Chapter 8.9
Improvement of Simulative Analysis in Ad Hoc Networks

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ABSTRACT
Ad hoc networks present special issues that often makes classical approaches for network analysis insufficient. In this paper we propose a new methodology to study communication protocols and architectures in ad hoc networks. Usually, solutions for ad hoc scenarios are analyzed and evaluated through simulative tools. The paper shows limitations of the traditional simulative approach and the improvements that the Discrete Fourier Transform analysis can produce if it is applied on the results from simulations. The proposed methodology gets advantages (such as simplicity and flexibility) from simulative investigation approaches overcoming the great drawback of loss of information on rare events. In fact, it transfers the time-dependent measurements into the frequency domain allowing to point out the occurrence of events which take place only under particular conditions and to detect occasional misbehaviors of the system. For these reasons the presented technique is suitable for both protocol debugging and system performances evaluation.

INTRODUCTION
Mobile Ad Hoc Networks (MANETs) are an emerging technology which allows establishing a communication system without relying on pre-existing fixed infrastructures. The increasing interest for this networking paradigm comes from its advantages such as rapid deployment, robustness, flexibility and inherent support for mobility. For these reasons it is a promising area of research for civilian and military applications. Target applications for mobile ad hoc networks include: collaborative and distributed mobile computing (sensors, conferences, conventions), disaster recovery (such as fire, flood, earthquake), law enforcement (crowd control, search and rescue)
and tactical communications (digital battlefields) (Haas 2002).

The successful implementation of ad hoc networks presents unique challenges which differentiate them from traditional wireless and wired systems (Toh 2002)(Giordano 2002)(Sesay et al. 2004). Ad hoc networks are self-organizing and nodes have to be highly cooperative: management tasks are distributed over nodes and any service is the result of collaboration among them. To increase the network capacity, nodes relay traffic on behalf of one another to reach distant stations along multi-hop paths. In many cases, nodes are battery-driven and it makes the power budget tight for all the power-consuming components in devices. Also, wireless links have limited bandwidth and are not reliable. All these features affect CPU processing, memory size/usage, signal processing and transceiver output/input power. Additional issues result from node mobility. In fact, users can connect or abruptly disconnect from the network or move in the surrounding space, causing continual changes in the network topology. Nonetheless, end-to-end communication services have to operate seamlessly to provide good experience to users.

Such complex communication paradigm requires new networking approaches and specific functionalities. In the past years many research groups have developed a lot of protocols and architectures to support ad hoc scenarios. Most of them have been tested and compared with different solutions through simulative methodologies. Simulations allow to study easily ad hoc networks through a model of the system. Working conditions (e.g., node mobility, transmission range, etc...) can be modified by simply tuning network parameters and a large spectrum of network scenarios can be considered. However the simulation analysis suffers from approximations in measurements due to simplified network models and limited time intervals to observe the system evolution. To reduce such approximations and to achieve more general results, several deterministic runs of a simulation are necessary (Lewis and Orav 1988). Therefore, to characterize a system (i.e., network protocol, Internet service, etc.) along with a simulation tool it is needed:

a. to choose one or more metrics that can be representative of the system (a metric is a sensitive parameter of the simplified network models);
b. to gather results achieved by several runs characterized by different initial network conditions;
c. to perform a statistical analysis of the results (e.g., normal distribution - Gaussian: mean, standard deviation, etc.). It provides a quantitative evaluation of the metrics and, consequently, a description of the behavior of the system during the time.

This analysis approach, often defined Monte Carlo method, is useful for an early stage of study of the system, but it is not able to assess rare events, which occasionally affect the network. Under particular conditions, the system could show an unstable behavior, causing problems in the communication infrastructure, such high overhead, increasing delay and so on. If the occurrence of such conditions is occasional, information on them are lost in the simulative analysis because of the “Law of Large Numbers”. To illustrate some practical problems related to the simulative analysis, we describe our experience in the code developing phase of our protocol AIPAC (Automatic IP Address Configuration) (Fazio et al. 2006) into the ns2 simulator (Fall and Varadhan 1999). AIPAC is a protocol for automatic IP address configuration in ad hoc networks, which supports merging and partitioning in the system. The goal of the protocol is to maintain a stable configuration of the IP address and the Network Identifier (NetId) and to minimize the reorganization time whenever a change in the address configuration occurs. The chief metrics we have used to evaluate the protocol are: configuration time and overhead.