Modeling MAC Performance in Mobile Ad Hoc Network Simulations

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Abstract:
We discuss some issues related to modeling the physical and MAC layers for discrete event simulation of mobile ad hoc networks. The proposed models play a key role in accurate evaluation of the effects of radio interference in the network performance. Performance results demonstrating the effect of the proposed models are presented.

INTRODUCTION

Computer simulations play an important role in performance evaluation of mobile ad hoc networks. Such simulations typically use packet-level event driven simulators, which implement the functions of traffic generation, networks protocols, signal transmissions, and node movements. However, the accuracy of modeling the signal and interference powers at the receiver is crucial for obtaining a realistic performance evaluation of the network. In this paper, we discuss the key issues in modeling the wireless received signal and the corresponding physical layer and medium access control (MAC) functions. We apply these models to modify the version of ns-2 network simulator which includes modifications made by the CMU MONARCH project [1] on the network simulator (ns) developed by the VINT project [3]. This version already has the wireless channel model, IEEE 802.11 MAC [2], node mobility model, some popular ad hoc routing protocols, and transport layer protocols, which make it most suitable for evaluating the performance of mobile ad hoc networking protocols. However, to limit excessive computational complexity, some of the aspects in the physical layer model are simplified, which generates inaccuracy. The proposed modifications improve the accuracy of capturing the effect of radio interference on the MAC layer performance. This will allow the usage of ns-2 to more accurately evaluate the effect of routing overhead, congestion, and channel irregularities on the end-to-end throughput and the average packet delay in mobile ad hoc networks.

SIGNAL PROPAGATION AND RECEPTION

In the wireless channel, propagation path loss causes the average power of the transmitted signal to decay with distance. The average power of the signal received at a receiver depends on the transmitted power, gains of the transmitting and receiving antennas, and the distance between the transmitting and receiving stations (nodes). Moreover, the actual power of the received signal may also vary with time, caused by multipath fading and Doppler. The distance at which the ratio of the average power of the received signal to that of the noise exceeds the minimum signal-to-noise ratio that gives an acceptable packet error rate is termed as the radio range of the transmitter. However, packets transmitted to a receiver within the radio range of the transmitter may also suffer from errors due to interference induced by other transmissions in the network. In order to accurately model all these characteristics, the physical-layer of a discrete event simulator should include the following: (a) Signal propagation model: to predict the power of a received signal from the propagation path loss, long term fading and short term fading effects; (b) Interference model: to keep track of the total interference power at a receiver calculated from the sum of the received powers from all interfering packets that are being transmitted in the network; (c) Receiver model: to determine if an incoming packet is received without errors, which is confirmed only if the signal-to-noise-plus-interference ratio (\(\text{SINR}\)) of the packet is greater than a minimum threshold \(\text{SNR}_{\text{min}}\) for the entire duration of the packet; (d) Capture model: to determine if one of several packets arriving at a receiver can be received without errors, which is confirmed if the \(\text{SINR}\) of the strongest packet is greater than the capture threshold \(T_{C,P}\) [4].

Existing model in ns-2: The current version of ns-2 uses a path loss model that combines the free space propagation model and a two-ray ground reflection model. This is implemented in the network interface object, which computes the received signal power of a transmitted packet at every node in the network using its distance from the transmitting node. A receiving node discards a packet if its power falls below the carrier sense threshold \(T_{CS}\). It also compares the power of the received packet to another threshold, known as the receive threshold, to determine if the packet is to be considered error-free. If the packet is error-free, and the MAC is idle, then the reception of the packet is successfully completed at the MAC layer. However, if the MAC is already receiving another packet, then the new packet is discarded if the power of the packet already being received is greater than the new packet by the capture threshold. Else, both packets are discarded at the MAC.

Revised model: We propose revisions to the above to address the following issues:

- The packet error probability is to be determined by comparing the \(\text{SINR}\) to the \(\text{SNR}_{\text{min}}\), rather than performing a threshold test on the signal power. This will take
into account the true interference power, which varies with time.

- Packets which are not detected by the receiver (when signal power < $T_{CS}$) are also to be considered as interference.

- Determination of packet capture should take into account all the detected packets rather than the most recently arriving packet.

To implement the above, we introduce the variables $I_1$ and $I_2$ to account for the total amount of interference powers from undetected and detected packets, respectively. This means that when the power of an arriving packet is less than $T_{CS}$, its power is added to $I_1$. This packet is then discarded. Else, the packet is passed to the MAC, where one of two things can happen. If the MAC is idle, the $\text{SINR}$ of the packet is compared to $\text{SNR}_{\text{min}}$ to check if the packet is to be considered as received without errors. The $\text{SINR}$ is computed by taking the ratio of its power to that of the sum of the receiver noise (a constant) and $I_1$. If $\text{SINR} < \text{SNR}_{\text{min}}$, then the packet is considered to be received with errors. If the MAC is already receiving a packet, then the possibility of capturing one of the two packets is computed by comparing the $\text{SINR}$ of the packet with the larger power to $T_{CP}$. If this is satisfied, then the stronger packet is considered for error-free reception and the time for completion of reception of the packet is scheduled. This $\text{SINR}$ is calculated based on the signal to receiver noise and the sum of $I_1$ and $I_2$. If this $\text{SINR}$ falls below $T_{CP}$, then both packets are dropped by the MAC and their powers are added to $I_2$. In that case, the receiver state is considered to be in collision.

PERFORMANCE RESULTS

Figure 1 depicts the difference obtained in the MAC layer throughput using the proposed revisions in a static ad hoc network of 100 nodes where the nodes are placed in a uniform grid. To focus on the MAC layer performance, all higher layer functions above the MAC were disabled. Fixed length packets were generated according to a Poisson arrival process in all nodes with the corresponding destinations chosen randomly from the neighbors of the source. The details included in the proposed revised model of $ns$-2 allow us to determine the effect of some physical layer parameters providing valuable insights to issues related to MAC performance. To demonstrate, we plot the variation of the throughput with the carrier sense threshold $T_{CS}$ in Figure 2, and the corresponding packet counts in Figure 3. The results show that reducing the sensitivity of carrier sensing results in increasing the number of packet transmissions as well as the collisions. The resulting number of successfully received packets is maximum for a certain value of $T_{CS}$ under the chosen network conditions.

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References


