Simulation Acceleration Techniques For Mobile Ad Hoc Networks

Shaowen Lu and John A. Schormans

Department of Electronic Engineering, Queen Mary University of London

Abstract: In this paper, we investigate the feasibility of using accelerating simulation techniques in mobile ad hoc networks. We propose two approaches both of which use a hybrid simulation technique to gain acceleration for simulation by taking advantage of their particular characteristics.

1 Introduction

Mobile Ad Hoc Networks (MANETs) are of growing importance in networking. In this paper, we propose two related methods by which simulation can be accelerated in MANETs. This is important because simulation has been more and more used as a primary method in MANET studies. This section gives a short description of ad hoc networks and techniques for accelerating simulation. Section 2 describes two possible approaches to apply simulation speedup in MANETs. Section 3 is our conclusion.

1.1. Mobile Ad Hoc Networks

A MANET is a multi-hop packet network without any fixed infrastructure. In any MANET, there is no central management system with configuration responsibility and mobile station communicate with each other in a distributed and self-organized manner [1, 2]. In such a network, each station acts both as a router and as a host. Figure 1 shows an example of a MANET. We can see that station A is able to communicate with station F with the "help" of other nodes although it cannot sense station F directly.

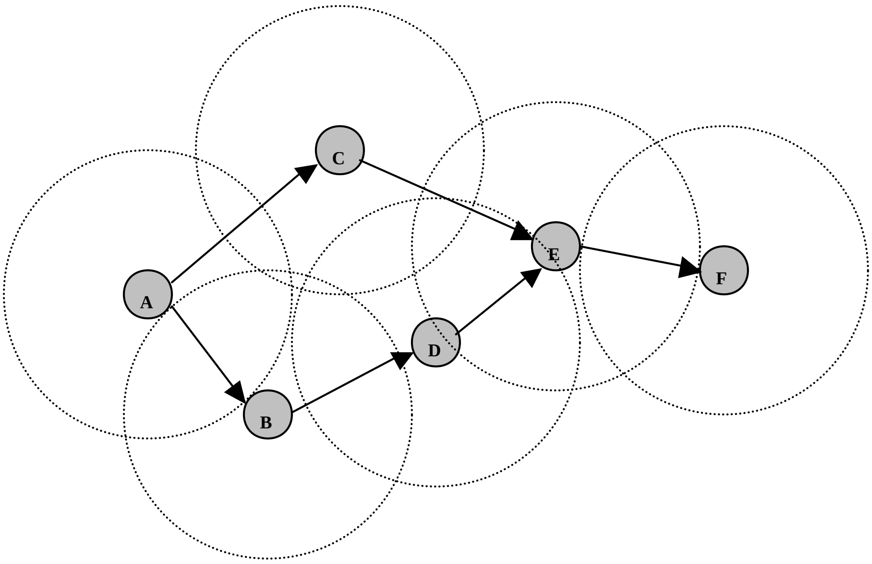

Figure 1: Example of a MANET

The dynamic nature of MANET has promoted some new and challenging research issues such as routing, mobility modelling and quality of service, etc [3]. In this paper we concentrate not only the individual network issues, but also the development of new MANET specific tools employing accelerated simulation.

1.2. Acceleration Techniques for Simulation

Telecommunication systems have experienced a rapid evolution and become more and more complicated during recent years. Traditionally there are three basic approaches to evaluate and analyze networks, which are measurement, analysis and simulation. All of these have their advantages and disadvantages. Measurement requires the system exists, which is inflexible and costly. Analysis allows for faster solutions, while simulation is more flexible in the sense that arbitrary level of details are allowed. However, when we are interested in some events which are rare, e.g. a cell loss in an ATM (Asynchronous Transfer Mode) switch, we have to simulate a large number of events before we get a sample of interest to the performance measure, and even more to obtain confident estimates, which usually leads to a long simulation time. The conventional means of simulation of packet-switched networks is not scalable because it uses a discrete event approach that models each packet level event through the network. When the size of networks become large, very large numbers of packets must be simulated in order to guarantee the accuracy of those results. This means very long simulation times. To solve this problem, several accelerated techniques [4] have been proposed:

- The parallel and distributed simulation [5, 6] uses multiple processors or workstations with parallel computing techniques to increase the computation ability and simulation efficiency.
- Variance reduction [7, 8] exploits the known correlation between different input and output samples to reduce the variance of the estimates and improve the accuracy of performance measures.
- Hybrid simulation techniques [9, 10, 12] partition the simulation model into separate subsystems, some treated by analysis and some by simulation.

In the next section, we propose two possible approaches that speedup simulation specifically designed for ad hoc networking studies, and based on prior experience of hybrid techniques [10, 12].

2. Possible Accelerating Simulation Approaches

MANET was initially proposed for the military use [3] and until now, as we know, no really satisfactory commercial application has ever been developed. So, only a few research groups are able to have their evaluations based on a real system or test-bed. Because the performance evaluation in ad hoc networks is affected not only by traffic pattern but also mobility factors, a pure analytic approach is too complicated. Therefore, we propose here an approach to use fast simulation techniques to reduce the simulation complexity and run time.

Our approach uses a hybrid simulation technique which combines analytic solutions and simulation decomposition. The basic idea is to decompose the simulation model into several different scale sub-components. The identified sub-components need to be analyzed or simulated only once. And by using the evaluation results of these sub-components instead of simulation, we can gain acceleration by avoiding unnecessarily repeating these parts of simulation.

As an example, consider a homogeneous ad hoc network, the objective is to evaluate the performance of a routing protocol with different traffic and mobility patterns. The simulation should deal with both traffic and mobility factors. We denote S_p as samples for packet level events and S_m as mobility events which may be the position or relative movements of each node. The sampling distribution is now $f(S_p, S_m)$, where function f is the density function. We can reasonably assume mobility events and traffic events are independent, thus:

$$f(S_p, S_m) = f(S_p) \cdot f(S_m)$$

We can find $f(S_p)$, (a) by simulation or (b) by analytic solution. Since we are interested in the traffic load only, we can set up a queue threshold as a traffic intensity/congestion indicator and only make sampling the “above threshold” and “below threshold” queue level events S_q (see figure 2).

If:

$$f(S_p) = g(f(S_q))$$

where g is the mapping function between these two levels of events distribution. Then:

$$f(S_p, S_m) = g(f(S_q)) \cdot f(S_m)$$

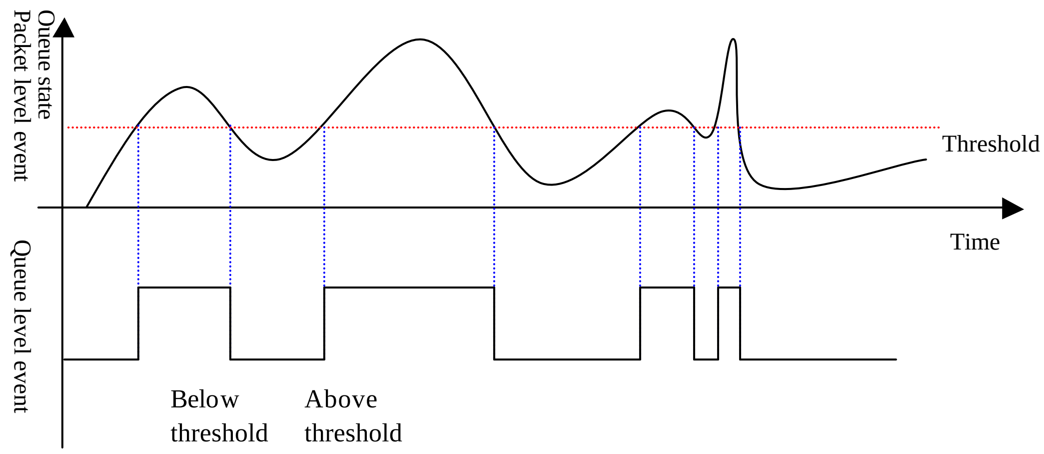

Figure 2

If the probability distribution of the queue level is known, we can find out S_q by using mathematic modelling solutions, e.g. multiplexed ON-OFF sources model [11]. We can also find out $g(f(S_q))$ by simulation and we need to simulate the sub-component S_q only once. The sub-component for the simulation can then be replaced by a fixed response system based on the results from the analytic solution or simulation and thus reduce the simulation overhead and computation demands. Since this part of system is a fixed response from either an analytic solution or a simulation result, the variance $\mathrm{var}(S_q) = 0$. Therefore, the variance for one interested objective value g is:

$$\mathrm{var}(\hat{g}) = \frac{1}{N}[\mathrm{var}(S_q) + \mathrm{var}(S_m)] = \frac{1}{N}\mathrm{var}(S_m)$$

where N is sample scale and $\hat{g}$ is an unbiased estimate of g. We can see that some of the variance reduction is achieved through the use of fixed system response for sub-component.

3. Conclusion

Compared with Internet, the history of ad hoc networking techniques is quite short. However, it has experienced a rapid evolution during the recent years. We realize that simulation will continue to be an important means to evaluate and analyze the network performance in ad hoc networks. Since speedup simulation techniques have been widely used in the evaluation of large scale telecommunication systems, we believe that the application in ad hoc networks can also be practical and beneficial.

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