. In addition, some transmission silences are to be expected in the implementation of the TCP protocol.

III. Propagation over Varied Terrain

Digital Elevation Maps (DEMs) can be obtained for every location in the United States [6]. The ability to read in and describe node motion on a DEM has been recently incorporated into *ns* [2]. Building on this capability, a knife-edge diffraction model has now been added to enable the simulation of communications over varied terrain. With DEMs, nodes in *ns* travel along the contour of the earth. Thus, they traverse hills and descend into valleys. Two nodes may be within propagation range of each other yet line of sight communication is blocked by a hill. The knife-edge diffraction loss model is used to determine propagation loss in this type of situation.

As an example, consider two nodes communicating over varied terrain. One node remains stationary while the other (Node 2) moves away from the first node at a speed of 10 meters per second. Figure 3 shows the terrain that Node 2 traverses. Node 1 remains stationary at the point of origin of Figure 3.

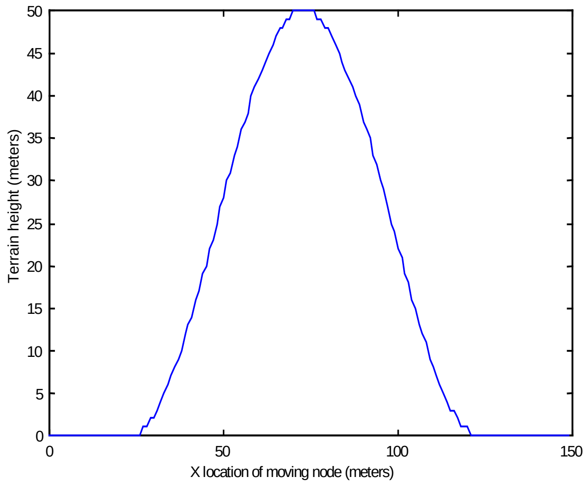

Figure 3. The mobile node traverses a hill in the DEM simulation example.

The received power versus distance is shown in Figure 4, while the throughput versus distance is shown in Figure 5. The transmitter and receiver are capable of communicating until they are about 275 meters apart on flat terrain. However, the hill that Node 2 travels in this scenario cuts off communication much sooner. For the first segment of the simulation, Figure 4 shows the signal strength falling off with distance in the same manner as the basic propagation model. At about 75 meters away from Node 1, the signal strength at Node 2 begins to be affected by the blockage from the hill. Shortly thereafter, Node 2 can no longer receive a valid signal from Node 1. The resulting drop in throughput is shown in Figure 5.

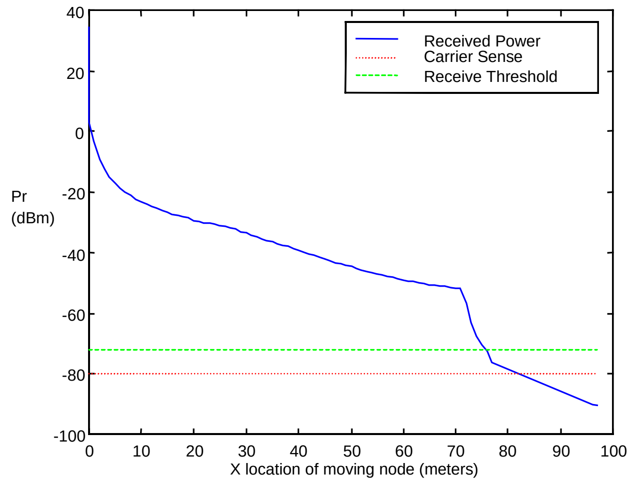

Figure 4. The received power drops sharply when Node 2 moves over the hill in the DEM example.

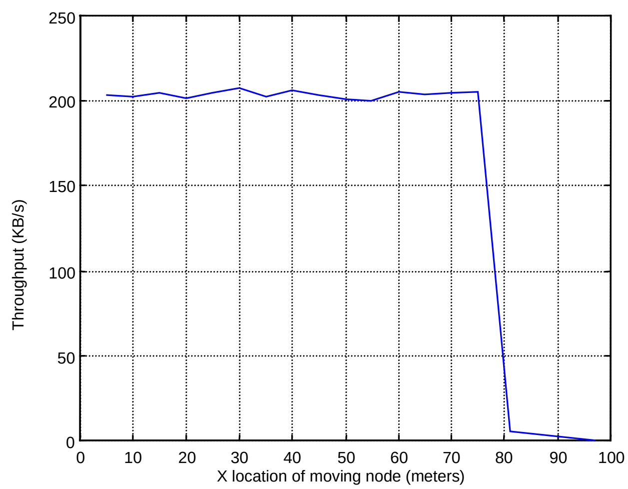

Figure 5. The throughput drops reflecting the loss of signal as Node 2 moves over the hill in the DEM example.

Conclusion

The addition of a propagation model to the *ns* simulator permits more realistic simulation of wireless networks. The predicted signal strength provided by the model can be used to determine when communication between two nodes will be lost or impaired and how various protocols perform under these adverse conditions.

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