UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF FLORIDA

Case No.: _____

UNIVERSITY OF FLORIDA	)	
RESEARCH FOUNDATION, INC.	)	
	)	
and	)	
	)	
RAPID MOBILE TECHNOLOGIES, INC.	)	
	)	JURY TRIAL
	)	
Plaintiffs,	)	
	)	
v.	)	
	)	
MOTOROLA MOBILITY LLC,	)	
	)	
Defendant.	)	

PLAINTIFFS' ORIGINAL COMPLAINT
FOR WILLFUL PATENT INFRINGEMENT

Plaintiffs the University of Florida Research Foundation, Inc. ("UFRF") and Rapid Mobile Technologies, Inc., ("Rapid Mobile"), by and through the undersigned, file this Complaint for Willful Patent Infringement against Motorola Mobility LLC, ("Motorola"), and alleges as follows based on information and belief:

JURISDICTION, VENUE AND THE PARTIES

1.   This action is brought pursuant to the Patent Laws of the United States, 35 U.S.C. § 271, *et seq.*

2.   This Court has original jurisdiction pursuant to Tile 28, United States Code, Section 1331 and 1338(a), as this case involves a federal question arising under Patent Laws and the Constitution, laws or treaties of the United States.

3.   At all times material hereto, UFRF has had its principal office in Gainesville, Florida.

4.   At all times material hereto, Rapid Mobile, had its principal address located in Palm Beach County, Florida.

5.   At all times material hereto, Motorola, a Delaware Corporation, was engaged in the conduct of interstate commerce, and regularly conducted business in this judicial district and was registered with the Florida Department of State, Division of Corporations, as a Foreign Profit Corporation. Further, Motorola has a place of business located at 8000 West Sunrise Boulevard, Plantation, Florida 33322, in Broward County, Florida.

6.   This action arises as a result of the infringing conduct of Motorola, which implicates interstate commerce.

7.   Venue is proper in the Southern District of Florida pursuant to Tile 28, United States Code, Section 1391(b) and (c) as Motorola "resides" in this judicial district, as the term "reside" is interpreted under Chapter 87, United States Code, and because a substantial part of the events giving rise to the infringement claims at issue occurred within this judicial district. Venue is also appropriate pursuant to Tile 28, United States Code, Section 1400(b), which provides, in part, that "[a]ny civil action for patent infringement may be brought in the judicial district where the defendant resides."

8.   All conditions precedent have been met, waived, or satisfied to bring this lawsuit.

GENERAL ALLEGATIONS

9.   In 2002, Edwin A. Hernandez, PhD, was a doctoral candidate graduate student at the University of Florida (hereinafter the "University").

10.   Leading up to 2002, and in that year, Dr. Hernandez was aware of the consuming and expensive tasks born by mobile and wireless companies in connection with the testing and configurations of their respective mobile devices.

11.   Intrigued by this reality, and studying the academic field of engineering in connection with his doctoral candidacy at the University, Dr. Hernandez with the assistance and support of his University supervisor, Dr. Abdelsalam A. Helal ("Dr. Helal"), began working on a solution to this problem. Ultimately, through research efforts sponsored by the University, Dr. Hernandez conceived of a method and system that would utilize both hardware and software components to model and test various mobile network configurations and scenarios. Perfected, this invention significantly reduces the time and expense previously expended by mobile and wireless companies in connection with the testing and configurations of their respective mobile devices.

12.   Together with Dr. Helal, Dr. Hernandez continued to perfect the characteristics of his invention, and on July 31, 2003, Dr. Hernandez, through the University's licensing office, filed a provisional patent application with the United States Patent and Trademark Office ("USPTO").

13.   On August 2, 2004, Dr. Hernandez, again through the University, filed a formal patent application with the USPTO, under application number 10/909,588, in which he and Dr. Helal were identified as co-inventors of the patent-in-suit.

14.   Meanwhile, in and around November 2003, after successfully completing his doctoral program at the University, Dr. Hernandez was hired by Motorola as an engineer. Dr. Hernandez worked for Motorola at its Plantation, Florida office.

15.   In response to an apparent high level of interest in his invention, following the commencement of his employment, there were several instances in which Dr. Hernandez disclosed the nature and substance of his invention to Motorola. For example, in mid-October 2006, Dr. Hernandez exchanged correspondence with Motorola wherein he provided Motorola with an actual copy of his pending patent application. Conversations between Motorola and Dr. Hernandez regarding Dr. Hernandez's invention continued following this exchange.

16.   Ultimately, on June 12, 2007, the United States of America issued the patent on Dr. Hernandez's and Dr. Helal's invention under United States Patent No. 7,231,330 ("the '330 Patent"). As a result of an assignment from Dr. Hernandez and Dr. Helal, the '330 Patent was issued to UFRF. A copy of the '330 Patent is attached as Exhibit A.

17.   Under the policy of UFRF, UFRF and Dr. Hernandez formed Rapid Mobile as the corporate vehicle to hold, license and market the '330 patent.   On December 14, 2009, Rapid Mobile entered into an exclusive licensing agreement relative to the '330 Patent with UFRF, which agreement provides Rapid Mobile the exclusive right to practice, market and sub-license the invention claimed through the '330 Patent. The exclusive license agreement also grants to UFRF, and with permission from UFRF, Rapid Mobile, the right to police and enforce the '330 Patent through any legal means, including, but not limited to, through the filing of a patent infringement lawsuit.

18.   On January 26, 2010, following additional discussions between Dr. Hernandez and Motorola executives concerning the subject matter of the '330 Patent, Motorola Director Chin P. Wong advised Dr. Hernandez that Motorola was using the invention claimed in the '330 Patent. Mr. Wong invited Dr. Hernandez to view the system, which Motorola calls its "Drive Test Simulator," at its Plantation, Florida office.

19.   On January 28, 2010, Mr. Wong escorted Dr. Hernandez to the location where the subject system was implemented, and provided Dr. Hernandez access to the same.   Dr. Hernandez was able to conclude that the system established by Motorola was that which he invented and is claimed in the '330 Patent. At the same time, Mr. Wong advised Dr. Hernandez that the invention had proven successful to Motorola. On information and belief, Motorola uses the Drive Test Simulator to test every model cell phone that uses the iDEN wireless signal protocol.

20.   Following the January 28, 2010 meeting with Mr. Wong, Dr. Hernandez advised Motorola of Rapid Mobile's rights to the '330 Patent, and notified Motorola that he considered the Drive Test Simulator to infringe the claims of the '330 Patent.

21.   Additionally, on February 17, 2010, Rapid Mobile corresponded in written fashion with Motorola and offered a license to use the invention claimed in the '330 Patent.

22.   On March 1, 2010, Rapid Mobile also engaged in a telephone conference with Edward Jay Fung and Chang Chu, both Motorola executives, concerning a potential license of the '330 Patent to Motorola.   In connection with this meeting, Rapid Mobile forwarded a copy of the actual '330 Patent document, along with an informational pamphlet describing the invention, to Fung and Chu.

23.   Amongst other things, during the March 1, 2010 telephone conference, Mr. Chu acknowledged that Motorola implemented a system that effectively performs in the manner described in the '330 Patent, but denied infringement. It was also alleged by Motorola that "several companies," if not the entire industry, was using the technology claimed in the '330 Patent.

24.   Following the March 1, 2010 telephone conference, Fung and Chu immediately confronted Dr. Hernandez and accused him of trying to sue the company. They also acknowledged that the entire industry was using this technology. Mr. Fung asked that Dr. Hernandez not sue the company, and promised that a licensing deal of the '330 Patent would be worked out between Motorola and Rapid Mobile.

25.   Sometime thereafter, upon following up with Fung and Chu concerning the March 1, 2010 conversation, Dr. Hernandez was instructed to direct all communications to Motorola's legal department.

26.   Accordingly, on April 12, 2010, having received no substantive follow-up communication from Motorola on the issue, Rapid Mobile communicated with Motorola's Senior Intellectual Property Attorney.

27.   Through the April 12, 2010 correspondence, Rapid Mobile again advised Motorola of its infringing conduct, and again offered it a license of the '330 Patent.

28.   On April 30, 2010, Motorola responded to Rapid Mobile advising that it was not interested in licensing the '330 Patent.

29.   On June 11 and June 18, 2010, Motorola having failed to address its actions, and choosing instead to ignore the claims of the '330 Patent, Dr. Hernandez and Rapid Mobile communicated directly with Motorola's Senior Intellectual Property Attorney. Demand was made that Motorola recognize the rights under the '330 Patent and either cease the aforementioned infringing conduct or enter into a licensing agreement with Rapid Mobile so that its use would be permitted and authorized.

30. Motorola has refused all efforts to reach a license and to use its Drive Test Simulator in a lawful manner. Accordingly, UFRF and Rapid Mobile were required to retain the undersigned counsel to pursue its interests in this matter. This lawsuit followed.

COUNT
WILLFUL PATENT INFRINGEMENT

31. Plaintiff realleges paragraphs 1-30 as if fully set forth herein.

32. This is an action for patent infringement pursuant to Tile 35, United States Code, Section 271, of the United States Patent Act.

33. As more fully set forth above, Motorola has infringed and continues to infringe the claims of the '330 Patent by, at least, making and using infringing technology known as the Drive Test Simulator.

34. All such infringing conduct of Motorola has occurred and was committed by Motorola in a willful manner, irrespective of and despite repeated demands that Motorola immediately cease its infringing conduct and recognize the rights under the '330 Patent.

35. Motorola's actions have been committed and performed in a willful, knowing and bad faith manner.

DEMAND FOR JURY TRIAL

Plaintiffs demand a jury trial on all claims and issues which may be tried by a jury.

PRAYER FOR RELIEF

UFRF and Rapid Mobile pray for an entry of judgment that:

A. Motorola has infringed one or more claims of the '330 Patent;

B. Motorola accounts for and pays to Plaintiffs all damages caused by its infringement of the '330 Patent, which by statute can be no less than a reasonable royalty;

C.   Motorola's infringement is and was willful and objectively reckless and accordingly Plaintiffs are entitled to enhanced damages under 35 U.S.C. § 284;

D.   This case is an exceptional one within the meaning of 35 U.S.C. § 285 and that Plaintiffs be awarded attorneys' fees;

E.   Plaintiffs be awarded costs, prejudgment and postjudgment interest; and

F.   Plaintiffs be granted all such other and further relief as the Court may deem just and proper.

Dated: May 16, 2013   Respectfully submitted,

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Exhibit A

(12) **United States Patent**
Hernandez-Mondragon et al.

(10) **Patent No.:** **US 7,231,330 B2**
(45) **Date of Patent:** **Jun. 12, 2007**

(54) **RAPID MOBILITY NETWORK EMULATOR METHOD AND SYSTEM**

(75) Inventors: **Edwin A. Hernandez-Mondragon,** Coral Springs, FL (US); **Abdelsalam A. Helal,** Gainesville, FL (US)

(73) Assignee: **University of Florida Research Foundation, Inc.,** Gainesville, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 367 days.

(21) Appl. No.: **10/909,588**

(22) Filed: **Aug. 2, 2004**

(65) **Prior Publication Data**

US 2005/0055195 A1   Mar. 10, 2005

Related U.S. Application Data

(60) Provisional application No. 60/491,637, filed on Jul. 31, 2003.

(51) **Int. Cl.**
G06F 17/50 (2006.01)
H04L 12/56 (2006.01)

(52) **U.S. Cl.** **703/2**; 455/423; 455/522

(58) **Field of Classification Search** 703/2, 703/13, 14; 455/423, 522; 370/238
See application file for complete search history.

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(57) **ABSTRACT**

A system for emulating mobile network communications can include one or more wireless nodes configured to variably adjust signal reception sensitivity and signal transmission strength; at least one mobile node configured to wirelessly communicate with selected ones of the wireless nodes; and a network emulator communicatively linked to each wireless node. The network emulator can replicate attributes of a wired communications network. The system also can include a controller communicatively linked with the wireless nodes and configured to control signal reception sensitivity and signal transmission strength of each said wireless node, as well as a home agent configured to interact with at least one mobile node via selected ones of the wireless nodes.

21 Claims, 2 Drawing Sheets
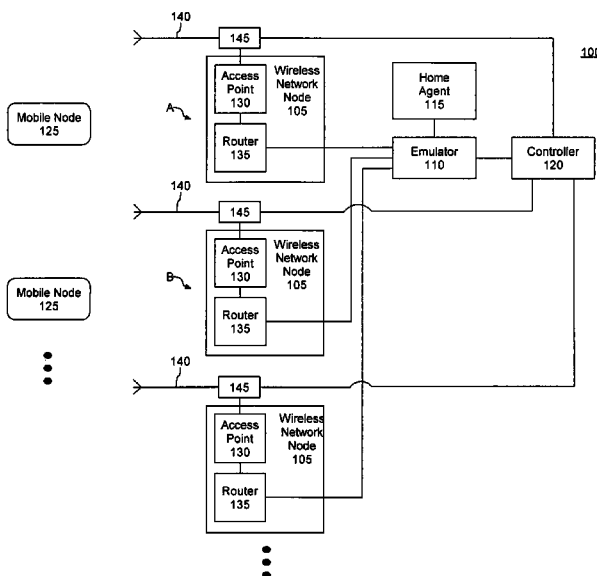
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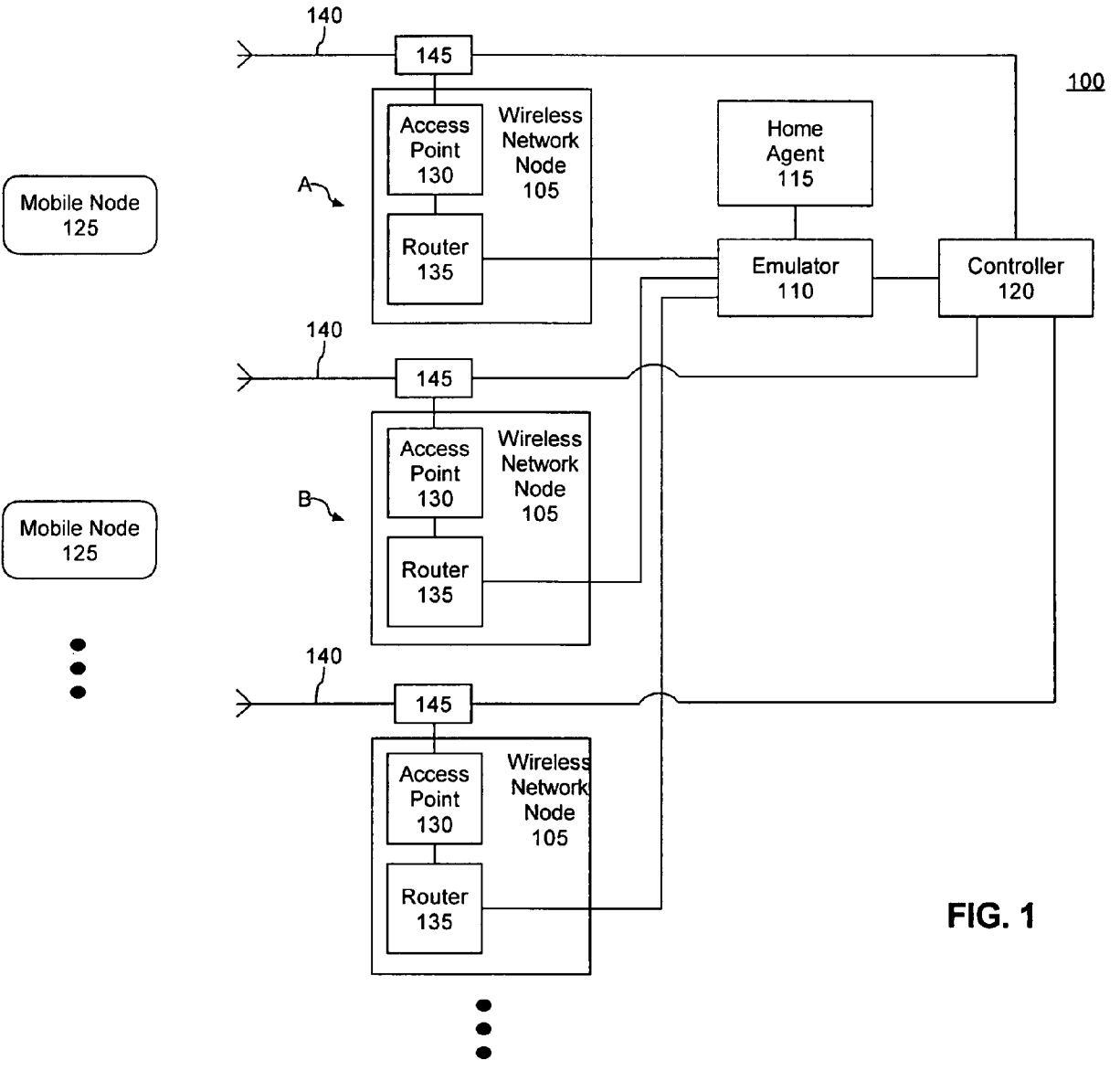
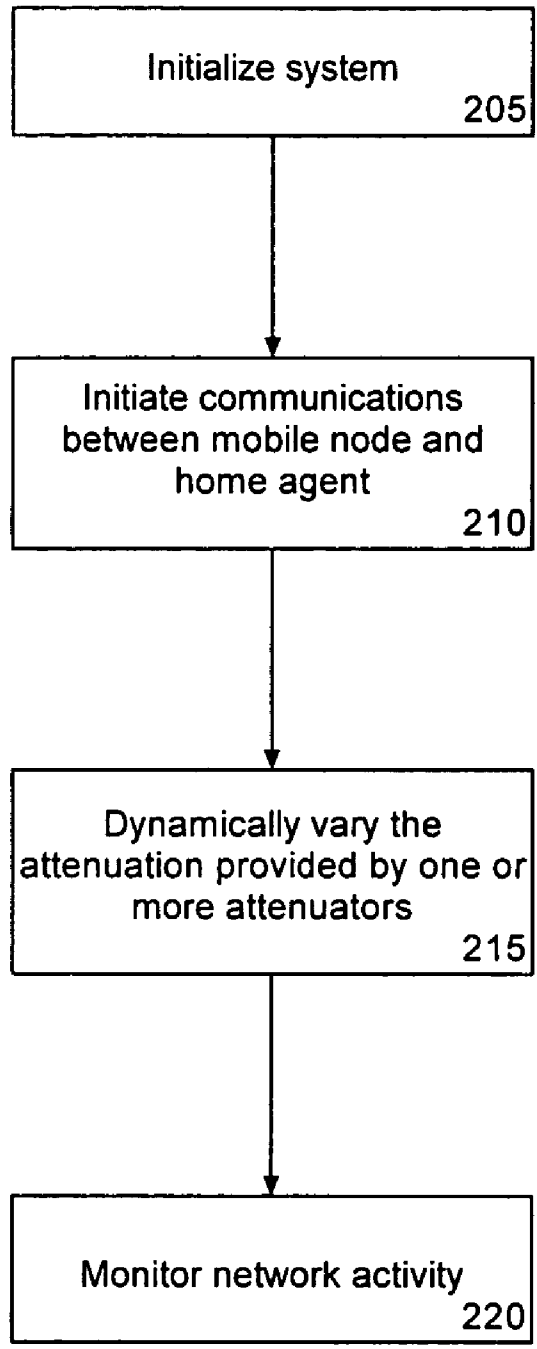* cited by examiner

FIG. 1

200

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┌─────────────────────────────┐
│      Initialize system      │
│                        205  │
└─────────────────────────────┘
               │
               ▼
┌─────────────────────────────┐
│   Initiate communications   │
│   between mobile node and   │
│        home agent           │
│                        210  │
└─────────────────────────────┘
               │
               ▼
┌─────────────────────────────┐
│    Dynamically vary the     │
│ attenuation provided by one or│
│     more attenuators        │
│                        215  │
└─────────────────────────────┘
               │
               ▼
┌─────────────────────────────┐
│   Monitor network activity  │
│                        220  │
└─────────────────────────────┘
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FIG. 2

RAPID MOBILITY NETWORK EMULATOR METHOD AND SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/491,637, filed in the United States Patent and Trademark Office on Jul. 31, 2003, the entirety of which is incorporated herein by reference.

BACKGROUND

1. Field of the Invention

This invention relates to the field of network emulation and, more particularly, to emulation of wireless networks.

2. Description of the Related Art

Mobile computing networks provide environments and scenarios that challenge current computing paradigms. Current network protocols frequently are unable to efficiently deal with mobility issues regarding both nomadic data and devices. In consequence, various software-based tools, referred to as simulators, and hardware-based tools, referred to as emulators, have been developed by the research community to study and improve the performance of network protocols, determine data restriction points in networks, and reduce the cost of hardware implementation.

While software-based simulation tools do provide researchers with the ability to model various networking scenarios, such systems have disadvantages. One disadvantage is that the duplication of the software development process for purposes of simulation, for example to support new operating system platforms and/or newly introduced wireless technologies, is costly, time consuming, and oftentimes impractical. As an example, to support a new network technology, each component used by a software-based network simulator, from traffic generators, Transmission Control Protocol (TCP) implementation, to application level interfaces, would have to be developed and implemented as an object file within the simulator library. Further development efforts would be required to use these objects or software components across different computing platforms.

Another disadvantage is the amount of time simulators require for performing different simulations. Typically, simulators required an amount of time that is several orders of magnitude larger than the amount of time that is being simulated. For example, on average, several hours of simulation time are needed to simulate several minutes of a given real-time network scenario. As software simulators already require a significant amount of time to model wired and/or wireless networks, the introduction of rapid mobility conditions and complex propagation models relating to mobile networks further challenges the utility and suitability of software-based simulators. Unfortunately, efforts to improve software-based simulator performance by simplifying modeling tasks through the reduction of the number of modeling parameters used during a simulation can lead to misleading, if not erroneous results.

Wire-line emulators provide researchers with a faster and more efficient alternative than software-based simulators. Several different wire-line emulators have been developed to replicate the conditions of end-to-end network delays. For example, the End-to-End Emulator as described in C. Bolot, *End-to-End Packet Delay and Loss Behavior in the Internet*, ACM Computer Communication Review, Vol., 23, No. 4, pp. 289–298 (October 1993), seeks to imitate the Internet by providing end-to-end network delay using Internet Control

Message Protocol (ICMP) packets as a real time traffic source. The Ohio Network Emulator (ONE) as described in M. Allman, A. Caldwell, S. Ostermann, *ONE: The Ohio Network Emulator*, TR-19972, School of Electrical Engineering and Computer Science, Ohio University (August 1997), is able to emulate transmission, queuing, and propagation delay between two computers interconnected by a router.

Presently, however, wire-line emulators do not account for characteristics of rapid mobility networks or complex signal propagation models. As such, conventional wire-line emulators are not available or are unable to model mobile networks.

SUMMARY OF THE INVENTION

The inventive arrangements disclosed herein provide a method and system for modeling mobile networks. More particularly, the present invention utilizes both hardware and software components to model and test various mobile network configurations and scenarios. According to one embodiment of the present invention, a mobile node can be configured to wirelessly communicate with an application via one or more wireless nodes. Motion of the mobile node can be simulated by dynamically adjusting the signal reception sensitivity and signal transmission strength of each wireless node. Communications exchanged between the application and the mobile node can be monitored and tracked to study the behavior of the mobile network, including the effects of motion of the mobile node upon overall network performance.

One aspect of the present invention includes a system for emulating mobile network communications. The system can include one or more wireless nodes configured to variably adjust one or more wireless communication characteristics; at least one mobile node configured to wirelessly communicate with selected ones of the wireless nodes; and a network emulator communicatively linked to each wireless node. The wireless communication characteristics can include signal reception sensitivity and signal transmission strength of the wireless nodes. The network emulator can be configured to replicate attributes of a wired communications network. The system also can include a home agent and a controller communicatively linked with the wireless nodes. The home agent can be configured to interact with one or more of the mobile nodes via selected ones of the wireless nodes. The controller can be configured to control signal reception sensitivity and signal transmission strength of each wireless node.

According to another embodiment of the present invention, three wireless nodes can be included. In any case, each of the wireless nodes can include a wireless access point having an antenna, for example an omni-directional antenna, and a variable attenuator. The wireless nodes also can include a routing device communicatively linking the access point with the network emulator.

The controller can be configured to dynamically adjust the wireless communication characteristics of one or more of the wireless access points by varying an amount of attenuation provided by the attenuators to simulate motion of one or more of the mobile nodes. For example, attenuation provided by at least one of the attenuators can be increased while simultaneously decreasing attenuation provided by another one of the attenuators. The controller can dynamically adjust the amount of attenuation provided by at least

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two of the attenuators to emulate at least one mobile network characteristic such as speed, acceleration, and/or trajectory of the mobile node.

The system also can include a data logging component configured to record data throughput of one or more of the wireless nodes and/or a measure of signal strength received from at least one of the wireless nodes at one or more of the mobile nodes.

Another aspect of the present invention can include a method of emulating mobile network communications. The method can include initiating communications between a home agent and a mobile node via one or more wireless nodes; while the mobile node wirelessly communicates with at least one of the wireless nodes, dynamically adjusting one or more wireless communication characteristics of one or more of the wireless nodes to simulate movement of the mobile node; and monitoring communications in the mobile node and/or one of the wireless nodes. As noted, the wireless communication characteristics can include signal reception sensitivity and signal transmission strength of the wireless nodes.

Notably, each of the wireless nodes can include a wireless access point having an antenna and a variable attenuator. The wireless nodes further can include a routing device. The wireless nodes can be communicatively linked with the home agent through a network emulator.

According to another embodiment of the present invention, the step of dynamically adjusting the wireless communication characteristics can include varying an amount of attenuation provided by at least one of the attenuators to emulate motion of the mobile node. The present invention dynamically adjusts the amount of attenuation provided by at least one of the attenuators to emulate at least one mobile network characteristic such as speed, acceleration, and/or trajectory of the mobile node. Notably, attenuation provided by at least one of the attenuators can be increased while attenuation provided by another one of the attenuators can be simultaneously decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

There are shown in the drawings, embodiments which are presently preferred, it being understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown.

FIG. 1 is a schematic diagram illustrating a system for modeling a mobile network in accordance with one embodiment of the present invention.

FIG. 2 is a flow chart illustrating a method of modeling a mobile network in accordance with the inventive arrangements disclosed herein.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method and system for simulating various mobile network configurations and/or scenarios. In particular, the present invention utilizes both hardware and software components to model various mobile networks. Communications exchanged between an application and a mobile node can be monitored and tracked to study the behavior of the mobile network.

The inventive arrangements disclosed herein provide a novel approach to mobile network emulation that incorporates existing software-based network simulation with wireless network hardware. Accordingly, the inventive arrangements disclosed herein provide realistic models of mobile

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networks and various mobile connection scenarios. Using the present invention, mobility in wireless networks can be emulated by affecting the physical parameters of the network to emulate various mobile network characteristics including, but not limited to, speed, acceleration, and/or trajectory changes of the mobile node by controlling the causality between network parameters and network behavior perceived by the mobile node.

FIG. 1 is a schematic diagram illustrating a system 100 for modeling a mobile network in accordance with one embodiment of the present invention. As shown, the system 100 can include one or more wireless nodes 105, an emulator 110, a home agent 115, and a controller 120. The system 100 further can include one or more mobile nodes 125. Thus, as illustrated, although only three wireless nodes 105 and two mobile nodes 125 are illustrated, those skilled in the art will recognize that any number of such components can be introduced or incorporated into the system 100 in order to emulate more diverse topologies and system architectures.

Each mobile node 125 represents a moving network node, communications device, and/or computer system. Each mobile node 125 can be a computing device having a suitable wireless communication interface. The mobile nodes 125 can be implemented as general purpose computing devices, each having a wireless transceiver such as an integrated transceiver or a separate transceiver communicatively linked to the unit, for example a wireless network interface card or other wireless peripheral attachment. For instance, the mobile node 125 can be a laptop or portable computer, a personal digital assistant, or portable telephone which has been configured to communicate using a suitable wireless communication protocol.

It will be readily appreciated by those of ordinary skill in the art that the mobile nodes 125 can be implemented as any suitable computing device having a wireless transceiver capable of communicating wirelessly with the wireless nodes 105. The mobile node 125 need not be a moveable or roaming component as the system 100 is configured to simulate motion of the mobile node 125 at any of a variety of different speeds, accelerations, or trajectories despite the mobile node 125 being stationary in nature. If desired, however, the mobile node 125 can be repositioned at any of a variety of different locations. The mobile nodes can be configured to communicate using any of a variety of different wireless communications protocols, including, but not limited to, 802.1a, 802.11b, 802.11g, 3G, Cellular-IP, and mobile-IP wireless communication protocols.

The wireless nodes 105 each can include a wireless access point 130. By using actual hardware components instead of modeling the components, the complexity of coding algorithms and the computation time required to simulate wireless communication characteristics including, but not limited to, radio-wave fading, antenna propagation, or other base station implementation details can be avoided. The wireless access points 130 can be high frequency wireless entry points configured to communicate using any of a variety of different wireless communications protocols so as to communicate with the mobile nodes 125. Any suitable wireless communication protocol can be implemented using the access points 130 and the mobile nodes 125 and, as such, can be tested using the system 100.

Each access point 130 can be a wireless access point having an antenna 140. Each antenna 140 can be an omnidirectional antenna so as to model base station signal transmission and reception behavior. Accordingly, each access point 130 can receive wireless communications via its antenna 140 and forward received wireless communica-

tions over a wired, packet-based communications network. Communications received by each wireless node **105** via the wired, packet-based communications network can be wirelessly transmitted via the antenna **140** of the receiving wireless node **105**.

Each wireless node **105** also can include an attenuator **145** disposed between each wireless access point **130** and antenna **140**. The attenuators **145** can be implemented as a variable or programmable attenuator for use with antennas. Each attenuator **145** can receive control signals allowing the amount of attenuation provided by that attenuator **145** to be controlled dynamically from another device. Accordingly, wireless communication characteristics such as the sensitivity of the access point with respect to both signal reception and signal transmission can be modified by adjusting the attenuators **145**.

For example, by increasing the amount of attenuation provided by an attenuator **145**, the power delivered from a wireless access point **130** to an attached antenna **140** for transmission as well as the power of a signal received by an antenna **140** that is delivered to the wireless access point **130** can be reduced. Decreasing the amount of attenuation allows the wireless access point **130** to deliver increased power to an attached antenna **140** for transmission as well as receive higher power signals from the attached antenna **140**.

The wireless nodes **105** further can include routers **135**. Although a dedicated hardware router can be used, according to another embodiment of the present invention, one or more of the routers **135** can be implemented using a computer system having appropriate routing software executing therein. The routers **135** also can include mobility management software providing thresholds and events notification to avoid system problems or failure, real-time updates on network events, automatic discovery of access points, tracking of network traffic and usage for analysis of network utilization, and data reporting and data export functions.

The controller **120** is operatively connected to each attenuator **145**. Accordingly, the controller **120** can provide control signals to each attenuator **145** of the wireless nodes **105**. The controller **120** can be implemented as a programmable computer system or as a standalone, dedicated controller unit. In either case, the controller **120** can variably and continually adjust the amount of attenuation provided by each attenuator **145** by sending appropriate control signals to the attenuators **145**.

The controller **120** can include a suitable communications interface for communicating with each attenuator **145**. While each attenuator **145** can be adjusted individually by the controller **120**, according to one aspect of the present invention, the controller **120** can vary the amount of attenuation provided by each attenuator **145** in a predetermined pattern so as to model the movement of a mobile node **125**. By varying the attenuation of one or more of the attenuators **145** according to a given pattern, various motion related parameters including, but not limited to, speech, acceleration, and trajectory of the mobile node **125** can be emulated. Additionally, the controller **120** can concurrently control and dynamically adjust the attenuation provided by each attenuator **145**.

The emulator **110** can be a hardware or a software network emulator. According to one embodiment of the present invention, the emulator **110** can be implemented as a software-based network emulator configured to emulate various performance scenarios such as tunable packet delay distributions, congestion and background loss, bandwidth limitation, and packet reordering and duplication. For example, the emulator **110** can be implemented using a

computer system executing the National Institute of Standards and Technology (NIST) emulator.

The home agent **115** can be a computing environment with which the mobile node **125** can communicate via the wireless and wired portions of system **100**. For example, the home agent **115** can be one or more application programs which the mobile node **125** can access, a virtual private network (VPN) configuration, virtual environment, or the like. Because the network and transport layers of the system **100** are isolated from the home agent **115**, any applications and/or other virtual environments can be tested without changing application programming interfaces (API's) to any such applications and/or virtual environments.

While the emulator **110**, the home agent **115**, and the controller **120** are depicted as independent components, it should be appreciated that one or more of these components can be combined into a single, more complex component. For example, the home agent **115**, the emulator **110**, and the controller **120**, if implemented as application programs, can be included within a single computer system. Similarly, various combinations of the emulator **110**, the home agent **115**, and the controller **120** can be implemented in two or more computer systems.

It should be appreciated that the various components discussed with reference to FIG. **1** have been provided for purposes of illustration. As such, the present invention can be embodied in other forms. For example, according to one embodiment of the present invention, wireless nodes **105** can be provided which allow for programmatic control of signal transmission strength or power. Such an embodiment also can include an attenuation mechanism for controlling the sensitivity of the receiver portion of the wireless node. Depending upon the configuration of system **100**, the controller **120** also can be communicatively linked with the emulator **110**. Accordingly, functions of the controller **120** can be directed by the home agent **115** if so desired.

In operation, one of the mobile nodes **125** can begin communicating with the home agent **115**. That mobile node **125** can establish a wireless communication link with the wireless node **105**, labeled A (hereafter **105A**). The controller **120** can be configured to initially set the attenuation level of the attenuator **145** of wireless node **105A** to a minimum, or at least set the attenuation to a level which permits the mobile node **125** to communicate with the wireless node **105A**. The controller **120** can continually increase the attenuation provided by the attenuator **145** of wireless node **105A** to simulate mobile node **125** traveling away from the wireless node **105A**.

The controller **120** can concurrently set the attenuator **145** of wireless node **105**, labeled B (hereafter **105B**), to maximize attenuation. That is, wireless node **105B** can be set for maximum attenuation while wireless node **105A** is communicating with the mobile node **125**. Subsequently, while the attenuation for wireless node **105A** is increasing, the controller **120** can cause the attenuation of wireless node **105B** to decrease so as to simulate mobile node **125** moving away from wireless node **105A** and moving toward wireless node **105B**. The emulator **110** can simulate various conditions of an attached wired network. By varying the amount of attenuation provided by each attenuator **145** and the rate at which the attenuation either increases and/or decrease in each respective network node **105**, the controller **120** emulates motion of the mobile node **125** for any of a variety of different trajectories, speeds, and/or accelerations. It should be appreciated that more than one mobile node **125** can be used or be active at one time.

One or more data logging components (not shown) can be disposed in one or more of the various components of the system **100**. For example, the mobile node **125** can be configured to record information such as the strength of the signal received at the mobile node **125** over time. Similarly, the routers **135** and/or the access points **130** can be configured to record information including, but not limited to, the amount of data passing through each wireless node **105**. The emulator **110**, the home agent **115**, and the controller **120** also can be configured to record transactions and component settings.

Recorded information can be time stamped for purposes of comparison with data recorded from other components. Additionally, each respective data logger can be configured to record the source of a received request. For example, each router **135** or other data logging component of the wireless nodes **105** can record which mobile node **125** is sending and/or receiving communications from that wireless node **105**.

Accordingly, recorded information and network behavior can be analyzed with respect to time and varying attenuation settings for the various wireless nodes **105**. For example, the strength of the signal received at the mobile node **125** can be analyzed and compared with the data throughput of each wireless node **105** over time. Such an analysis can reveal hand-off rates between the wireless nodes **105**.

FIG. **2** is a flow chart illustrating a method **200** of emulating mobile network communications in accordance with the inventive arrangements disclosed herein. The method can begin in step **205** where the system is initialized. The wireless nodes, the controller, and the emulator are brought online and the home agent is initialized. For example, an application program or other virtual environment that can interact with the mobile nodes can be executed or instantiated.

One or more mobile nodes can be positioned at a location (or locations) within communication range of each of the wireless nodes. For example, a mobile node can be positioned approximately 10 meters from a perimeter established by the antennas of the wireless nodes. It should be appreciated, however, that the mobile nodes can be located at any suitable distance from the wireless nodes so long as wireless communications can be exchanged between the mobile node and the wireless node when little or no attenuation is used.

In step **210**, communications between the mobile node and the home agent can be initiated. For example, the mobile nodes can initiate a file transfer or some other task which can either be conducted throughout the method **200** or can be performed in an iterative manner.

In step **215**, the attenuation provided by one or more of the attenuators can be dynamically varied. For example, the controller can decrease the amount of attenuation for one of the wireless nodes while increasing the amount of attenuation with respect to the other wireless nodes. In this manner, motion of the mobile node can be emulated. As noted, by varying the rate and amount of attenuation of one or more of the attenuators, different characteristics of motion such as the trajectory, speed, and/or acceleration of the mobile node can be emulated.

For example, in order to emulate speed, two factors can affect the mobile node: received signal strength and signal-to-noise ratio (SNR). As. the SNR is defined by the Log (signal/noise), modifying the signal strength modifies the SNR. The SNR also can be emulated by adding randomness to the attenuation mechanism. Noise can be added in the form of a Gaussian Distribution (Normal Distribution) at a certain mean and variance. In any case, these factors can be

varied from the wireless access point and can be received at the client adaptor (network card) level. Mobility is then emulated by increasing the signal strength and reception sensitivity of one wireless access point and decreasing the signal strength and reception sensitivity of the other two wireless access points. Signal strength and reception sensitivity of any two or more wireless access points can be varied to emulate-a predetermined path of motion, or the trajectory, of the mobile node(s) and the wireless communication scenario under evaluation. Other wireless communication characteristics can be similarly varied. Besides signal strength, reception sensitivity, and SNR, other communication characteristics that can be varied include, for example, a bit error rate (BER).

The controller can be programmed to vary the attenuation of one or more attenuators of each of the wireless nodes to emulate mobility scenarios where the mobile node is moving at a particular speed, at a particular directional path, and over particular terrain. Equation 1 represents the path loss and the signal received by a network node at a distance d from a wireless access point.

$$S_r(dBW) = S_t(dBW) + G_t(dB_i) + G_r(dB) - K_o - n\log_{10}(d) \tag{1}$$

The values of G_i indicate the gains at the both ends of an antenna, using the isotropic in dB_i. In other words, the signal strength received at the mobile node is the summation of all the gains (S_t, G_i) minus the propagation loss due to fading of the signal. This propagation loss depends on the many characteristics of the terrain and can be empirically defined as discussed in K. Pahlavan, A. Levesque, *Wireless Information Networks*, John Wiley & Son's, New York (1995), using different values of K_o and n, depending upon different terrain conditions at different frequency values.

The experimental values and equations used for signal propagation correspond to the modeling for indoor and micro-cellular environments, as discussed in K. Pahlavan, et al., *Wireless Information Networks*, are illustrated with reference to equation 2. The empirical model indicates that the attenuation is negligible at closer distances from the antenna, and quickly, logarithmically decays at certain distances using different values of n and K_o. In this case, 10 and 20 are used in equation 2.

(2)	A(d) =	0,	$d \leq R/100$ and $d >= 1.2R$
		$10 + n\log(d)$,	$R/100 < d \leq 0.9R$
		$20 + 10(n + 1.3)\log(d)$,	$d > 0.9R$

In equation 2, d is the distance between the wireless access point and the mobile node and R is the cell ratio having a value of 500 meters. A square attenuation model was used to determine the handoff rate between the wireless nodes as set forth in equation 3.

(3)	A(d) =	0,	$0 \leq d \leq 0.9R$
		128,	$d > 0.9R$

Although the attenuators can be varied to provide several different values of attenuation, acceptable values of attenuation can be determined through empirical study. For example, attenuation can range from approximately 0 to 60 dB or another range so as to prevent wireless access point signal leakage.

Accordingly, attenuation of each wireless node can be varied using the equations specified above to emulate motion of mobile nodes. As noted, various mobile network characteristics such as speeds, accelerations, and trajectories of the mobile node(s) can be emulated by varying attenuation levels. The controller and/or the home agent can be programmed to vary attenuations to emulate a variety of different mobile network characteristics. Notably, with respect to terrain, different terrains also can be emulated by mapping survey data to settings of the attenuators. As used herein, the term "terrain" can be used to refer to different natural and/or man-made landscapes. For example, "terrain" can be used to describe a mountainous landscape, a landscape having valleys, lakes, and the like. The term further can refer to urban and/or rural landscapes as well as the landscape of a city in reference to building height, placement, and the like.

In step **220**, network activity can be monitored and logged. More particularly, the data throughput at each wireless node can be tracked over time and compared with the attenuation function as applied to each respective wireless node. Accordingly, by analyzing the data throughput of each wireless node, the handoff rate, or the rate at which the mobile node leaves the coverage area of one network node and enters the coverage area of another, can be determined. The signal strength as measured at the mobile node also can be monitored and compared with the attenuation function applied to the wireless nodes.

It should be appreciated that other quantities and/or characteristics can be measured and/or monitored such as the power consumed at the mobile node, the handoff protocol performance, and protocol synchronization. According to one aspect of the present invention, the performance of IP Security (IPSec) protocol and IP in IP tunneling can be evaluated, for example in the context of Mobile-IP, in conjunction with Virtual Private Networks (VPN) and Layer 2 Tunnel Protocol (L2TP) as secured links over Mobile wireless Networks. Handoff performance also can be evaluated.

Additionally, wireless communication characteristics such as authentication and authorization latencies, for example in the case of IEEE 802.11i, can be emulated. A Radius Server (authentication server) can be co-located in one of the wired nodes such that delays can be measured and wireless authentication also can be emulated. Throughput performance can be monitored for any of a variety of different communications protocols such as Mobile IP v. 6. The performance of any higher-layer protocol, including but not limited to Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Universal Plug and Play (UPnP), Simple Mail Transfer Protocol (SMTP), multimedia applications over User Datagram Protocol (UDP) or TCP, and Layer-2 protocols such as WME and IEEE 802.11e can be evaluated by simply switching access points.

The present invention also can emulate other wireless communication characteristics such as load and congestion by limiting the wireless point response time. Network topologies can be emulated by setting (x,y) coordinates of the base stations or access points. A mobile node moving from point (**x1**, **y1**) to (**x2**, **y2**) will then intercept a set of access points such that handoff will occur. Depending upon the velocity equations and the location of each node in an emulated network topology, an emulated sense of location can then be acquired. Location-based services can be evaluated and tested using the present invention by mapping signal strength to a (x,y) location. Any application at the mobile node and the emulator can use (x,y) coordinates to

perform handoff, create virtual foreign agents or wireless access points, and anticipate resource allocation.

While Mobile IP and Home agent were used as examples, those skilled in the art will recognize that the inventive arrangements disclosed herein can be used to emulate any Layer 2 or 3 Mobility protocol including, but not limited to Mobile IP, Mobile IP v. 6, Cellular-IP, and the like. Other protocols not requiring a Home Agent can also be emulated.

The various references disclosed throughout this application are hereby incorporated by reference.

The present invention can be realized in hardware, software, or a combination of hardware and software. The present invention can be realized in a centralized fashion in one computer system, or in a distributed fashion where different elements are spread across several interconnected computer systems. Any kind of computer system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software can be a general purpose computer system with a computer program that, when being loaded and executed, controls the computer system such that it carries out the methods described herein.

One or more aspects of the present invention also can be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which when loaded in a computer system is able to carry out these methods. Computer or application program in the present context means any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following: a) conversion to another language, code or notation; b) reproduction in a different material form.

This invention can be embodied in other forms without departing from the spirit or essential attributes thereof. Accordingly, reference should be made to the following claims, rather than to the foregoing specification, as indicating the scope of the invention.

What is claimed is:

1. A system for emulating mobile network communications comprising:
   a plurality of fixedly-located wireless network nodes configured to variably adjust wireless communication characteristics;
   at least one mobile node configured to wirelessly communicate with selected ones of said plurality of wireless network nodes;
   a network emulator communicatively linked to each of said plurality of wireless network nodes, said network emulator configured to emulate attributes of a packet-based wired communications network for simulating network conditions experienced by said at least one mobile node in communicating with other nodes through the wired communications network, the emulated attributes comprising at least one of tunable packet-delay distribution, network congestion, bandwidth limitation, and packet re-ordering and duplication; and
   a controller communicatively linked to each of said plurality of wireless network nodes, said controller configured to control the wireless communication characteristics of each of said plurality of wireless network nodes to simulate, without changing operating parameters of said at least one mobile node, different wireless communication conditions experienced by said at least one mobile node in actual operation.

2. The system of claim 1, further comprising a home agent configured to communicatively link the at least one mobile node to said plurality of wireless network nodes and to a wired communications network whose attributes are emulated by said emulator.

3. The system of claim 1, wherein said wireless communication characteristics include a signal reception sensitivity.

4. The system of claim 1, wherein said wireless communication characteristic includes at least one of signal transmission strength, signal-to-noise ratio (SNR), and bit error rate (BER).

5. The system of claim 1, wherein at least one of said plurality of wireless network nodes includes:
   a wireless access point having an antenna and at least one variable attenuator; and
   a routing device communicatively linking said access point with said network emulator.

6. The system of claim 5, wherein said controller is configured to vary an amount of attenuation provided by said variable attenuator by dynamically adjusting at least one of a signal reception sensitivity and a signal transmission strength of said wireless access point to thereby simulate motion of said at least one mobile node.

7. The system of claim 6, wherein said variable attenuator comprises a plurality of variable attenuators; and wherein the amount of attenuation is varied by increasing attenuation provided by at least one of said plurality of variable attenuators while simultaneously decreasing attenuation provided by another one of said attenuators.

8. The system of claim 7, wherein said controller dynamically adjusts the amount of attenuation provided by at least two of said attenuators to thereby emulate at least one of speed, acceleration, and trajectory of said mobile node.

9. The system of claim 6, further comprising:
   a data logging component configured to record at least one of a data throughput of at least one of said plurality of wireless network nodes and a measure of signal strength received at said mobile node.

10. The system of claim 5, wherein said antenna is an omni-directional antenna.

11. A method of emulating mobile network communications comprising the steps of:
   initiating communications between a home agent and a mobile node via at least one fixedly-located wireless network node connected to a controller;
   while the mobile node wirelessly communicates with the at least one wireless network node, dynamically adjusting with the controller at least one wireless communication characteristic of the wireless node to simulate, without changing operating parameters of the mobile node, different wireless communication conditions experienced by the mobile node in actual operation; and
   emulating with an emulator connected to the at least one wireless network node attributes of a packet-based wired communications network to simulate network conditions experienced by the mobile node in communicating with network-connected nodes through the wired communications network, the emulated attributes comprising at least one of tunable packet-delay distribution, network congestion, bandwidth limitation, and packet re-ordering and duplication.

12. The method of claim 11, wherein the wireless communication characteristic includes signal reception sensitivity.

13. The method of claim 11, wherein wireless communications characteristic includes at least one of signal transmission strength, signal-to-noise ratio (SNR), and bit error rate (BER).

14. The method of claim 11, wherein the wireless network node comprises a wireless access point, having an antenna and a variable attenuator.

15. The method of claim 14, the wireless network node further comprising a routing device.

16. The method of claim 14, wherein the wireless network node is communicatively linked with the home agent through a network emulator.

17. The method of claim 14, said step of dynamically adjusting at least one wireless communication characteristic further comprising varying an amount of attenuation provided by the variable attenuator to emulate motion of the mobile node.

18. The method of claim 17, wherein the variable attenuator comprises a plurality of variable attenuators and further comprising the step of increasing attenuation provided by the variable attenuators while simultaneously decreasing attenuation provided by another one of the variable attenuators.

19. The method of claim 18, wherein dynamically adjusting the amount of attenuation provided by at least one of the variable attenuators emulates at least one of speed, acceleration, and trajectory of the mobile node.

20. A computer readable storage medium for use in emulating mobile network communications, the storage medium comprising computer instructions for:
   initiating communications between a home agent and a mobile node via at least one fixedly-located wireless network node connected to a controller;
   while the mobile node wirelessly communicates with the at least one wireless node, dynamically adjusting with the controller at least one wireless communication characteristic of the wireless node to simulate, without changing operating parameters of the mobile node, different wireless communication conditions experienced by the mobile node in actual operation; and
   emulating with an emulator connected to the at least one wireless network node attributes of a packet-based wired communications network to simulate network conditions experienced by the mobile node in communicating with network-connected nodes through the wired communications network, the emulated attributes comprising at least one of tunable packet-delay distribution, network congestion, bandwidth limitation, and packet re-ordering and duplication.

21. The computer readable storage medium of claim 20, wherein the at least one wireless node comprises a plurality of wireless nodes, and wherein the computer readable storage medium further comprises a computer instruction for increasing attenuation provided by a variable attenuator communicatively linked to the one of the plurality of wireless nodes while simultaneously decreasing attenuation provided by another variable attenuator communicatively linked to another of the plurality of wireless nodes.

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