Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**MAC Modeling and Simulation Tools: Recommendations**
Date Submitted	**2000-01-05**
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Re:	This contribution is in response the MAC Call for Contributions for 802.16 session #5, regarding the MAC common simulation environment.
Abstract	Presents requirements for MAC modeling and simulation tools and recommends a possible tool set.
Purpose	The 802.16.1 MAC task group should consider this document when determining a MAC simulation environment.
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MAC Modeling and Simulation Tools: Recommendations

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Introduction

This document presents requirements for a common MAC layer protocol modeling and simulation environment and presents two possible systems.

The central goal of MAC simulation for 802.16.1 is to agree on methods that allow for MAC protocols to be evaluated and compared objectively, with particular attention to performance. With such common methods, the pluses and minuses of an entire MAC protocols, features, or enhancements should be readily evident, and easily compared one with another.

In addition to the specifications for source traffic models, performance metrics, and network topologies, a common simulation environment which all 802.16.1 MAC Task Group members and observers can use, and verify, is an important component of a successful, objective, study of 802.16.1 MAC protocols.

Requirements

Following are simulation tool requirements which I think are important:

- The complete simulation environment should be inexpensive and readily attainable by task group members and observers. A no-cost environment hosted on cost-effective PCs is optimal.
- The tools must be reliable and have a good track record in industry and/or academia.
- The tools must be capable of simulating the bearer services specified in the 802.16.1 Functional Requirements [5].
- The language(s) and tools for specifying models must be easy to use and maintain. They must be well documented.
- The tools must contain models and queuing algorithms common to computer networks. It would be optimal if the tools were designed for the purpose of simulating computer networks and protocols (including MAC).
- The tools must provide a basic discrete-event simulation system that keeps track of time and schedules events to "happen" at discrete points in time. The tool must contain basic models for queue management, including statistical traffic source models, a good random number generator, timers, delays, event tracing/monitoring, etc.
- Multiple simulation "runs" using the same inputs and random number generator seed must produce identical results.
- The tools must contain means for statistically analyzing and visualizing the results of simulation "runs," for instance, delay vs. load graphs.
- The tool must provide common statistical arrival distributions and both self-similar and trace-based traffic source models designed for network simulation.
- The tools must provide the means to easily define network topologies (the MAC task group should chose a small set of topologies for testing).
- The tools must provide a convenient way to iterate multiple simulation "runs" over various parameter sets.
- Like data traffic, the tool must provide error models that are both statistically-, and trace-based (models following real-world measurements).
- The tool must provide protocol models for common protocols of layers 2 through 7, needed for performance comparison, including:
  - Various MAC models (802.3, .11, etc.). It would be optimal if the tool contained a model for related MAC protocols, such as the DOCSIS 1.1 MAC
  - IP: Datagrams, addressing, multicast, routing

- TCP, including modern additions for congestion management and control [RFCs 2001, 2581, 2582]
- RTP
- VoIP
- ATM: TC, Cell, SAR, AAL 0-5, PVC, SVC
- Internet traffic/apps: Telnet, FTP, HTTP

(Note: I omitted signaling protocols---e.g., ATM, RSVP, etc.---from the list because I thought they were not pertinent to performance measurement.)

Two Tools

Given the requirement of easy attainability for 802.16 members and observers, I eliminated expensive commercial protocol simulation systems from my recommendations. Such packages include Mil3's *Opnet*, Cadence *Bones* and CACI *Comnet*. Two systems I think would be suitable are *ns* (Network Simulator) [2] [6], and the *NIST ATM Simulator* [7] [8].

Ns is maintained a DARPA-funded consortium called Virtual Internetwork Testbed (VINT), UC Berkeley, Lawrence Berkeley National Labs, Xerox PARC, and USC. However, many commercial and academic institutions use it and contribute models to the system. It's main focus is Internet- and MAC-related protocol evaluation. It meets all of the requirements listed above, except it does not have built-in support for ATM simulation. Ns is typically hosted on a UNIX system (workstation- or PC-based UNIX/Linux), but it also runs on Windows 95/98/NT. The full source code for the system is available, and is free. It's primary uses in academia are evaluation of real-time Internet protocols and studying the effects of multicast in large scale network (e.g., Internet) topologies. 802.11 MAC and wireless error models are available. I have experience developing MAC models under *ns* and evaluating their relative performance.

The *NIST ATM/HFC Network Simulator* is maintained by the NIST High Speed Network Technologies (HSNT) Group. The system was used by IEEE 802.14 to evaluate MAC protocols and options [9] [10] [11] [12]. The simulation tool was based on an ATM simulation system (with support for end stations, switches and various traffic classes), and the HSNT group added support for IP datagrams, 802.14 and DOCSIS MAC models. The cable-modem models include head-end queue policy algorithms and transport of IP- ATM- services. Thus, the tool was explicitly tailored for the modeling requirements of the 802.14 working group. The system includes algorithms for self-similar and MPEG-II video stream arrival distributions. The tool appears to be not as general-purpose or as widely-used as *ns*. And it seems to lack models for layers 4-7, such as TCP, web traffic, file transfer, etc. Although the HSNT group currently does not have staff actively working on the simulator, they would help 802.16 get started (according to David Su, HSNT leader). Also, if 802.16 issued a request to the HSNT for substantial work effort, they would re-evaluate their priorities.

Recommendations

I recommend that the 802.16 MAC task group evaluate the effectiveness of both *ns* and the NIST simulators, and evaluate the possibility of porting relevant models from the NIST simulator to *ns*.

The benefits of *ns* are a strong, and on-going community of interest, particularly in Internet-related protocol studies, and its general-purpose nature. It has many powerful tools and models for a variety of protocol studies. However, the NIST simulator has support for ATM cells and traffic classes, and models for the HFC head-end and CPE used in 802.14, the topology and queuing algorithms of which should be similar to the 802.16.1 MAC. *Ns* contains models for upper layer protocols that have an important effect on performance. For example, the congestion management and control functions of TCP and RTP have a direct impact on performance. Even for a protocol study focused on the MAC layer, the interaction with upper layer protocols can demonstrate more "real-world" effects of MAC algorithms. For such technical reasons, I recommend that the 802.16 MAC task group closely evaluate both simulators, and evaluate the effort required to combine functionality by porting relevant models from the NIST simulator to *ns*. Also, since both simulators are maintained or sponsored by U.S. Government research (DARPA and Dept. of Commerce), it seems that combining the functionality into one tool makes the best use of U.S. residents' taxes.

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