Exhibit 1

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
TEXARKANA DIVISION

WIAV NETWORKS, LLC, a Virginia limited liability company,	
Plaintiff,	Civil Action No. 3:06-cv-00101
v.	
3COM CORPORATION, a Delaware company, ACER, INC., a Taiwanese company, ACER AMERICA CORPORATION, a California company, APPLE, INC., a California company, ASUS COMPUTER INTERNATIONAL, a California company, ASUSTEK COMPUTER INC., a Taiwanese company, BELKIN, INC., a Delaware company, BELKIN INTERNATIONAL, INC., a Delaware company, BROTHER INDUSTRIES, LTD., a Japanese company, BROTHER INTERNATIONAL CORPORATION, a Delaware company, BUFFALO TECHNOLOGY (USA), INC., a Delaware company, CANON INC., a Japanese company, CANON U.S.A., INC., a New York company, CISCO SYSTEMS, INC., a California company, DELL INC., a Delaware company, D-LINK CORPORATION, a Taiwanese company, D-LINK SYSTEMS, INC., a California company, EPSON AMERICA, INC., a California company, FUJITSU AMERICA, INC., a California company, FUJITSU LTD., a Japanese company, FUTUREWEI TECHNOLOGIES, INC., a Texas company, GATEWAY, INC., a California company, GENERAL DYNAMICS ITRONIX CORPORATION, a Delaware company, HEWLETT PACKARD CO., a Delaware company, HUAWEI TECHNOLOGIES CO., LTD., a Chinese company, LENOVO GROUP LTD., a	JURY TRIAL DEMANDED

Chinese company, LENOVO (UNITED STATES) INC., a Delaware company, LENOVO HOLDING COMPANY, INC., a Delaware company, LEXMARK INTERNATIONAL, INC., a Delaware company, MOTOROLA, INC., a Delaware company, NETGEAR, INC., a Delaware company, NINTENDO COMPANY, LTD, a Japanese company, NINTENDO OF AMERICA, INC., a Washington company, NOKIA CORPORATION, a Finnish company, NOKIA, INC., a Delaware company, NOVATEL WIRELESS INC., a Delaware company, NOVATEL WIRELESS SOLUTIONS, INC., a Delaware company, NOVATEL WIRELESS TECHNOLOGY, INC., a Delaware company, OPTION NV, a Belgian company, OPTION WIRELESS USA, INC., a Delaware company, PALM, INC., a Delaware company, PANASONIC CORPORATION, a Japanese company, PANASONIC CORPORATION OF NORTH AMERICA, a Delaware company, SEIKO EPSON CORPORATION, a Japanese company, SHARP CORPORATION, a Japanese company, SHARP ELECTRONICS CORPORATION, a New York company, SIERRA WIRELESS, INC., a Canadian company, SIERRA WIRELESS AMERICA, INC., a Delaware company, SONY CORPORATION, a Japanese company, SONY CORPORATION OF AMERICA, a New York company, SONY ELECTRONICS INC., a Delaware company, SONY ERICSSON MOBILE COMMUNICATIONS AB, a Swedish company, SONY ERICSSON MOBILE COMMUNICATIONS (USA) INC., a Delaware company, TOSHIBA AMERICA, INC., a Delaware company, TOSHIBA AMERICA INFORMATION SYSTEMS, INC., a California company, TOSHIBA CORPORATION, a Japanese) company, UTSTARCOM, INC., a Delaware company, XEROX CORPORATION, a New York company, ZTE CORPORATION, a Chinese company, ZTE (USA) INC., a New Jersey company,)

Defendants.)

AMENDED COMPLAINT

Plaintiff WIAV Networks, LLC ("WIAV"), by counsel and pursuant to Federal Rule of Civil Procedure 8(a), alleges the following against Defendants 3Com Corporation, Acer, Inc., Acer America Corporation, Apple, Inc., ASUS Computer International, ASUSTeK Computer Inc., Belkin, Inc., Belkin International, Inc., Brother Industries, Ltd., Brother International Corporation, Buffalo Technology (USA) Inc., Canon Inc., Canon U.S.A., Inc., Cisco Systems, Inc., Dell Inc., D-Link Corporation, D-Link Systems, Inc., Epson America, Inc., Fujitsu America, Inc., Fujitsu Ltd., Futurewei Technologies, Inc., Gateway, Inc., General Dynamics Itronix Corporation, Hewlett Packard Co., Huawei Technologies Co., Ltd., Lenovo Group Ltd., Lenovo (United States) Inc., Lenovo Holding Company, Inc., Lexmark International, Inc., Motorola, Inc., Netgear, Inc., Nintendo Company, Ltd., Nintendo of America, Inc., Nokia Corporation, Nokia Inc., Novatel Wireless Inc., Novatel Wireless Solutions, Inc., Novatel Wireless Technology, Inc., Option NV, Option Wireless USA, Inc., Palm, Inc., Panasonic Corporation, Panasonic Corporation of North America, Seiko Epson Corporation, Sharp Corporation, Sharp Electronics Corporation, Sierra Wireless, Inc., Sierra Wireless America, Inc., Sony Corporation, Sony Corporation of America, Sony Electronics Inc., Sony Ericsson Mobile Communications AB, Sony Ericsson Mobile Communications (USA) Inc., Toshiba America, Inc., Toshiba America Information Systems, Inc., Toshiba Corporation, UTStarCom, Inc., Xerox Corporation, ZTE Corporation, and ZTE (USA) Inc. (collectively "Defendants" and individually "Defendant") for patent infringement:

NATURE OF THE ACTION

1. Plaintiff WIAV owns United States Patent No. 6,480,497 entitled "Method and Apparatus for Maximizing Data Throughput in a Packet Radio Mesh Network" (the "'497 Patent") and United States Patent No. 5,400,338 entitled "Parasitic Adoption of Coordinate-Based Addressing by Roaming Node" (the "'338 Patent").

2. Each Defendant has used and continues to use the technology claimed by the '497 Patent and the '338 Patent in systems and methods that it makes, uses, sells, and offers for sale, without Plaintiff's permission.

3. Plaintiff seeks damages for each Defendant's infringement of the '497 Patent and the '338 Patent.

THE PARTIES

4. Plaintiff WIAV is a Virginia limited liability company with its principal place of business at 11289 Stones Throw Drive, Reston, Virginia 20194.

5. On information and belief, 3Com Corporation ("3Com") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 350 Campus Drive, Marlborough, Massachusetts 01752-3064.

6. On information and belief, Acer, Inc. is a Taiwanese corporation, with a principal place of business at 21F88 Hsin Tai Wu Road, Section 1, Taiwan. On further information and belief, Acer America Corporation is a wholly owned subsidiary of Acer, Inc., and is organized and existing under the laws of California, with a principal place of business at 333 West San Carlos Street, Suite 1500, San Jose, California 95110. On further information and belief, Gateway, Inc. is also a wholly owned subsidiary of Acer, Inc., and is a corporation organized and existing under the laws of Delaware, with a principal place of business at 7565 Irvine Center Drive, Irvine, California 92618. Acer, Inc., Acer America Corporation, and Gateway, Inc. will be referred to herein individually and collectively as the "Acer Defendants."

7. On information and belief, Apple, Inc. ("Apple") is a corporation organized and existing under the laws of California, with a principal place of business at 1 Infinite Loop, Cupertino, California 95014.

8. On information and belief, ASUSTeK Computer Inc. is a Taiwanese company with a principal place of business at 150 Li-Te Road, Peitou, Taipei 112, Taiwan. On information and belief, ASUS Computer International is a wholly owned subsidiary of ASUSTeK Computer Inc., and is organized and existing under the laws of California, with a principal place of business at 800 Corporate Way, Fremont, California 94539. ASUSTeK Computer Inc. and ASUS Computer International will be referred to herein individually and collectively as the "ASUS Defendants."

9. On information and belief, Belkin International, Inc. and Belkin, Inc. are corporations organized and existing under the laws of the Delaware, with a principal place of business at 501 West Walnut Street, Compton, California 90220. Belkin International, Inc. and Belkin, Inc. will be referred to herein individually and collectively as the "Belkin Defendants."

10. On information and belief, Brother Industries, Ltd. is a Japanese corporation with a principal place of business at 15-1 Naeshiro-cho, Mizuho-ku, Nagoya 467-8561, Japan. On information and belief, Brother International Corporation is a wholly owned subsidiary of Brother Industries, Ltd., and is organized and existing under the laws of Delaware, with a principal place of business at 100 Somerset Corporate Boulevard, Bridgewater, New Jersey 08807-0911. Brother Industries, Ltd. and Brother International Corporation will be referred to herein individually and collectively as the "Brother Defendants."

11. On information and belief, Buffalo Technology (USA), Inc. ("Buffalo Tech") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 11100 Metric Boulevard, Suite 750, Austin, Texas 78758.

12. On information and belief, Canon Inc. is a Japanese corporation, with a principal place of business at 30-2 Shimomaruko 3-Chome, Ohta-Ku, Tokyo 146-8501, Japan. On information and belief, Canon U.S.A., Inc. is a wholly owned subsidiary of Canon Inc., and is organized and existing under the laws of New York, with a principal place of business at One Canon Plaza, Lake Success, New York 11042. Canon Inc. and Canon U.S.A., Inc. will be referred to herein individually and collectively as the "Canon Defendants."

13. On information and belief, Cisco Systems, Inc. ("Cisco") is a corporation organized and existing under the laws of California, with a principal place of business at 170 West Tasman Drive, San Jose, California 95134.

14. On information and belief, Dell Inc. ("Dell") is a corporation organized and existing under the laws of Delaware, with a principal place of business at One Dell Way, Round Rock, Texas 78682.

15. On information and belief, D-Link Corporation is a Taiwanese corporation, with a principal place of business at No. 289, Sinhu 3rd Rd., Neihu District, Taipei City 114, Taiwan. On information and belief, Defendant D-Link Systems, Inc. is a wholly owned subsidiary of D-Link Corporation, and is organized and existing under the laws of California, with a principal place of business at 17595 Mt. Hermann Street, Fountain Valley, California 92708. D-Link Corporation and D-Link Systems, Inc. will be referred to herein individually and collectively as the "D-Link Defendants."

16. On information and belief, Fujitsu Ltd. is a Japanese company with a principal place of business at Shiodome City Center, 1-5-2 Higashi-Shimbashi, Minato-Ku, Tokyo 105-7123, Japan. On information and belief, Fujitsu America, Inc. is a wholly owned subsidiary of Fujitsu Ltd., and is organized and existing under the laws of California, with a principal place of business at 1250 East Arques Avenue, Sunnyvale, California 94085. Fujitsu Ltd. and Fujitsu America, Inc. will be referred to herein individually and collectively as the "Fujitsu Defendants."

17. On information and belief, General Dynamics Itronix Corporation ("General Dynamics") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 12825 East Mirabeau Parkway, Spokane Valley, Washington 99216.

18. On information and belief, Hewlett Packard Co. ("HP") is a company organized and existing under the laws of Delaware, with its principal place of business at 3000 Hanover Street, MS 1050, Palo Alto, California 94304.

19. On information and belief, Huawei Technologies Co., Ltd. is a Chinese company, with a principal place of business at HQ Office Building, Huawei Industrial Base, Bantian, Longgang District, Shenzen 518129, P.R. China, and with its North American headquarters at 1700 Alma Drive, Suite 100 Plano, Texas 75075. Futurewei Technologies, Inc., on information and belief, is a wholly owned subsidiary of Huawei Technologies Co., Ltd. and is a corporation organized and existing under the laws of Texas, with a principal place of business at 1700 Alma Drive, Suite 10, Plano, Texas 75075. Huawei Technologies Co., Ltd. and Futurewei Technologies, Inc. will be referred to herein individually and collectively as the "Huawei Defendants."

20. On information and belief, Lenovo Group Ltd. is a Chinese company, with a principal place of business at No. 6 Chuang Ye Road, Shangdi Information Industry Base, Haidan District, Beijing, China 100085. Lenovo Holding Company, Inc., on information and belief, is a wholly owned subsidiary of Lenovo Group Limited and is a corporation organized and existing under the laws of the Delaware, with a principal place of business at 1009 Think Place, Morrisville, North Carolina 27560. On information and belief, Lenovo (United States) Inc. is a wholly owned subsidiary of Lenovo Group Ltd., and is organized and existing under the laws of Delaware, with a principal place of business at 1009 Think Place, Morrisville, North Carolina 27560. Lenovo Group Ltd., Lenovo Holding Company, Inc. and Lenovo (United States) Inc. will be referred to herein individually and collectively as the "Lenovo Defendants."

21. On information and belief, Lexmark International, Inc. ("Lexmark") is a corporation organized and existing under the laws of Delaware, with a principal place of business at One Lexmark Centre Drive, 740 West New Circle Road, Lexington, Kentucky 40550.

22. On information and belief, Motorola, Inc. ("Motorola") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 1303 East Algonquin Road, Schaumberg, Illinois 60196.

23. On information and belief, Netgear, Inc. ("Netgear") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 350 East Plumeria Drive, San Jose, California 95134.

24. On information and belief, Nintendo Company, Ltd. is a Japanese company, with a principal place of business at 11-1 Kamitoba Hokotatecho, Minami-ku, Kyoto, 601-8501, Japan. On information and belief, Nintendo of America, Inc., is a wholly owned subsidiary of Nintendo Company, Ltd., and is organized under the laws of Washington, with a principal place of business at 4820 150th Avenue N.E., Redmond, Washington 98052. Nintendo Company, Ltd. and Nintendo of America, Inc. will be referred to herein individually and collectively as the "Nintendo Defendants."

25. On information and belief, Nokia Corporation is a Finnish corporation with a principal place of business at Keilalahdentie 4, P.O. Box 226, FI-00045 Nokia Group, Espoo, Finland. On information and belief, Nokia, Inc. is a wholly owned subsidiary of Nokia Corporation, and is organized and existing under the laws of Delaware, with a principal place of business at 6000 Connection Drive, Irving, Texas 75039. Nokia Corporation and Nokia, Inc. will be referred to herein individually and jointly as the "Nokia Defendants."

26. On information and belief, Novatel Wireless Inc. is a corporation organized and existing under the laws of Delaware, with a principal place of business at 9645 Scranton Road, Suite 205, San Diego, California 92121. Novatel Wireless Solutions,

Inc., on information and belief, is a wholly owned subsidiary of Novatel Wireless Inc. and is a corporation organized and existing under the laws of Delaware, with a principal place of business at 9645 Scranton Road, Suite 205, San Diego, California 92121. Novatel Wireless Technology, Inc., on information and belief, is a wholly owned subsidiary of Novatel Wireless Inc. and is a corporation organized and existing under the laws of Delaware, with a principal place of business at 9645 Scranton Road, Suite 205, San Diego, California 92121. Novatel Wireless Inc., Novatel Wireless Solutions, Inc., and Novatel Wireless Technology, Inc. will be referred to herein individually and collectively as the "Novatel Defendants."

27. On information and belief, Option NV is a Belgian corporation, with a principal place of business at Gaston Geenslan 14, 3001 Leuven, Belgium. Option Wireless USA, Inc., on information and belief, is a wholly owned subsidiary of Option NV and is a corporation organized and existing under the laws of Delaware, with a principal place of business at 13010 Morris Road, 6th Floor, Building 1, Alpharetta, Georgia 30004. Option NV and Option Wireless USA, Inc. will be referred to herein individually and collectively as the "Option Defendants."

28. On information and belief, Palm, Inc. ("Palm") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 950 West Maude Avenue, Sunnyvale, California 94085.

29. On information and belief, Panasonic Corporation is a Japanese company, with a principal place of business at 1006 Oaza Kadoma, Kadoma, Osaka 571-8501, Japan. Panasonic Corporation of North America, on information and belief, is a wholly owned subsidiary of Panasonic Corporation, and is organized and existing under the laws of Delaware, with a principal place of business at One Panasonic Way, Secaucus, New Jersey 07094. Panasonic Corporation and Panasonic Corporation of North America will be referred to herein individually and collectively as the "Panasonic Defendants."

30. On information and belief, Seiko Epson Corporation is a Japanese company with a principal place of business at 3-3-5 Owa, Suwa, Nagano 392-8502, Japan. On information and belief, Epson America, Inc. is a wholly owned subsidiary of Seiko Epson Corporation, and is organized under the laws of California, with a principal place of business at 3840 Kilroy Airport Way, Long Beach, California 90806. Seiko Epson Corporation and Epson America, Inc. will be referred to herein individually and collectively as the "Epson Defendants."

31. On information and belief, Sharp Corporation is a Japanese corporation with a principal place of business at 22-22 Nagaike-Cho, Abeno-Ku, Osaka 545-8522, Japan. On information and belief, Sharp Electronics Corporation is a wholly owned subsidiary of Sharp Corporation, and is organized and existing under the laws of New York, with a principal place of business at 1 Sharp Plaza, Mahwah, New Jersey 07430. Sharp Corporation and Sharp Electronics Corporation will be referred to herein individually and collectively as the "Sharp Defendants."

32. On information and belief, Sierra Wireless, Inc. is a Canadian corporation, with a principal place of business at 13811 Wireless Way, Richmond BC Canada V6V 3A4. Sierra Wireless America, Inc., on information and belief, is a wholly owned subsidiary of Sierra Wireless, Inc., and is incorporated under the laws of Delaware, with a principal place of business at 2290 Cosmos Ct., Carlsbad, California 92011. Sierra Wireless, Inc. and Sierra Wireless America, Inc. will be referred to herein individually and collectively as the "Sierra Wireless Defendants."

33. On information and belief, Sony Corporation is a Japanese corporation with a principal place of business at 1-7-1 Konan, Minato-Ku, Tokyo, Japan. On information and belief, Sony Corporation of America is a wholly owned subsidiary of Sony Corporation, and is organized and existing under the laws of New York, with a principal place of business at 550 Madison Avenue, 27th Floor, New York, New York 10022. On information and belief, Sony Electronics Inc. is a wholly owned subsidiary of Sony

Corporation of America, and is organized and existing under the laws of Delaware, with a principal place of business at 16530 Via Esprillo, San Diego, California 92127. Sony Corporation, Sony Corporation of America, and Sony Electronics Inc. will be referred to herein individually and collectively as the "Sony Defendants."

34. On information and belief, Sony Ericsson Mobile Communications AB is a Swedish corporation, with a principal place of business at 202 Hammersmith Road, London W6 7DN, United Kingdom. On information and belief, Sony Ericsson Mobile Communications (USA) Inc. is a wholly owned subsidiary of Sony Ericsson Mobile Communications AB, and is organized and existing under the laws of Delaware, with a principal place of business at 7001 Development Drive, Research Triangle Park, North Carolina 27709. Sony Ericsson Mobile Communications AB and Sony Ericsson Mobile Communications (USA) Inc. will be referred to herein individually and collectively as the "Sony Ericsson Defendants."

35. On information and belief, Toshiba Corporation is a Japanese corporation, with a principal place of business at 1-6 Uchisaiwaicho 1–Chome Chiyoda-Ku, Tokyo 105-8001, Japan. On information and belief, Toshiba America, Inc. is a wholly owned subsidiary of Toshiba Corporation, and is organized and existing under the laws of Delaware, with a principal place of business at 1251 Avenue of the Americas, New York, New York 10020. On further information and belief, Toshiba America Information Systems, Inc. is a wholly owned subsidiary of Toshiba America, Inc., and is a corporation organized and existing under the laws of California, with a principal place of business at 9740 Irvine Boulevard, Irvine, California 92618. Toshiba Corporation, Toshiba America, Inc., and Toshiba America Information Systems, Inc. will be referred to herein individually and collectively as the "Toshiba Defendants."

36. On information and belief, UTStarCom, Inc. ("UTStarCom") is a corporation organized and existing under the laws of Delaware, with a principal place of business at 1275 Harbor Bay Parkway, Alameda, California 94502.

37. On information and belief, Xerox Corporation ("Xerox") is a corporation organized and existing under the laws of New York, with a principal place of business at 45 Glover Avenue, Norwalk, Connecticut 06856.

38. On information and belief, ZTE Corporation is a Chinese corporation, with a principal place of business at ZTE Plaza, Hi-Tech Road South, Hi-Tech Industrial Park, Nanshan District, Shenzen, China 518057. ZTE (USA) Inc., on information and belief, is a wholly owned subsidiary of ZTE Corporation, and is incorporated under the laws of New Jersey, with a principal place of business at 33 Wood Avenue South, Iselin, New Jersey 08830. ZTE Corporation and ZTE (USA) Inc. will be referred to herein individually and collectively as the "ZTE Defendants."

JURISDICTION AND VENUE

39. This action arises under the patent laws of the United States, Title 35 of the United States Code, §§ 271 and 281, *et seq*. because Defendants each have committed acts of patent infringement within the United States and this judicial District. Accordingly, this Court has subject-matter jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1338(a).

40. Venue is proper in this judicial District because each Defendant is a corporation subject to personal jurisdiction in this judicial District, 28 U.S.C. §§ 1391(b)-(c).

41. On information and belief, Defendants are subject to this Court's specific and general personal jurisdiction consistent with the principles of due process and/or the Texas Long Arm Statute, due at least to their substantial business in this forum, including: (i) a portion of the infringements alleged herein, including using, selling, and offering to sell products, methods, and systems that infringe the claims of the '497 Patent and '338 Patent; (ii) the presence of established distribution channels for Defendants' products in this forum; and (iii) regularly doing or soliciting business, engaging in other

persistent courses of conduct, and/or deriving substantial revenue from goods and services provided to individuals in Texas and in this judicial District.

COUNT I

INFRINGEMENT OF THE '497 PATENT

42. Plaintiff repeats and incorporates by reference each of the allegations contained in Paragraphs 1 through 41 above, and further alleges as follows:

43. The United States Patent and Trademark Office issued the '497 Patent on November 12, 2002. A true and correct copy of the text of the '497 Patent is attached to this Complaint as Exhibit A. Plaintiff WIAV is the owner of the '497 Patent.

44. Without a license or permission from Plaintiff, Defendant 3Com infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the MSR series of wireless routers (e.g., MSR 20-15). 3Com's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, 3Com's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

45. Without a license or permission from Plaintiff, the Acer Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the TravelMate, Aspire, Extensa and Aspire One series of notebooks and netbooks (e.g., TravelMate 6593, Aspire 8930, Extensa 5635, and Aspire One 751h), and the C, LT, M, MC, MD, ML, MT, MX, NV, P, and T series of notebooks and netbooks under the Gateway brand. The Acer Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Acer Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

46. Without a license or permission from Plaintiff, Defendant Apple infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Macbook, MacBook Pro, and MacBook Air series, and wireless communications devices, such as the iPhone 3G and iPhone 3G S series. Apple’s infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, Apple’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

47. Without a license or permission from Plaintiff, the ASUS Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as their various notebook series which are designated by letter and number combinations (e.g., A6Km, ASUS-Lamborghini VX1, B50A, C90, F3E, G1, K401J, M50Sv, N10E, R1E, S6F, U1E, V1Jp, W2Jb, X71SL, Z33A, and L50Vn). The ASUS Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the ASUS Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

48. Without a license or permission from Plaintiff, the Belkin Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as wireless desktop and notebook cards, wireless USB adapters, wireless routers (e.g., Wireless G Router, Wireless G+ MIMO Router, Wireless G+ MIMO USB Network Adapter, and Wireless G+ MIMO Notebook Card). The Belkin Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Belkin Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

49. Without a license or permission from Plaintiff, the Brother Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the HL, MFC and DCP series of printer and multifunction products (e.g., HL-4070CDW, MFC-255CW, and DCP-585CW). The Brother Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Brother Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

50. Without a license or permission from Plaintiff, Defendant Buffalo Tech infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the Nfiniti™ Wireless-N, Nfiniti™ Wireless-N Dual-Band, and Wireless-G High Power series of routers. Buffalo Tech’s infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, Buffalo Tech’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

51. Without a license or permission from Plaintiff, the Canon Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the PIXMA series of printer and multifunction products (e.g., PIXMA MX860). The Canon Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Canon Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

52. Without a license or permission from Plaintiff, Defendant Cisco infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices,

such as the WRT and WAP series of routers (e.g., WRT120N and WAP54G). Cisco's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, Cisco's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

53. Without a license or permission from Plaintiff, Defendant Dell infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Mini, Inspiron, Studio, XPS, Alienware, Latitude, Vostro, Adamo, and Precision series of laptops, netbooks, and mobile workstations (e.g., Mini 12, Inspiron 15, XPS M1330, Studio 15, Vostro A90, Latitude E5400, Alienware M17x, and Precision M2400). Dell's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, Dell's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

54. Without a license or permission from Plaintiff, the D-Link Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the DIR, DAP, DGL, and WBR series of routers (e.g., DIR-600 Wireless 150 Router, DAP-1522 Xtreme N Duo Wireless Bridge/Access Point, DGL-4300 Wireless 108G, and WBR-2310 RangeBooster G Router). The D-Link Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the D-Link Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

55. Without a license or permission from Plaintiff, the Epson Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging devices, such as the Artisan, Workforce, and Stylus NX series of printer and multifunction products (e.g., Artisan 700, WorkForce 600, and Stylus NX515). The

Epson Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Epson Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

56. Without a license or permission from Plaintiff, the Fujitsu Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Lifebook series of notebooks and tablet PCs (e.g., Lifebook S7220, T1010, M2010, and U820). The Fujitsu Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Fujitsu Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

57. Without a license or permission from Plaintiff, Defendant General Dynamics infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the GD, GoBook and Duo-Touch series of notebooks and tablet PCs (e.g., Duo-Touch, Duo-Touch II, GoBook XR-1, GoBook VR-2, GoBook MR-1, GoBook Q200, GD600, GD8000, and GoBook III). General Dynamics' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, General Dynamics' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

58. Without a license or permission from Plaintiff, Defendant HP infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer devices, such as the Pavillion, HDX, TouchSmart, EliteBook, ProBook, Compaq, Compaq Presario, and Mini series of laptops, notebook PCs, and tablet PCs (e.g., Mini 110 XP, Compaq Presario CQ60Z, G60t, Pavilion dv6z, HDX 16t Premium, and TouchSmart tx2z). HP's

infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, HP’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

59. Without a license or permission from Plaintiff, the Huawei Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the HG, MT, and BM series of routers (e.g., HG520s, HG522, HG527a, MT841, BM635, BM625, and BM325). The Huawei Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Huawei Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

60. Without a license or permission from Plaintiff, the Lenovo Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the IdeaPad, ThinkPad, and Value Line G series of laptops, netbooks, and tablets (e.g., IdeaPad S10, ThinkPad R500, and Value Line G530). The Lenovo Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Lenovo Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

61. Without a license or permission from Plaintiff, Defendant Lexmark infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the Z, X, C and E series of printer and multifunction products (e.g., Z2420, X3385, C544DW, and E460DW). Lexmark’s infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, Lexmark’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

62. Without a license or permission from Plaintiff, Defendant Motorola infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the MotoZine ZN5. Motorola’s infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, Motorola’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

63. Without a license or permission from Plaintiff, Defendant Netgear infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the MBR, WNR, WNMR, WPN, WGT, WGR, DG, DGN, DGNB, DGB, CG, and RP series of routers and gateways. Netgear’s infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, Netgear’s infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

64. Without a license or permission from Plaintiff, the Nintendo Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, such as the Wii and DS series of video game consoles and portable video game consoles. The Nintendo Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff. On information and belief, the Nintendo Defendants’ infringement of the ‘497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

65. Without a license or permission from Plaintiff, the Nokia Defendants infringed the ‘497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the E and N series (e.g., E66 and N85). The Nokia Defendants’ infringement of the ‘497 Patent has caused substantial damage to Plaintiff.

On information and belief, the Nokia Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

66. Without a license or permission from Plaintiff, the Novatel Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the MiFi series (e.g., MiFi 2200 and MiFi 2352). The Novatel Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Novatel Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

67. Without a license or permission from Plaintiff, the Option Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the Globesurfer series of routers (e.g., Globesurfer III and Globesurfer X1). The Option Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Option Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

68. Without a license or permission from Plaintiff, Defendant Palm infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the Prē, Centro, and the Trēo Pro. Palm's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, Palm's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

69. Without a license or permission from Plaintiff, the Panasonic Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling

products and devices which embody the patented invention, including portable computer products, such as the Toughbook series of mobile computers and laptops (e.g., Toughbook F8, Toughbook T8, Toughbook W8, Toughbook 52, Toughbook 74, Toughbook 19, Toughbook 30, Toughbook U1, and Toughbook H1). The Panasonic Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Panasonic Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

70. Without a license or permission from Plaintiff, the Sharp Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Actius and Widenote series of notebooks. The Sharp Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Sharp Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

71. Without a license or permission from Plaintiff, the Sierra Wireless Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the AirLink series of modems and routers (e.g., AirLink MP 595W, AirLink MP 880W, AirLink MP 881W, AirLink Helix RT, and AirLink Junxion Box). The Sierra Wireless Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Sierra Wireless Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

72. Without a license or permission from Plaintiff, the Sony Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the VAIO series of notebooks (e.g., VAIO P, Π, Z, SR, CS, NW, FW,

and AW series) and the PlayStation® Portable game consoles, also known as PSP. The Sony Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Sony Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

73. Without a license or permission from Plaintiff, the Sony Ericsson Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the XPERIA™ X1, and the W and C series (e.g., W995a and C905a). The Sony Ericsson Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Sony Ericsson Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

74. Without a license or permission from Plaintiff, the Toshiba Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer devices, such as the Satellite, Satellite Pro, Tecra, Qosmio, Protégé, and "mini" series of laptops (e.g., Satellite U500, Satellite Pro U400, Tecra M10, Qosmio X305, Protégé A600, and mini NB205). The Toshiba Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the Toshiba Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

75. Without a license or permission from Plaintiff, Defendant UTStarCom infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the F1000G and F3000. UTStarCom's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief,

UTStarCom's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

76. Without a license or permission from Plaintiff, Defendant Xerox infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the Phaser series of printer and multifunction products (e.g., Phaser 6130). Xerox's infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, Xerox's infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

77. Without a license or permission from Plaintiff, the ZTE Defendants infringed the '497 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the ZXV10 series of routers (e.g., ZXV10 H108N, ZXV10 H211, ZXV10 H201, ZXV10 H260, ZXV10 I20X, ZXV10 W300B, and ZXV10 H108N). The ZTE Defendants' infringement of the '497 Patent has caused substantial damage to Plaintiff. On information and belief, the ZTE Defendants' infringement of the '497 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

COUNT II

INFRINGEMENT OF THE '338 PATENT

78. Plaintiff repeats and incorporates by reference each of the allegations contained in Paragraphs 1 through 77 above, and further alleges as follows:

79. The United States Patent and Trademark Office issued the '338 Patent on March 21, 1995. A true and correct copy of the text of the '338 Patent is attached to this Complaint as Exhibit B. Plaintiff WIAV is the owner of the '338 Patent.

80. Without a license or permission from Plaintiff, Defendant 3Com infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices,

such as the MSR series of wireless routers (e.g., MSR 20-15). 3Com's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, 3Com's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

81. Without a license or permission from Plaintiff, the Acer Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the TravelMate, Aspire, Extensa and Aspire One series of notebooks and netbooks (e.g., TravelMate 6593, Aspire 8930, Extensa 5635, and Aspire One 751h), and the C, LT, M, MC, MD, ML, MT, MX, NV, P, and T series of notebooks and netbooks under the Gateway brand. The Acer Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Acer Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

82. Without a license or permission from Plaintiff, Defendant Apple infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Macbook, MacBook Pro, and MacBook Air series, and wireless communications devices, such as the iPhone 3G and iPhone 3G S series. Apple's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Apple's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

83. Without a license or permission from Plaintiff, the ASUS Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as their various notebook series which are designated by letter and number combinations (e.g., A6Km, ASUS-Lamborghini VX1, B50A, C90, F3E, G1, K401J,

M50Sv, N10E, R1E, S6F, U1E, V1Jp, W2Jb, X71SL, Z33A, and L50Vn). The ASUS Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the ASUS Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

84. Without a license or permission from Plaintiff, the Belkin Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as wireless desktop and notebook cards, wireless USB adapters, wireless routers (e.g., Wireless G Router, Wireless G+ MIMO Router, Wireless G+ MIMO USB Network Adapter, and Wireless G+ MIMO Notebook Card). The Belkin Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Belkin Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

85. Without a license or permission from Plaintiff, the Brother Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the HL, MFC and DCP series of printer and multifunction products (e.g., HL-4070CDW, MFC-255CW, and DCP-585CW). The Brother Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Brother Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

86. Without a license or permission from Plaintiff, Defendant Buffalo Tech infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the Nfiniti™ Wireless-N, Nfiniti™ Wireless-N Dual-Band, and Wireless-G High Power series of routers. Buffalo Tech's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Buffalo

Tech's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

87. Without a license or permission from Plaintiff, the Canon Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the PIXMA series of printer and multifunction products (e.g., PIXMA MX860). The Canon Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Canon Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

88. Without a license or permission from Plaintiff, Defendant Cisco infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the WRT and WAP series of routers (e.g., WRT120N and WAP54G). Cisco's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Cisco's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

89. Without a license or permission from Plaintiff, Defendant Dell infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Mini, Inspiron, Studio, XPS, Alienware, Latitude, Vostro, Adamo, and Precision series of laptops, netbooks, and mobile workstations (e.g., Mini 12, Inspiron 15, XPS M1330, Studio 15, Vostro A90, Latitude E5400, Alienware M17x, and Precision M2400). Dell's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Dell's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

90. Without a license or permission from Plaintiff, the D-Link Defendants infringed the ‘338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the DIR, DAP, DGL, and WBR series of routers (e.g., DIR-600 Wireless 150 Router, DAP-1522 Xtreme N Duo Wireless Bridge/Access Point, DGL-4300 Wireless 108G, and WBR-2310 RangeBooster G Router). The D-Link Defendants’ infringement of the ‘338 Patent has caused substantial damage to Plaintiff. On information and belief, the D-Link Defendants’ infringement of the ‘338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

91. Without a license or permission from Plaintiff, the Epson Defendants infringed the ‘338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging devices, such as the Artisan, Workforce, and Stylus NX series of printer and multifunction products (e.g., Artisan 700, WorkForce 600, and Stylus NX515). The Epson Defendants’ infringement of the ‘338 Patent has caused substantial damage to Plaintiff. On information and belief, the Epson Defendants’ infringement of the ‘338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

92. Without a license or permission from Plaintiff, the Fujitsu Defendants infringed the ‘338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Lifebook series of notebooks and tablet PCs (e.g., Lifebook S7220, T1010, M2010, and U820). The Fujitsu Defendants’ infringement of the ‘338 Patent has caused substantial damage to Plaintiff. On information and belief, the Fujitsu Defendants’ infringement of the ‘338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

93. Without a license or permission from Plaintiff, Defendant General Dynamics infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the GD, GoBook and Duo-Touch series of notebooks and tablet PCs (e.g., Duo-Touch, Duo-Touch II, GoBook XR-1, GoBook VR-2, GoBook MR-1, GoBook Q200, GD600, GD8000, and GoBook III). General Dynamics' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, General Dynamics' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

94. Without a license or permission from Plaintiff, Defendant HP infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer devices, such as the Pavillion, HDX, TouchSmart, EliteBook, ProBook, Compaq, Compaq Presario, and Mini series of laptops, notebook PCs, and tablet PCs (e.g., Mini 110 XP, Compaq Presario CQ60Z, G60t, Pavilion dv6z, HDX 16t Premium, and TouchSmart tx2z). HP's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, HP's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

95. Without a license or permission from Plaintiff, the Huawei Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the HG, MT, and BM series of routers (e.g., HG520s, HG522, HG527a, MT841, BM635, BM625, and BM325). The Huawei Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Huawei Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

96. Without a license or permission from Plaintiff, the Lenovo Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the IdeaPad, ThinkPad, and Value Line G series of laptops, netbooks, and tablets (e.g., IdeaPad S10, the ThinkPad R500, and Value Line G530). The Lenovo Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Lenovo Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

97. Without a license or permission from Plaintiff, Defendant Lexmark infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the Z, X, C and E series of printer and multifunction products (e.g., Z2420, X3385, C544DW, and E460DW). Lexmark's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Lexmark's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

98. Without a license or permission from Plaintiff, Defendant Motorola infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the MotoZine ZN5. Motorola's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Motorola's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

99. Without a license or permission from Plaintiff, Defendant Netgear infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the MBR, WNR, WNMR, WPN, WGT, WGR, DG, DGN, DGNB, DGB, CG,

and RP series of routers and gateways. Netgear's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Netgear's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

100. Without a license or permission from Plaintiff, the Nintendo Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, such as the Wii and DS series of video game consoles and portable video game consoles. The Nintendo Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Nintendo Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

101. Without a license or permission from Plaintiff, the Nokia Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the E and N series (e.g., E66 and N85). The Nokia Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Nokia Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

102. Without a license or permission from Plaintiff, the Novatel Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the MiFi series (e.g., MiFi 2200 and MiFi 2352). The Novatel Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Novatel Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

103. Without a license or permission from Plaintiff, the Option Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the Globesurfer series of routers (e.g., Globesurfer III and Globesurfer X1). The Option Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Option Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

104. Without a license or permission from Plaintiff, Defendant Palm infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the Prē, Centro, and the Trēo Pro. Palm's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Palm's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

105. Without a license or permission from Plaintiff, the Panasonic Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the Toughbook series of mobile computers and laptops (e.g., Toughbook F8, Toughbook T8, Toughbook W8, Toughbook 52, Toughbook 74, Toughbook 19, Toughbook 30, Toughbook U1, and Toughbook H1). The Panasonic Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Panasonic Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

106. Without a license or permission from Plaintiff, the Sharp Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer

products, such as the Actius and Widenote series of notebooks. The Sharp Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Sharp Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

107. Without a license or permission from Plaintiff, the Sierra Wireless Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the AirLink series of modems and routers (e.g., AirLink MP 595W, AirLink MP 880W, AirLink MP 881W, AirLink Helix RT, and AirLink Junxion Box). The Sierra Wireless Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Sierra Wireless Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

108. Without a license or permission from Plaintiff, the Sony Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer products, such as the VAIO series of notebooks (e.g., VAIO P, Π, Z, SR, CS, NW, FW, and AW series) and the PlayStation® Portable game consoles, also known as PSP. The Sony Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Sony Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

109. Without a license or permission from Plaintiff, the Sony Ericsson Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the XPERIA™ X1, and the W and C series (e.g., W995a and C905a). The Sony Ericsson Defendants' infringement of the '338 Patent has

caused substantial damage to Plaintiff. On information and belief, the Sony Ericsson Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

110. Without a license or permission from Plaintiff, the Toshiba Defendants infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including portable computer devices, such as the Satellite, Satellite Pro, Tecra, Qosmio, Protégé, and "mini" series of laptops (e.g., Satellite U500, Satellite Pro U400, Tecra M10, Qosmio X305, Protégé A600, and mini NB205). The Toshiba Defendants' infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, the Toshiba Defendants' infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

111. Without a license or permission from Plaintiff, Defendant UTStarCom infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless communications devices, such as the F1000G and F3000. UTStarCom's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, UTStarCom's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

112. Without a license or permission from Plaintiff, Defendant Xerox infringed the '338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including printing and imaging products, such as the Phaser series of printer and multifunction products (e.g., Phaser 6130). Xerox's infringement of the '338 Patent has caused substantial damage to Plaintiff. On information and belief, Xerox's infringement of the '338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

113. Without a license or permission from Plaintiff, the ZTE Defendants infringed the ‘338 Patent by importing, making, using, offering to sell, and/or selling products and devices which embody the patented invention, including wireless networking devices, such as the ZXV10 series of routers (e.g., ZXV10 H108N, ZXV10 H211, ZXV10 H201, ZXV10 H260, ZXV10 I20X, ZXV10 W300B, and ZXV10 H108N). The ZTE Defendants’ infringement of the ‘338 Patent has caused substantial damage to Plaintiff. On information and belief, the ZTE Defendants’ infringement of the ‘338 Patent was willful and deliberate, entitling Plaintiff to enhanced damages and attorneys fees.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff prays for relief as follows:

A. For a judgment declaring that each Defendant infringed at least one claim of the ‘497 Patent.

B. For a judgment awarding Plaintiff compensatory damages as a result of each Defendant’s infringement of the ‘497 Patent, together with interest and costs, and in no event less than a reasonable royalty.

C. For a judgment declaring that each Defendant’s infringement of the ‘497 Patent has been willful and deliberate.

D. For a judgment awarding Plaintiff treble damages and pre-judgment interest under 35 U.S.C. § 284 as a result of each Defendant’s willful and deliberate infringement of the ‘497 Patent.

E. For a judgment declaring that each Defendant infringed at least one claim of the ‘338 Patent.

F. For a judgment awarding Plaintiff compensatory damages as a result of each Defendant’s infringement of the ‘338 Patent, together with interest and costs, and in no event less than a reasonable royalty.

G. For a judgment declaring that each Defendant’s infringement of the ‘338 Patent has been willful and deliberate.

H. For a judgment awarding Plaintiff treble damages and pre-judgment interest under 35 U.S.C. § 284 as a result of each Defendant's willful and deliberate infringement of the '338 Patent.

I. For a judgment declaring that this case is exceptional as to each Defendant and awarding Plaintiff its expenses, costs, and attorneys fees, against each Defendant, under 35 U.S.C. § 285.

J. For a grant of permanent injunction pursuant to 35 U.S.C. § 283, enjoining each Defendant from further acts of infringement.

K. For such other and further relief as the Court deems just and proper.

JURY DEMAND

Plaintiff demands a trial by jury of all matters to which it is entitled to trial by jury pursuant to Fed. R. Civ. P. 38.

Dated: September 2, 2009

Respectfully submitted,

/s/Andrew Choung

Tae H. Kim
Andrew Choung
ECHELON LAW GROUP, PC
150 Spear Street, Suite 825
San Francisco, CA 94105
(T) (415) 830-9462
(F) (415) 762-4191

Adrian M. Pruetz
Erica J. Pruetz
PRUETZ LAW GROUP LLP
200 N. Sepulveda Blvd., Suite 1525
El Segundo, California 90245
(T) (310) 765-7650
(F) (310) 765-7641

K. Kevin Mun
ECHELON LAW GROUP, PC
1919 Gallows Road, Suite 330
Vienna, Virginia 22182
(T) (703) 496-5000
(F) (703) 579-0105

Attorneys for Plaintiff WIAV Networks, LLC

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(54) **METHOD AND APPARATUS FOR MAXIMIZING DATA THROUGHPUT IN A PACKET RADIO MESH NETWORK**

(75) Inventors: **George Henry Flammer, III**, Cupertino; **Curtis Bradford**, Los Gatos, both of CA (US)

(73) Assignee: **Ricochet Networks, Inc.**, Denver, CO (US)

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(52) **U.S. Cl.** **370/400**; 370/252; 370/278
(58) **Field of Search** 370/230, 235, 370/252, 276, 278, 280, 281, 294, 295, 310.2, 319, 320, 321, 328, 332, 336, 400, 465; 375/133, 135, 136; 455/24, 226.1

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Sampei et al., "Adaptive Modulation/TDMA with a BDDFE for 2Mbp/s Multi–Media WireLess Communication Systems," *IEEE VTC'95*, pp. 311–315 (Jul. 1995).

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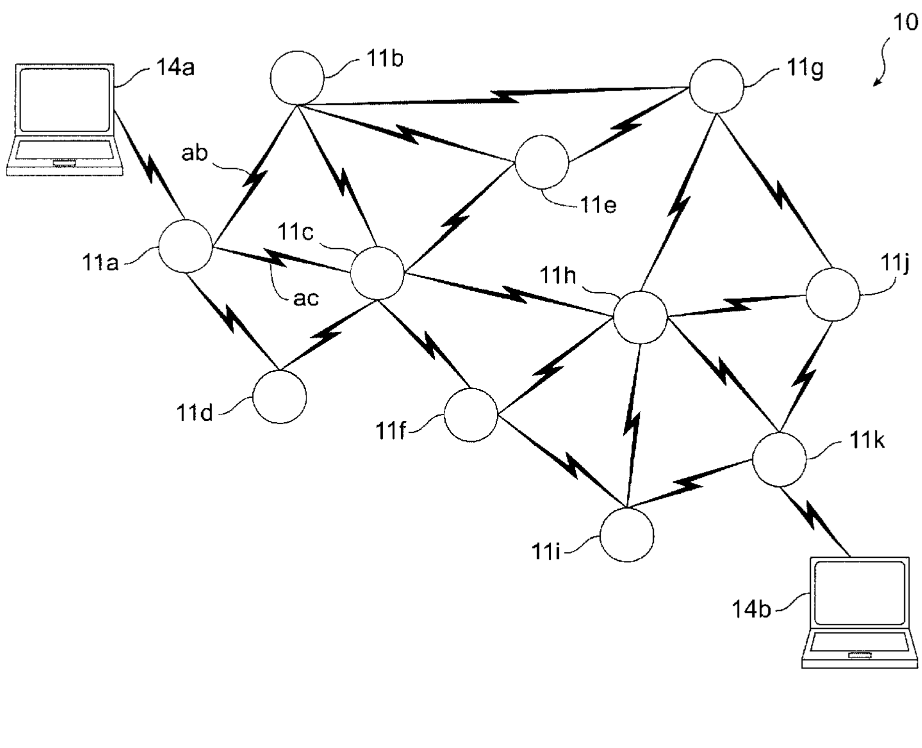
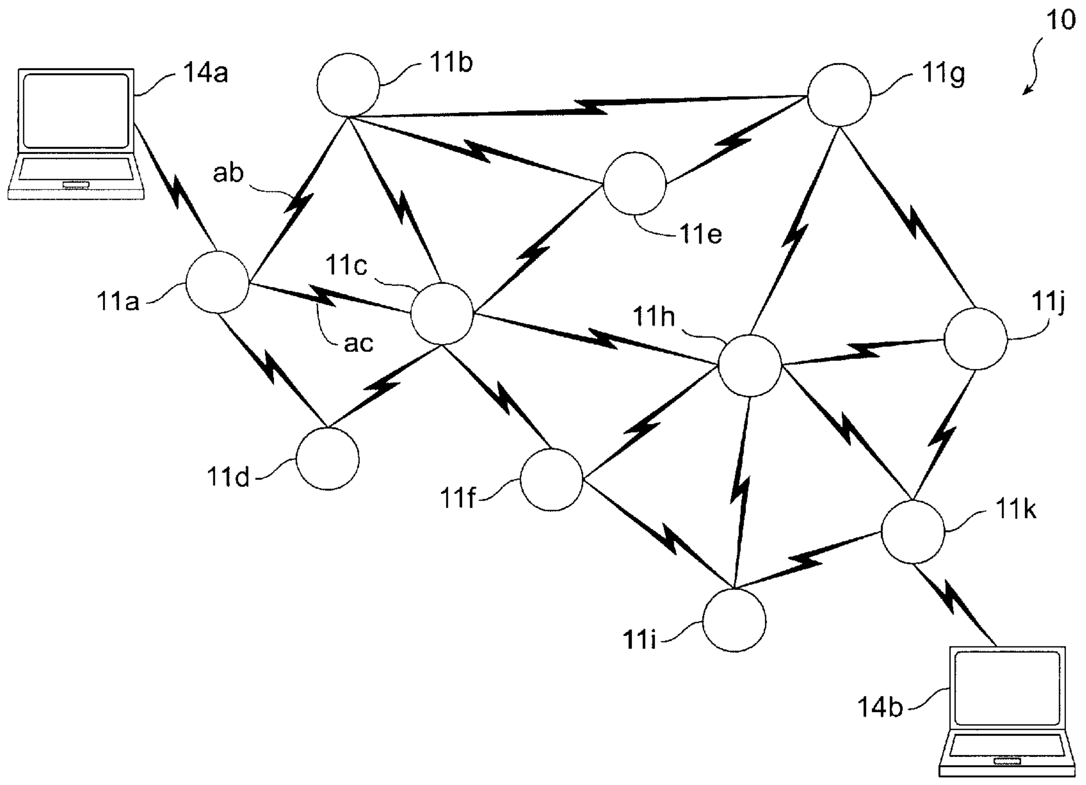
Primary Examiner—Kwang Bin Yao
Assistant Examiner—Frank Duong

(57) **ABSTRACT**

In a mesh network communication system, net throughput is optimized on the link between the communicating nodes by dynamically modifying signal characteristics of the signals transmitted between nodes in response to performance metrics which have been determined from analysis at the receivers for the corresponding links. The signal characteristics can be the data rate, modulation type, on-air bandwidth, etc. The performance metrics are calculated based on data-link on-air characteristics of received signals.

28 Claims, 3 Drawing Sheets




10
14a
11b
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11e
11c
11a
ac
11h
11j
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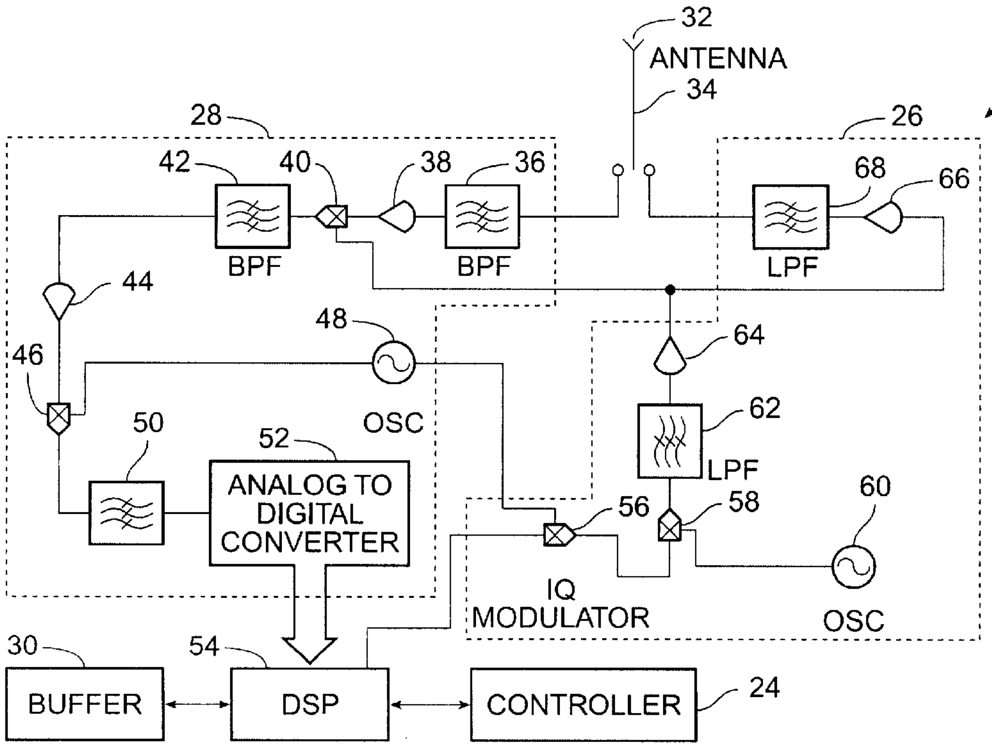
11f
11k
11i
14b

FIG. 1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20
28
26
42
40
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36
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66
BPF
BPF
LPF
44
48
64
46
OSC
62
50
52
ANALOG TO DIGITAL CONVERTER
LPF
60
56
58
IQ MODULATOR
OSC
30
54
BUFFER
DSP
CONTROLLER
24

FIG. 2

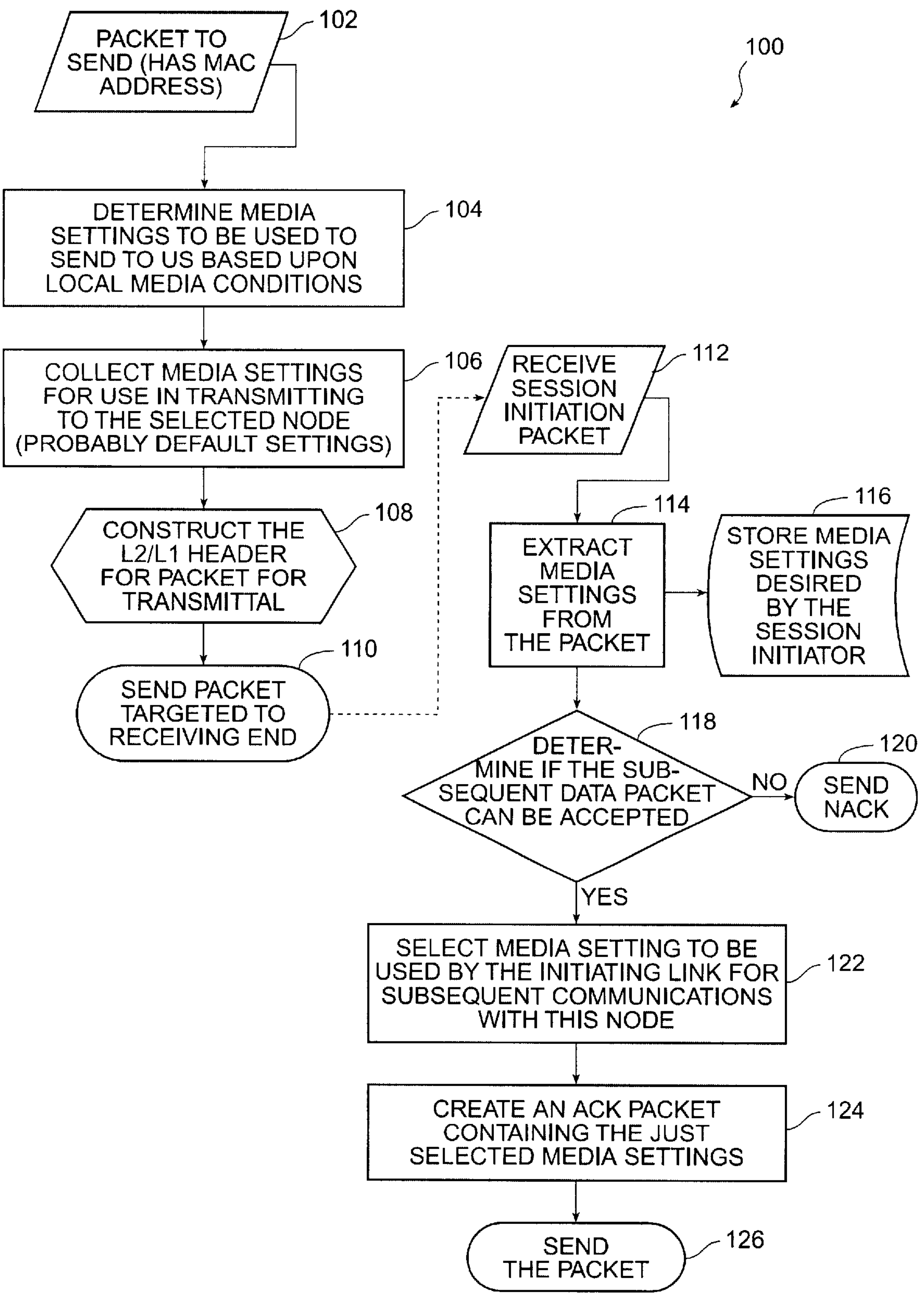
100
PACKET TO SEND (HAS MAC ADDRESS)
102
DETERMINE MEDIA SETTINGS TO BE USED TO SEND TO US BASED UPON LOCAL MEDIA CONDITIONS
104
COLLECT MEDIA SETTINGS FOR USE IN TRANSMITTING TO THE SELECTED NODE (PROBABLY DEFAULT SETTINGS)
106
CONSTRUCT THE L2/L1 HEADER FOR PACKET FOR TRANSMITTAL
108
SEND PACKET TARGETED TO RECEIVING END
110
RECEIVE SESSION INITIATION PACKET
112
EXTRACT MEDIA SETTINGS FROM THE PACKET
114
STORE MEDIA SETTINGS DESIRED BY THE SESSION INITIATOR
116
DETER-MINE IF THE SUB-SEQUENT DATA PACKET CAN BE ACCEPTED
118
NO
SEND NACK
120
YES
SELECT MEDIA SETTING TO BE USED BY THE INITIATING LINK FOR SUBSEQUENT COMMUNICATIONS WITH THIS NODE
122
CREATE AN ACK PACKET CONTAINING THE JUST SELECTED MEDIA SETTINGS
124
SEND THE PACKET
126

FIG. 3

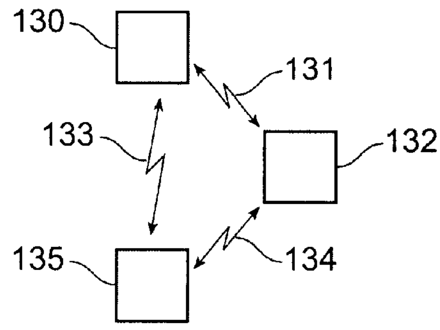

FIG. 4

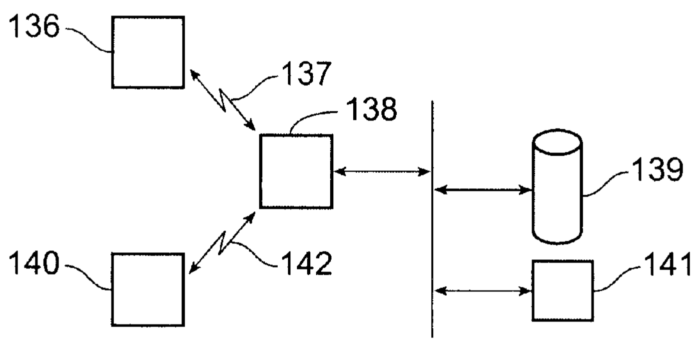

FIG. 5

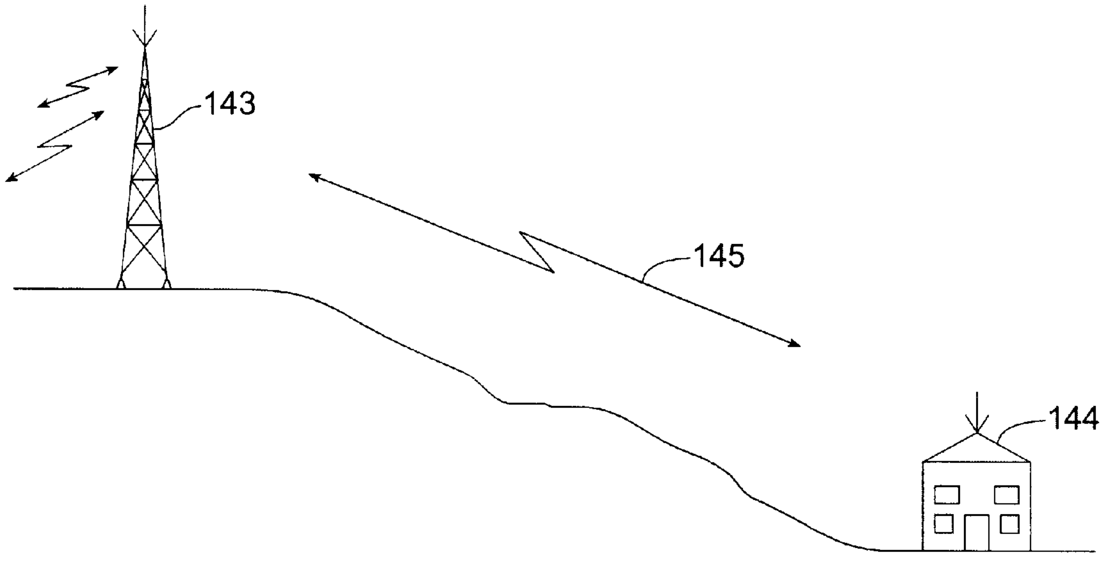

FIG. 6

METHOD AND APPARATUS FOR MAXIMIZING DATA THROUGHPUT IN A PACKET RADIO MESH NETWORK

BACKGROUND OF THE INVENTION

This invention relates to packet communications in a radio-based mesh network, and in particular to techniques for improving throughput of packets via such a network.

In a mesh network, there is an collection of nodes which autonomously connect, send, receive, forward and analyze packetized traffic in the network, which is a shared resource having limitations on traffic capacity. There is a need to optimize performance throughput to the greatest number of users in the network. Heretofore, the nodes have been able to develop performance metrics about themselves and their neighboring nodes which can prove useful in developing throughput improvement schemes. Due to a large installed base of nodes, it is important that new nodes be made backwards compatible with previously installed nodes so that the older nodes are not rendered inoperable.

Mesh packet radio networks are used throughout the world to provide data communication between nodes. These networks are one of several type of data communication network architectures (the other major types being star (e.g., conventional wireline and cellular) and bus (e.g., computer backplane and cable television) and have several advantages over other architectures for providing high capacity data communication over a large area and to a large number of users.

When known radio mesh networks communicate, the radios use a single data rate among all radio that can communicate. There are at least two reasons for using a single data rate:

Hardware simplicity. If the modulation and demodulation hardware operates at but one data rate, it is often much easier and less expensive to implement.

Protocol simplicity. A broadcast on-air protocol supporting only a single data rate is much simpler to design and implement than one intending to coordinate multiple data rates (and, sometimes equivalently, occupied bandwidth) among a plurality of communicating nodes.

Use of a single data rate has permitted implementation of several successful networks, e.g. Metricom's Ricochet data communication network. These networks occupy a spectra, collect, transport and deliver packets at an acceptable level of performance. This level of performance is in many respects limited by the speed of the constituent links. Extending the performance of these types of networks is the subject of continuing development efforts; this invention teaches the results of one such effort.

Technologies from other environments are known which have been considered as useful in developing solutions to the problems hereinabove described. For example, there are modulation techniques previously considered for PCS radio systems, as in Ue et al., Symbol Rate and Modulation Level Controlled Adaptive Modulation/TDMA/TDD for Personal Communication Systems, IEEE VTE, July 1995, pp. 306–310 (0-7803-3742-X/95). Therein the concern was mainly to combat delay spread, which is the temporal distortion in the time of arrival of a particular bit or symbol of information. The function was to estimate the channel based upon conditions at the transmitter.

Seiichi Sampei, Norihiko Morinaga, and Yukiyoshi Kamio, Adaptive Modulation/TDMA with a BDDFE for 2 Mbp/s Multi-Media Wireless Communication Systems, IEEE VTC'95, July 1995, pg. 311–315. This reference describes a technique whereby a modulation scheme is chosen based upon estimates by or at the transmitter which then "sends" the link to a channel preselected to support that modulation scheme.

Patents uncovered during the course of research include the following.

U.S. Pat. No. 5,048,054 to Eyuboglu, et. al. issued Sep. 10, 1991 entitled Line Probing Modem and assigned to Codex Corporation describes an adaptive modem which probes both ends of a link.

U.S. Pat. No. 5,557,644 to Kuwabara issued Sep. 17, 1996 entitled Signal Demodulating and Decoding Apparatus and Signal Demodulating and Decoding Method and assigned to Hitachi, Ltd. describes parallel demodulators.

U.S. Pat. No. 5,490,168 to Phillips, et. al. issued Feb. 6, 1996 entitled Method and System for Automatic Optimization of Data Throughput Using Variable Packet Length and Code parameters and assigned to Motorola, Inc. describes modification of the packet length with changing channel characteristics, with the two "predetermined" coding rates, using varying packet length, as well as a method for transitioning the receiving and transmitting ends of the link from the "efficient" packet to the more "robust" (i.e., shorter) packet, and changing between the predetermined coding rates and packet lengths. An alternative includes transitioning from the shorter packets to the longer packets, using counts of the channel errors to change the length of the packets and their related coding rates.

U.S. Pat. No. 5,150,368 to Autruong, et. al. issued Sep. 22, 1992 entitled Minimization of Modem Retransmissions originally assigned to Rolm Systems (now part of Siemens) describes selective retransmission (BEC) with bitwise voting to reach a valid checksum.

U.S. Pat. No. 5,425,051 to Mahany issued Jun. 13, 1995 entitled Radio Frequency Communication Network Having Adaptive Parameters and assigned to Norand Corporation (Cedar Rapids, Iowa) describes an adaptive RF network. U.S. Pat. No. 5,548,821 to Coveley issued Aug. 20, 1996 entitled Adaptive System for Self-Tuning and Selecting a Carrier Frequency in a Radio Frequency Communication System describes an automatic frequency control technique.

Patents uncovered in a survey of keywords include: U.S. Pat. No. 5,432,818 issued Jul. 11, 1995 to Yuang Lou entitled Method and Apparatus of Joint Adaptive Channel Encoding, Adaptive System Filtering, and Maximum Likelihood Sequence Estimation Process by Means of an Unknown Data Training; and U.S. Pat. No. 5,448,593 issued Sep. 5, 1995 to Lawrence Hill, assigned to Cyplex Corporation, entitled Frequency Hopping Time-diversity Communications Systems and Transceivers for Local Area Networks. This patent describes power line carrier communication which uses modulation of frequency pairs selected from sets of pairs. Both ends communicate using the same modulation scheme.

Reference is also made to the prior work of the current inventors, such as Method and System for Routing Packets in a Packet Communication Network Using Locally Constructed Routing Tables, U.S. Pat. No. 5,488,608 issued Jan. 30, 1996; and Method for Routing Packets by Squelched Flooding, U.S. Pat. No. 5,007,052 issued Apr. 9, 1991.

SUMMARY OF THE INVENTION

According to the invention, net throughput is optimized on the link between the communicating nodes by dynamically modifying signal characteristics of the signals transmitted between nodes in response to performance metrics which have been determined from analysis at the receivers for the corresponding links. The signal characteristics can be the data rate, modulation type, on-air bandwidth, etc. The performance metrics are calculated based on data-link on-air characteristics of received signals.

In one embodiment, the performance metrics are based upon the historical information about the link that are available at the affected nodes. Each node in the radio network continually collects information regarding measurable on-air characteristics (or specific parameters) while retaining information regarding categories of interference to received packets. The node collects and retains these data both on a per-link and per transmission (specific packets sent and received from a specific node) and a locality-specific basis.

The communication between two nodes has signal characteristics that affect the performance metrics. These signal characteristics include data rate, packet length, modulation type, forward error correction, backwards error correction, bit-wise interleaving, frequency channel selection, power level, block size and/or computational complexity. Probability information can be gathered as a performance metric, such as, a probability of successful transmission between the two nodes, a probability of a bit error in the communication upon receipt at a receiving node, a probability of a packet error in the signal at the receiving node, and a signal strength of the signal at the receiving node. In one embodiment, the data rate of the signal transmitted between the nodes is dependent on a required link signal strength. Some embodiments could communicate between the nodes using spread spectrum transmission.

The optimization is achieved by providing dynamically-varying data rate, modulation techniques, occupied bandwidths, etc., on a per-link basis using intelligent (computer-controlled) radio hardware. The intended receiver dynamically adapts to the signal being received. In one embodiment, the receiver adapts by sensing data rate through a start sequence delivered with each packet where adaptive operation is required.

This start sequence is transmitted with each packet from the transmitting node. The receiving node senses the start sequence of each packet sent to the receiving node. Interpretation of each packet can be adjusted in response to the start sequence in order to adapt to the received signal. For example, the start sequence could indicate a particular modulation technique where the receiving node dynamically adapts to the particular modulation technique indicated by the start sequence.

When a mesh network is created using dynamically varying links according to the invention, the resultant system delivers the highest performance capable of being supported given the topology and propagation extant at the time of the transmission. This variability is designed to be exploited on a per-link basis. This means that a given radio might use a lower data rate for transmitting on a link from, for example, Node A to Link B (Link A=>B) while using a higher data rate for transmitting on another link such as from Node A to Node C (Link A=>C). Additionally, Node B may (and will often) use a different data rate when communicating back to Node A (Link B=>A). Since each radio is capable of several different data rates, each can select the speed that will probabilistically provide the highest net speed.

The foregoing, together with other objects, features and advantages of this invention, will become more apparent when referring to the following specification, claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a mesh network illustrating nodes having a plurality of data rate capabilities in accordance with the invention.

FIG. **2** is a detailed block diagram of a typical node with transmitter(s), receiver(s), buffer storage and control elements.

FIG. **3** is a flow chart illustrating the control function of the control elements.

FIG. **4** is a block diagram for illustration of one networking scenario.

FIG. **5** is a block diagram for illustration of an alternative networking scenario.

FIG. **6** is a block diagram for illustration of still further networking scenarios.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, there is shown a block diagram of a mesh network **10** illustrating nodes A, B, C, D, E, F, G, H, I, J, K numbered **11***a*–**11***k*, respectively. In accordance with the invention, each node **11** has capabilities for transmitting to and receiving from various other nodes **11** at one of a plurality of data rates in each direction. In such a network **10**, an interconnected mesh of data-packet sending and receiving nodes is collectively collecting, routing and delivering data packets.

The network **10** has a controller **24** at each node **11** (see FIG. **2**). Initially, each node **11** (for example, Nodes A and B) operates at a default data rate in order to establish a pair of links, such as Link A=>B and Link B=>A. Each controller-controlled radio-based node **11** monitors traffic and the success of traffic, as indicated by repetitions, information on lost packets, and the like, and constantly develops performance metrics between itself and other regularly-linked nodes. Each node **11** may then optionally and dynamically vary one or more signal characteristics of signals transmitted to other nodes **11** on a per-link basis to maintain the highest possible network speed. For example, the node **11** can vary the transmit data rate and/or the transmission-occupied bandwidth. It should be noted that the links may, but need not, share the same spectrum or time slot, in a time slotted or frequency hopping network.

Referring to FIG. **2**, there is shown a detailed block diagram of a typical transceiver **20** within each node **11**. Transceiver **20** comprises transmitter(s) **26**, receiver(s) **28**, buffer storage **30** and a controller **24**. Signals from one link are received on an antenna **32** and routed through a hybrid or switch **34** to a bandpass filter **36**. The filtered signal from filter **36** is amplified by buffer amplifier **38** and provided to IF converter **40**. The output of the IF converter **40** is provided to another bandpass filter **42** and the filtered output is provided to an amplifier **44**. The output of amplifier **44** is provided to a mixer **46** which is controlled by a local oscillator **48**. The downconverted signal from mixer, **46** is provided to a further bandpass filter **50** and the filtered output is provided to an analog to digital converter **52**. The digital output of converter **52** is provided to a DSP processor **54**.

The DSP processor **54** extracts the information and passes the control data to the controller **24**. The information can be stored in buffer storage **30** which is connected to the DSP processor **54**. The controller **24** in turn, among other tasks, provides the collection, analysis and storage of the performance metrics of the node. The controller **24** further instructs the DSP processor **54** to assemble outbound packets with the proper signal characteristics (e.g., the bit rate, packet length, frequency and bandwidth) suited for the link to which it is to be applied.

The outbound packets from DSP processor **54** are provided to an IQ modulator **56** which is under control of the oscillator **48**. The modulated signal from modulator **56** is provided to a mixer **58** which is under control of a local oscillator **60**. In frequency-agile embodiments, the frequency of oscillator **60** is typically chosen on a time slot or on a packet by packet basis.

Output of mixer **58** is provided to a lowpass filter **62** (which might alternatively be a bandpass filter) and the filtered output is provided to a buffer amplifier **64**. The output of amplifier **64** is provided to amplifier **66**. The output of amplifier **66** is provided to an output bandpass/lowpass filter **68**, through the switch **34** and transmitted from the antenna **32**. The output of amplifier **64** is also provided as an input to IF converter **40** for the purpose of providing a precise Local Oscillator (LO) signal to multiply with the received signal resulting in a baseband signal for the DSP processor.

During the receive interval, the received signal enters each node via antenna **32** through transmit-receive switch **34**. It then is routed through a first bandpass filter **36** and receive preamplifier **38**. At a first mixer **40**, the amplified and filtered receive signal is mixed with a local oscillator (LO) signal which was generated by oscillator **60**. The intermediate frequency (IF) product of the two signals is passed through second bandpass filter **42**, again amplified at second amplifier **44** and presented to a second receive mixer **46**. At this mixer, it is multiplied by a second local oscillator **48** to create a baseband signal which, after passing through a further lowpass filter **50**, it is presented to an Analog-to-Digital (A/D) converter **52** which converts the analog signal to a stream of digital words representing its amplitude variations over time.

The digital stream is processed by the Digital Signal Processor (DSP) unit **54** under control of a controller **24** to extract the transmitted information it carries. Since the data are sent in short sequences known as "packets", the DSP unit **54** further processes the signal to determine the extent of each packet, which it stores in a shared memory buffer **30**. Here the packet and its attendant media-specific information (e.g., packet signal strength, data rate, etc.) are available for other, higher layer processes within the node **11**.

Referring to FIG. **3**, there is shown a flow chart **100** illustrating the sequence to be performed to during the initiation phase of communication between two nodes. Initially, at block **102**, a transmitting node has an initiation packet to send to a receiving node within the network. The initiation packet comprises a Media Access Contention (MAC) address which allows the transmitting node to determine the identity of the receiving node. At block **104**, the transmitting node determines the media settings, (i.e., the transmit parameters such as modulation type, which may be QPSK or 16 QAM, for example, channel (frequency), symbol rate, and codings (such as FEC or Reed-Solomon)) to be used to send the packet based upon local media conditions. At block **106**, the transmitting node determines the media settings to use in transmitting the packet to the selected receiving node. Again, the media settings are selected based upon local media conditions, which are known at the transmitting node, of the link to the receiving node. However, since the local media conditions are not known initially, the transmitting node uses the default settings. At block **108**, the transmitting node constructs the L2/L1 header for the data packet for transmittal. The L1 header contains information about the physical (e.g. L1) layer of the packet processing. It contains the signal strength of the received packet, its length (in bytes), the time of arrival and the port it came in (or is due to go out on). The L2 Header contains information required to assure that correct and ordered packets can be presented to the next higher layer (L3, the routing layer). The L2 header consists of the MAC address of the destination and source and some control fields for communication between the L2 entities at each end of the link. Finally, at block **110**, the transmitting node sends the packet targeted to the receiving node.

The receiving node receives the session initiation packet at block **112**. At block **114**, the media settings are extracted from the packet. The session initiator within the receiving node stores the desired media settings at block **116**.

At block **118**, the receiving node determines if the subsequent data packet can be accepted. If the data packet cannot be accepted, a negative acknowledgment (NACK) packet is transmitted back to the transmitting node to indicate this condition, at block **120**. Otherwise, the receiving node selects the media settings to be used by the initiating link (from the transmitting node to the receiving node) for subsequent communications with this transmitting node, at block **122**. The receiving node then creates an acknowledgment (ACK) packet that contains the just selected media settings, at block **124**. The receiving node then sends the ACK packet to the transmitting node, at block **126**. Upon receiving the ACK packet, the transmitting node extracts the media settings for use in future transmission to the receiving node. At this point, each end of the dual link has received the media settings to use when communicating with the other end of the link.

Referring to FIG. **4**, an alternative embodiment is disclosed. A node **130**, having analytically or algorithmically determined the media parameters which perform best (deliver the highest performance or reliability) at its location, delivers the parameters across a link **131** to a media parameter repository **132**. This repository **132** holds media parameters for all nodes **11** within single hop range. It may then either deliver these parameters to the intended destination node **135** over link **134** or it may respond to a query form node **135** with the desired parameters.

Referring to FIG. **5**, a third alternate embodiment uses an online database to store media parameters for, potentially, the entire network. In this embodiment, any node **136** can, after determining the preferential media parameters for its location, send these parameters to a database computer **138** which then stores these data in a long term memory **139** for retrieval by any or all. Having a single location containing the media information for all nodes in the network simplifies network software and provides a secure storage location. Additionally, performance monitoring software running on workstations **141** can access immediate and historical media parameters to spot trends and developing network performance problems.

Optimization of the throughput of the network can be achieved by dynamically modifying the signal characteristics of signal transmitted between nodes. Specifically, since the signal characteristic which is typically modified is bit rate, modification of this parameter affects the complexity and/or bandwidth of the transmitted signal. Bit rate is defined as the number of information bits per second transmitted over the link. Complexity is the amount of computation required to create the modulated signal and to demodulate it upon reception. And bandwidth is the amount of spectrum the signal occupies during an arbitrary time duration. The complexity and bandwidth are the determining factors in the probability of a successful transmission on a link: the faster the bit rate, the lower the probability of success, with other factors, such as noise and power, being unchanged.

Each node in the radio network continually collects information regarding measurable on-air parameters while retaining information regarding categories of interference to received packets. The node collects and retains these data both on a per-link (specific packets sent and received from a specific node) and a locality-specific basis. Carrying these data entails at least two costs: the costs of the local memory to store the information until it collectively obtains statistical validity, and the protocol costs of making sure that the modulation, bitspeed, error correcting codes and decisions being made by the nodes use valid (current) data.

To illustrate how the media parameters are calculated; the following two examples are presented. Referring to FIG. **6**, there are two radio locations: One is located on a hill or other propagationally-favorable location **143** and is within range of a number of nodes, including node **144**. Node **144** is located for illustration purposes on the roof of a building near a potential network user. The building is not located favorably to many other radios and thus may well depend upon node **143** for its network connectivity. Moreover, the local conditions for reception of signals will vary greatly between the two locations, **143** and **144**. At node **143**, since it is within range of a large number of nodes (not illustrated) it is subject to interference from unintended reception of other's signals. Node **144**, on the other hand, enjoys the relative quiet in its sheltered location. Clearly, since the conditions for optimal reception differ between site **143** and site **144**, the network throughput would be optimized by selecting the highest speed transmission that historical statistics predict will be received at each end of the link **145**. With this (not unlikely) scenario in mind, and with the additional information that communication between the node is possible at the slower "default" speeds, Node **143** would convey to Node **144** the results of its analysis of packets received (both successfully and unsuccessfully) by itself. In this scenario, analysis would indicate that, since the link **145** is short and signal levels are high, the optimal media parameters are very high speed (and thus short packets) but with a high degree of redundancy (to combat the large number of packet "collisions" node **143** is experiencing). In this case, the proper redundancy to add to the packet is called "block coding". Block coding can dramatically lengthen the packet and thus the transmission time, but permits recovery of the whole packet even if some part of it is damaged by simultaneous reception of another signal. Conversely, Node **144** requires no such expensive coding and therefore informs node **143** that such coding is unnecessary.

A second example of the use of this method can again be illustrated by referencing FIG. **6**. Assume Node **144** is located atop a factory with a large amount of machinery. Many times such machinery generates static or shot noise of very short duration but of high amplitude. In such a case, having performed "packet autopsies" on received packets and determined that the type of errors are 'single bit or single symbol' errors, Node **144** would inform communicating nodes (e.g. node **143**) to use a different kind of coding with their packets, a coding technique called "interleaving" where single bit errors can be repaired.

These examples illustrate the degree of control the receiving node in a link can have. In a distributed network, each node has the best and most immediate information regarding the potential for data throughput to its location. Through the method and using the apparatus taught in this patent, each link can be optimized very rapidly as packet success and signal speed information is instantaneously incorporated into the on-air signal parameters use on the affected links. Each packet exchanged potentially has a field for the communication of the best on-air parameters to be used in the very next transmission. The method is very general in its application to semi-autonomous nodes communicating within a data communications network.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. In a mesh network communication system capable of dynamically establishing links between communicating nodes, a method for optimizing net throughput on a link from a first node to a second node, the method comprising steps of:

dynamically establishing the link between the first node and the second node with a first signal, wherein:

the first and second nodes are part of a mesh network communication system, and

each of the first and second nodes sends, receives, forwards packets with the mesh network communication system;

determining at least one performance metric, at the second node, of data-link on-air characteristics of the first signal from the first node;

relaying information relating to the at least one performance metric from the second node to the first node; and

dynamically modifying at least one signal characteristic of a second signal transmitted from the first node to the second node, wherein the dynamically modifying step is responsive to at least one performance metric.

2. The method of claim **1** wherein the at least one signal characteristic is selected from the set:

data rate, packet length, modulation type, forward error correction, backwards error correction, bit-wise interleaving, frequency channel selection, power level, block size and computational complexity.

3. The method of claim **1** wherein the performance metric is based, in part, on a probability of successful transmission on the link.

4. The method of claim **1** wherein the performance metric is based, in part, on a probability of bit error of the first signal received at the second node.

5. The method of claim **1** wherein the performance metric is based, in part, on a probability of packet error of the first signal received at the second node.

6. The method of claim **1** wherein the performance metric is based, in part, on a signal strength of the first signal received at the second node.

7. The method of claim **1** wherein the performance metric is based on historical information about the link.

8. The method of claim **1** wherein the performance metric is based on statistical information about the link.

9. The method of claim **1** wherein a data rate of the signal transmitted from the first node is dependent on a required link signal strength.

10. The method of claim **1** wherein the performance metric is calculated in response to a channel setup message received from the first node.

11. The method of claim **1** wherein the dynamically modifying is performed in accordance with a signal parameter message received from the second node.

12. The method of claim **1** wherein a start sequence is transmitted with each packet from the first node to indicate adaptations for receiving a subsequent packet.

13. The method of claim **12** further comprising:

sensing the start sequence of each packet at the second node; and

adjusting interpretation of each packet responsive to the start sequence in order to adapt to the received signal.

14. The method of claim **1** further comprising:

transmitting the signal by the first node using time division multiplexing.

15. The method of claim **1** further comprising

transmitting the first signal by the first node using spread spectrum transmission.

16. The method of claim **1** further comprising:

transmitting the first signal by the first node using frequency hopping.

17. The method of claim **1** wherein the at least one signal characteristic of the signal is chosen from the group consisting of data rate, modulation and occupied bandwidth.

18. The method of claim **1** wherein information relating to the performance metric is stored away from the first node and the second node.

19. In a mesh network communication system capable of dynamically establishing links between a plurality of communication nodes substantially simultaneously, a method for optimizing net throughput on the links between connected nodes, the method comprising steps of:

dynamically establishing links between the plurality of communication nodes, wherein the mesh network transports communications through a series of the plurality of communication nodes in the mesh network;

determining at least one performance metric of data-link on-air characteristics for each of a plurality of signals received at a plurality of receiving nodes;

relaying information relating to the at least one performance metric of data-link on-air characteristics for each of the plurality of signals to a corresponding plurality of transmitting nodes; and

dynamically modifying at each of the plurality of transmitting nodes at least one signal characteristic for each of the plurality of signals transmitted to the respective plurality of receiving nodes, wherein the modifying step for a particular transmitting node of the plurality of transmitting nodes is responsive to the determining step for a particular receiving node of the plurality of receiving nodes that receives a particular signal sent from the particular transmitting node.

20. The method of claim **19** wherein the data-link on-air signal characteristics are selected from the set:

data rate, packet length, modulation type, forward error correction, backwards error correction, bit-wise interleaving, frequency channel selection, power level, block size and computational complexity.

21. The method of claim **19** wherein the receiving nodes each adaptively modifies the signal characteristics of signal transmitted to the transmitting nodes based on the performance metric calculated by the receiving node for the corresponding transmitting nodes.

22. The method of claim **19** wherein the transmitting nodes transmit through limited bandwidth channels.

23. The method of claim **22** wherein the limited bandwidth channels support selected sets of signal characteristics.

24. The method of claim **19** wherein the performance metric is based on historical information about the link from the transmitting node to the receiving node.

25. The method of claim **24** wherein the performance metric is further based on current information about the link from the transmitting node to the receiving node.

26. The method of claim **19** wherein the transmitting node is co-located with another receiving node, whereby both transmitting and receiving are possible from a single location.

27. In a mesh network communication system capable of dynamically establishing links between communication nodes, a transceiver in each node of the communication system comprising:

a receiver for receiving signals transmitted from at least one other node;

a transmitter for transmitting to at least one other node, wherein all nodes are part of the mesh network communication system capable of dynamically establishing links between communication nodes;

a controller connected to the receiver and the transmitter for computing at least one performance metric based on data-link on-air characteristics for each of selected ones of the received signals; and

wherein the transmitter dynamically modifies signal characteristics of selected ones of the transmitted signal based on performance metrics corresponding to the transmitted signals at respective receiving nodes.

28. In a mesh network wireless communication system having dynamically established links between nodes, a controller in a node of said communication system comprising:

a receiver for receiving inbound data signal from at least one other node, wherein the node and the other node are part of a mesh network wireless communication system having dynamically established links between nodes to transport data through a multitude of nodes in the mesh network wireless communication system;

a transmitter for transmitting outbound data signal to at least one other node;

a demodulator connected to the receiver for demodulating the received signal from the receiver;

means for detecting data rate of the demodulated signal from the demodulator; and

means for controlling data rate of the outbound data signal applied to the transmitter.

* * * * *

US005400338A

United States Patent [19]

Flammer, III

[11] Patent Number: 5,400,338

[45] Date of Patent: Mar. 21, 1995

[54] **PARASITIC ADOPTION OF COORDINATE-BASED ADDRESSING BY ROAMING NODE**

[75] Inventor: **George H. Flammer, III,** Cupertino, Calif.

[73] Assignee: **Metricom, Inc.,** Los Gatos, Calif.

[21] Appl. No.: **193,337**

[22] Filed: **Feb. 8, 1994**

[51] **Int. Cl.**[6] **H04L 12/56;** H04Q 7/00

[52] **U.S. Cl.** **370/94.1;** 379/60; 455/33.2; 455/56.1

[58] **Field of Search** 370/60, 60.1, 94.1, 370/94.2, 94.3, 95.1, 95.3, 54; 379/58, 57, 220, 211, 59, 60; 455/33.1, 54.1, 56.1; 340/825.52, 825.53

[56] **References Cited**

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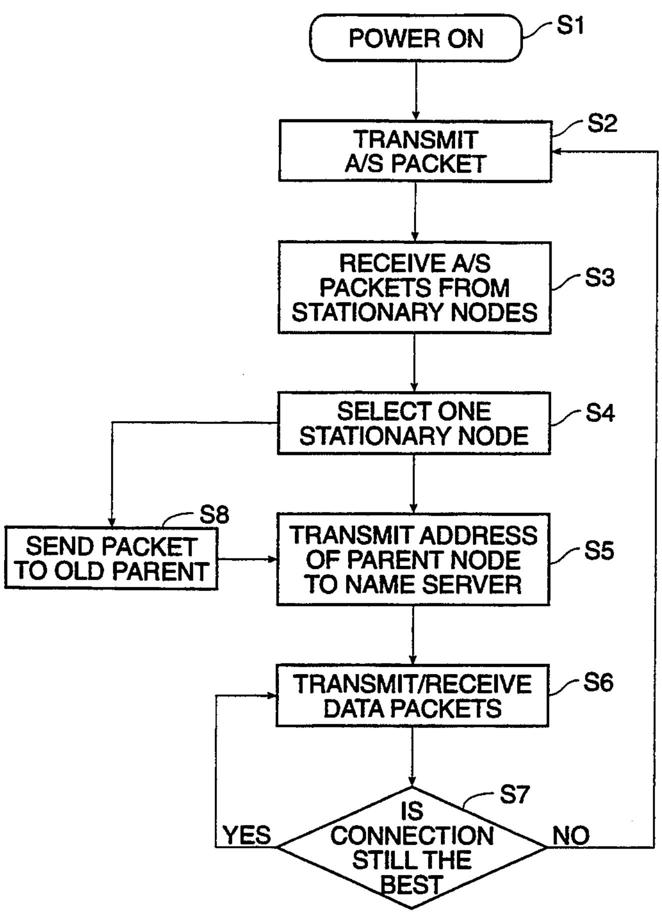
Primary Examiner—Douglas W. Olms
Assistant Examiner—Hassan Kizou
Attorney, Agent, or Firm—Townsend and Townsend Khourie and Crew

[57] **ABSTRACT**

In a packet communication system wherein stationary nodes are assigned an absolute coordinate-based address, the addressing of roaming nodes is accomplished by parasitically adopting a coordinate routing scheme used for addressing stationary nodes. Each roaming node selects a parent stationary node with which the roaming node can communicate directly. During the course of network operation, the roaming node may select a new parent node. At the time of reassignment, the coordinates of the new parent node, along with the identity of the roaming node, is recorded at the former parent node. Forwarding of packets to stationary nodes is accomplished according to a known coordinate-based routing scheme. A packet addressed to a destination roaming node is forwarded and directed through the then current stationary parent node. The packet is then forwarded to the destination roaming node.

6 Claims, 3 Drawing Sheets

Microfiche Appendix Included
(1 Microfiche, 19 Pages)



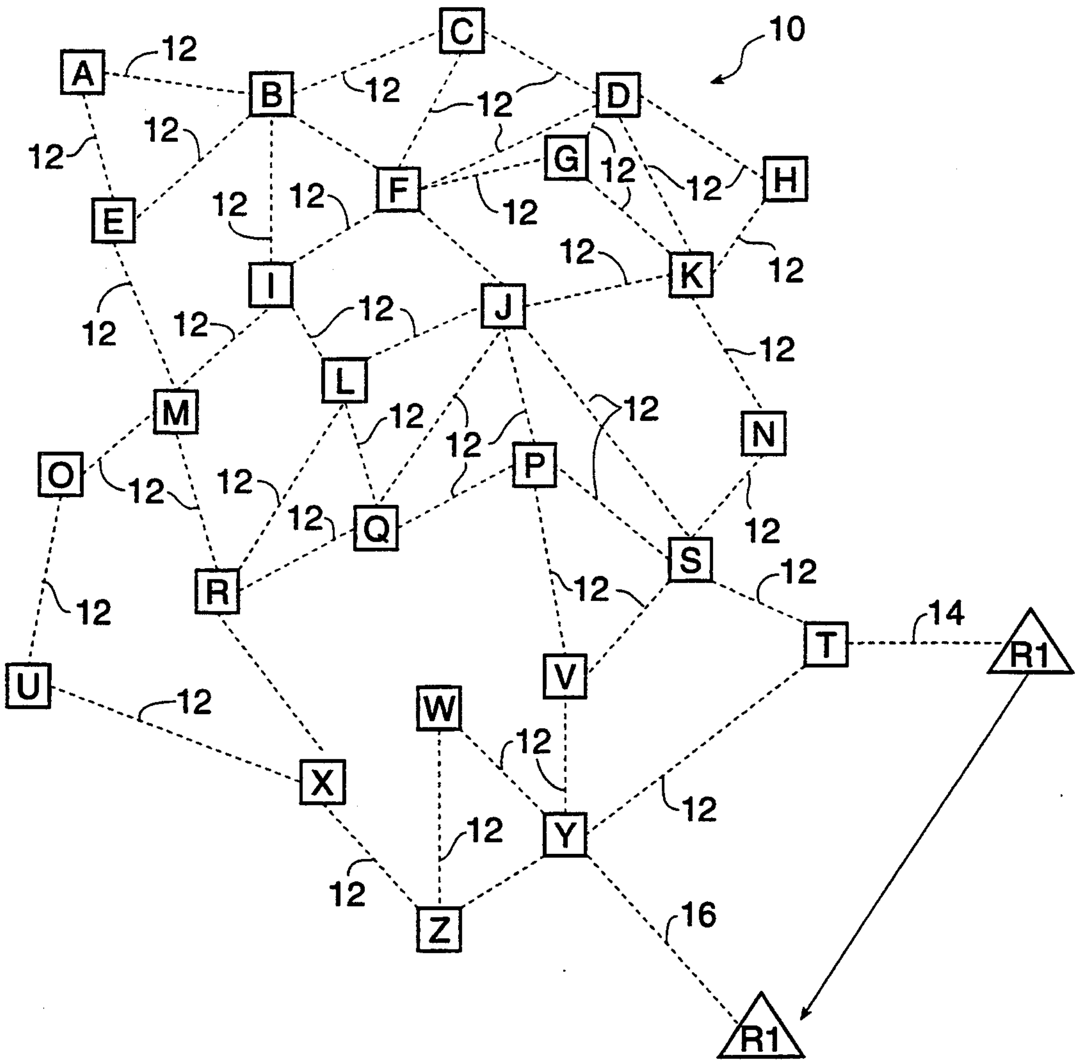


FIG. 1

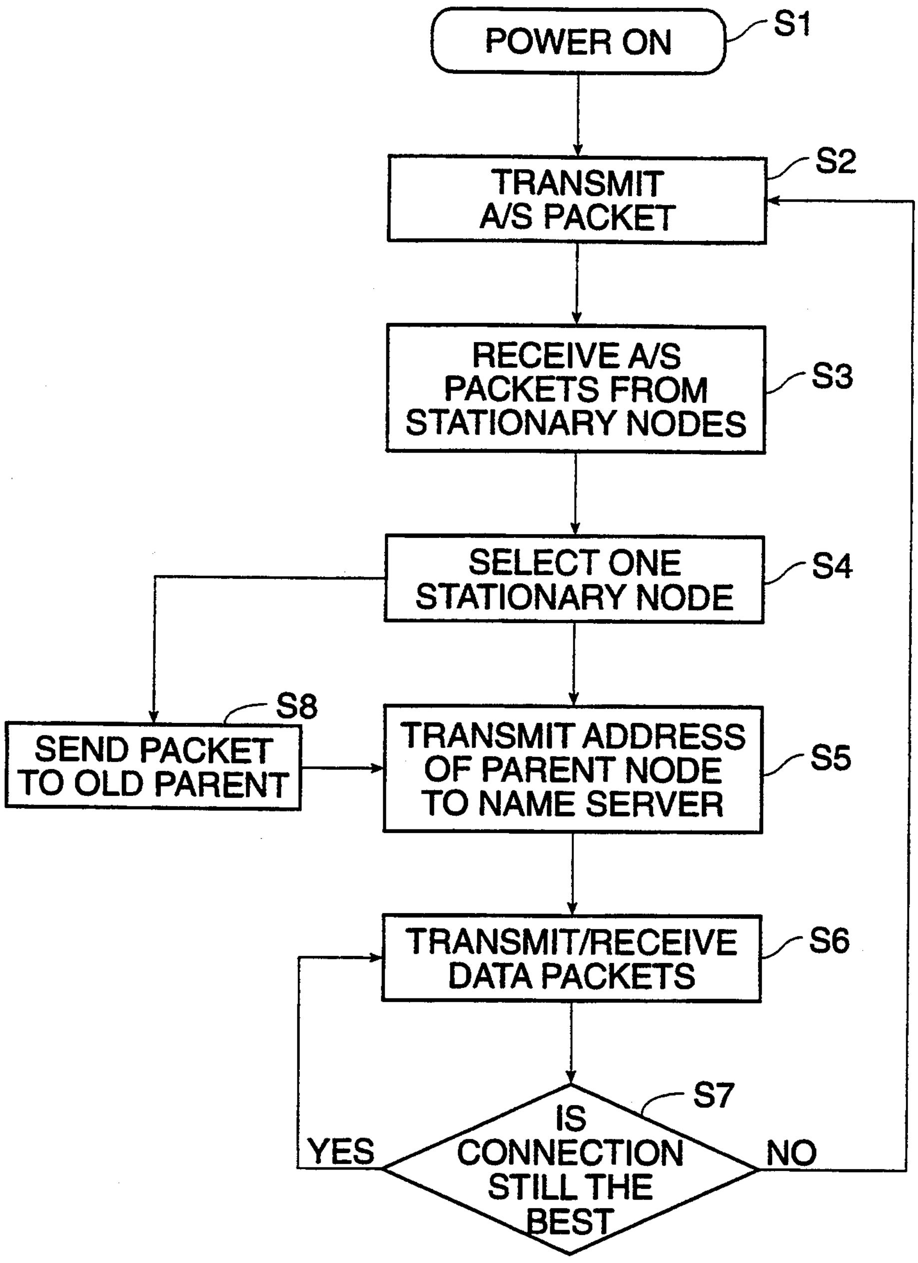

POWER ON
S1
TRANSMIT A/S PACKET
S2
RECEIVE A/S PACKETS FROM STATIONARY NODES
S3
SELECT ONE STATIONARY NODE
S4
S8
SEND PACKET TO OLD PARENT
TRANSMIT ADDRESS OF PARENT NODE TO NAME SERVER
S5
TRANSMIT/RECEIVE DATA PACKETS
S6
S7
YES
IS CONNECTION STILL THE BEST
NO

FIG. 2

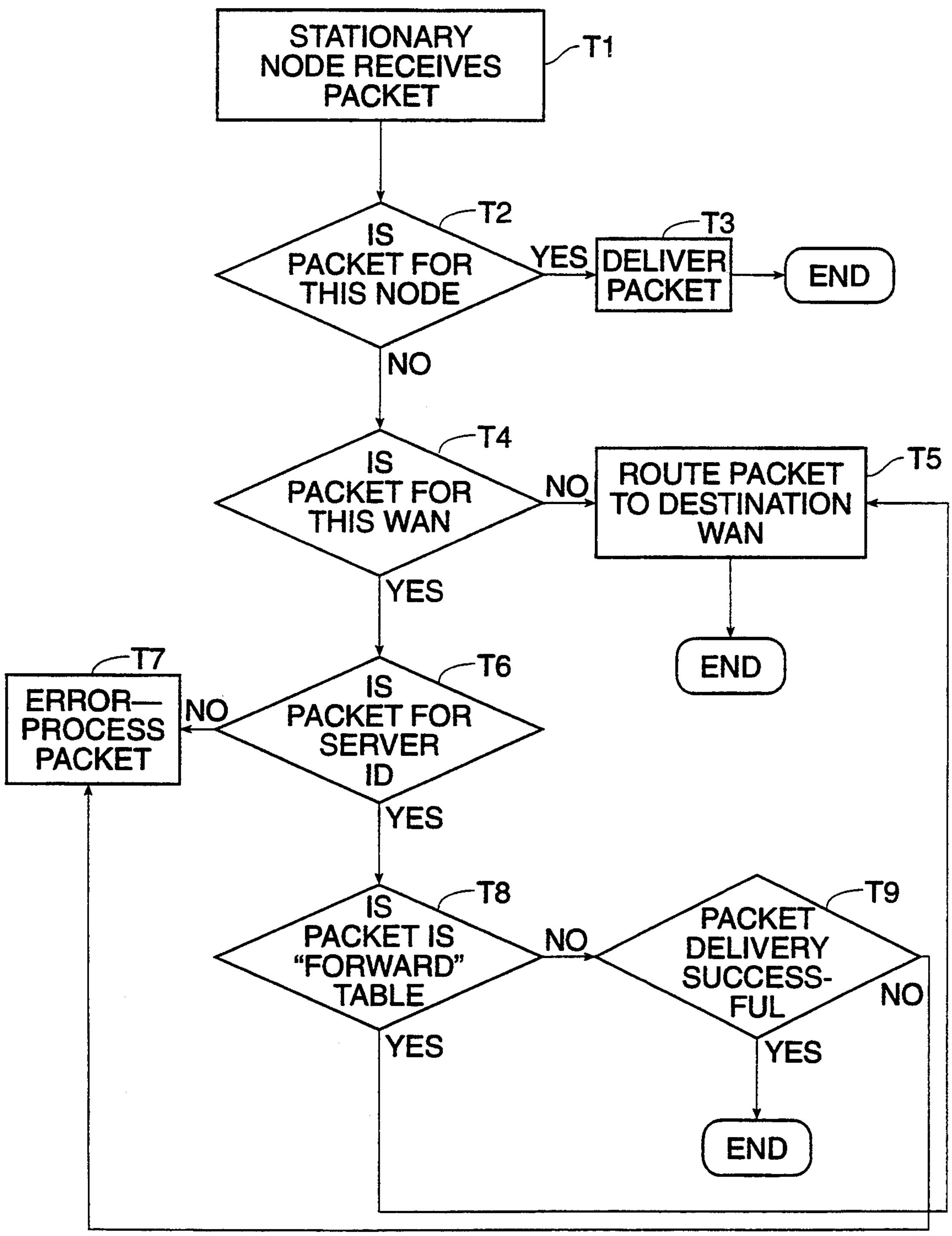

STATIONARY NODE RECEIVES PACKET
T1
IS PACKET FOR THIS NODE
T2
YES
DELIVER PACKET
T3
END
NO
IS PACKET FOR THIS WAN
T4
NO
ROUTE PACKET TO DESTINATION WAN
T5
END
YES
ERROR— PROCESS PACKET
T7
NO
IS PACKET FOR SERVER ID
T6
YES
IS PACKET IS "FORWARD" TABLE
T8
NO
PACKET DELIVERY SUCCESS-FUL
T9
NO
YES
END
YES

FIG. 3

PARASITIC ADOPTION OF COORDINATE-BASED ADDRESSING BY ROAMING NODE

A microfiche appendix including 19 frames on one fiche is included herewith.

BACKGROUND OF THE INVENTION

The invention relates generally to a method for routing data packets through a packet communication network and more specifically to a method for routing data packets in a network where some nodes can roam during network operation.

Packet communication is a form of data communication whereby segments or packets of data are routed with error checking and confirmation of receipt. Packets may be transmitted directly between a source and destination or relayed via relay stations. Several methods of data packet routing are known.

One method is known as directory-based routing. According to this method the address in the header of a packet is used as an index to a directory of packet routing lists stored in a transmitting or source node. A packet routing list consists of an ordered list of packet node identifiers or call signs that represent a transmission path from the transmitting node to the destination. Packet routing lists must be prepared with knowledge about the location of each node in the network. Directory-based routing schemes require continued maintenance and communication of network interconnection information employed in the directory. Each of these functions drains network resources and this can severely reduce performance in a large network. However, directory-based routing techniques have the advantage of permitting optimization of routing for a wide variety of network parameters, including data delay, throughput, reliability, priority and the like.

Another basic routing technique is the non-directory-based routing technique. In non-directory-based routing, the complexities associated with directory-based routing techniques are avoided. There is no need to store connectivity information for each transmitting node in the network thus reducing the amount of overhead processing that must be done by the network to preserve network connections. However, non-directory-based routing techniques generally do not permit network parameter optimization.

In U.S. Pat. No. 4,939,726, issued to Baran et al. and assigned to the assignee of the present invention, a non-directory-based routing method and system that permit network parameter optimization are disclosed. According to the method described therein, each stationary node in a network is uniquely identified by absolute geographical coordinates or by a code indicating absolute location in an external coordinate-based reference system (node coordinates), and such absolute geographical coordinates or the equivalent are employed as part of a packet identifier for each packet. A means at each node through which a packet is routed uses the packet destination coordinates and the node coordinates its neighboring nodes to determine a desired forwarding route of a data packet. The routing may be prioritized according to preselected criteria, preferably achieving optimum forward progress, that is, maximum forward progress using the least amount of power and taking into account characteristics of the system.

Accordingly, the disclosed packet routing method requires no routing directory or table to perform data routing. Each stationary node of the network collects or is otherwise provided with information about the quality of communication between itself and the nodes within the stationary node's communication range. When a data packet has been received at a node, the data packet is routed further through the network based on criteria derived from the history of communication between the local node and its neighbors. The criteria include distance, power requirements, retry history (reliability), throughput history, speed of transfer (net data rate), network delay, and data priority. Typically, there is an initialization procedure which is executed to determine the latitude and longitude of neighbors within a destination quadrant, and the criteria are weighted in accordance with preselected preferences to establish, at each subject node, a link quality (LQ) factor for each possible destination local to the subject node.

A packet in the Baran network is organized with four layers of header information as follows:

¦L1H¦ L2H¦ L3H¦ L4H¦ data¦ L1T¦

where:

L indicates "layer";

H indicates "header";

T indicates "tailer."

The Layer 1 header is responsible for transferring data in a packet in error-free form and includes a checksum value for comparing accuracy of packet transmission.

The Layer 2 header comprises the local destination address, the local or circuit source address, a pro-type field (packet protocol and type) and a frame identification. The destination address is the geographic coordinates of the next local destination and the source address is the geographic coordinates of the local node. The destination address of a received packet becomes the source address of the same packet on its retransmission, and the destination address for retransmission is selected by the local node based on analysis of the metrics used to establish optimum forward progress. The Layer 2 local destination is not the ultimate destination of the packet. The ultimate destination address is contained in a Layer 3 header, which is used for routing a packet between any source and any destination within a wide area net or between wide area nets.

The Layer 3 header is examined upon receipt of a packet at any node to determine if the wide-area-network destination address (WANDA) in the header corresponds to the WANDA of the node. If the WANDAs are not identical, the node forwards the packet to a next hop in the network. Several routing protocols may be used.

The LAN Destination Address is the identifier of the exact device within the LAN. The LAN Source Address is the device identifier of the originating device. The LAN Source Address is used by the destination device for formatting a response packet. Routing a response back to the source merely involves swapping the LAN Destination Address for the LAN Source Address, assuming the Layer 3 header has been properly rebuilt for the return.

Each device in the network thus has a primary address, namely, the WAN Address, and a secondary address, namely, the LAN Address. The WAN address is the unique latitude and longitude designation of each repeater node, within one second (20 meters) of geographic accuracy. All devices within the LAN of the repeater node use the WAN Address of the repeater node as their WAN Address.

The coordinate-based addressing method described above provides a satisfactory solution to the problem of non-directory routing in a network consisting entirely of stationary nodes. However, many networks further comprise mobile or roaming nodes. Such nodes cannot be assigned the absolute geographic coordinates required by the geographical addressing method.

One method that has been employed in prior art networks designed for use with roaming nodes, such as cellular telephone systems, is for the stationary nodes in the system to continuously keep track of and in touch with each roaming node and to "hand off" roaming nodes from one stationary node to another. Such a system requires tremendous processing and communication overhead to take place within and between each stationary node and is contrary to the reduced processing desired in a non-directory-based system. Such an approach is particularly inefficient when a roaming node does not continuously transmit data, but instead transmits packets infrequently and at unpredictable times.

What is needed is a routing method that permits roaming nodes to be addressed in a network in which stationary nodes are addressed using a coordinate-based addressing method and that does not require excessive processing by the network or the stationary nodes in the network to maintain contact with the roaming nodes.

SUMMARY OF THE INVENTION

According to the invention, in a packet communication system wherein stationary nodes are assigned an absolute coordinate-based address, the addressing of roaming nodes is accomplished by parasitically adopting the coordinate-based routing scheme used for addressing stationary nodes. Each roaming node initially selects a parent stationary node with which the roaming node can communicate directly. The coordinates of this parent stationary node are used in the header block of each packet transmitted from the roaming node and these coordinates are seen by all receiving nodes and then used in subsequent transmissions back to the roaming node. During the course of network operation, the roaming node will select a new parent node when the roaming node is no longer within direct communication range from the current parent node or for other reasons, such as addition or deletion of nodes. When a new parent is selected, the coordinates of the new parent node, along with the identity of the roaming node, are recorded at the former parent node. In one embodiment of the invention, a roaming node may, in addition to selecting a single parent node, maintain a list of alternate stationary nodes with which it can communicate when the parent node is unavailable.

In accordance with the method according to the invention, once a roaming node has moved from the range of its initial parent node, a packet addressed to that roaming node at its old parent node address is forwarded through a chain of stationary parent nodes beginning with the address of the old parent node and culminating in the current parent node. Upon receipt of a packet addressed to a parent node for a roaming node, each parent node determines whether it is the current parent node for the addressed roaming node. If the node is the current parent node, the packet is forwarded directly to the destination roaming node. If the node is not the current parent node, the node forwards the packet to the immediate successor parent node using the previously recorded coordinates of the immediate successor parent node.

In one embodiment of the invention, the network also includes a "name server" to which the roaming node periodically transmits its location. Nodes wishing to send to the roaming node may query the name server to get the most recently transmitted location of the roaming node.

The invention will be better understood by reference to the following detailed description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a general data network topology with a roaming node according to the invention.

FIG. **2** is a flow chart describing the operation of a roaming node.

FIG. **3** is a flow chart describing the operation of a stationary node according to the invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

FIG. **1** shows a data network **10** in a topology in accordance with the patent to Baran and incorporating the present invention to allow for communication with roaming nodes. The network **10** consists of stationary nodes labelled A through Z interconnected by paths **12** representing allowable communication links between nodes and roaming node **R1** connected to a parent node by a parasitic roaming communication link **14**. Consider, for example, data arriving at a local node J with a destination of node Y. Routing to node Y would be most directly routed via node P and node V. Each node would consult its internal neighbor list and route data, in turn, to the next neighbor node on the path to destination Y.

Now consider data arriving or originating at local node H with a destination **R1**. Local node H will have obtained information about **R1**'s most recent parent node by receiving a packet from **R1** with a header containing that information. H will transmit data to the geographic address of that parent node, in this case T. That data will be routed from K to N to S to T. If **R1** has continued to remain in transmitting distance from T, T will then transmit the packet to **R1**. However, **R1** may have moved out of the range of node T and into the range of node Y since the last time H received a packet from **R1**. **R1** will have established a new connection **16** with node Y. In this case, T will have stored the location of **R1**'s next parent node in its local memory and will use that information to forward the packet for **R1** to Y for delivery.

FIG. **2** depicts a flow chart illustrating the operation of a roaming node according to the invention. The process begins when the roaming node is turned on (Step **S1**). The roaming node then begins transmitting acquisition/synchronization packets on various network channels to any stationary nodes that can hear the transmission (Step **S2**). The roaming node then receives an acquisition/synchronization packet back from each stationary node that heard a packet (Step **S3**). The roaming node uses the information it received in these acquisition/synchronization packets and the signal strength of each packet to determine the stationary nodes to which it can most effectively communicate based on the power needed to reach that stationary and on the amount of empty capacity of that node. In one embodiment of the invention, the roaming node may receive from a stationary node an acquisition/synchronization packet containing not only information about that one stationary node but also information about other stationary nodes in the area with which the roaming node may be able to communicate. The roaming node may then use this information to transmit acquisition/synchronization packets to those other stationary nodes. Once the roaming node has received information about the stationary nodes in its area, the roaming node uses that information to select a parent node with the best communication link (Step S4). In one embodiment of the invention, the roaming node also stores information about other stationary nodes with which it can communicate and the roaming node transmits packets to the network through one of the alternate nodes if communication with the parent node is not possible. Once the communication link with the parent node is established, the roaming node in one embodiment transmits its current parent location to a name server node in the network (Step S5) and transmits and receives data to nodes in the network through the parent node (Step S6). In an embodiment of the invention with a name server, that name server can provide information regarding the location of any node in the network. The roaming node also continuously tests the received data packets and sends out additional acquisition/synchronization packets to determine the status of the roaming nodes ability to transmit to other stationary nodes in order to make a decision regarding whether the communication link with the current parent node is still the best link (Step S7). If the link with the current parent node is still the best link, the roaming node continues to transmit data through that parent (Step S6). If the link with the current parent node is not still the best link, the roaming node begins the process of selecting a new link again (Step S2). However, this time, once the new parent is selected, the roaming node sends a packet to the old parent informing the old parent that the old parent's link has been broken and telling the old parent the location of the new parent so that the old parent can forward data packets addressed to the roaming node to the new parent (Step S8). In an alternative embodiment, the name server may inform the old parent of the location of the current parent for forwarding purposes.

FIG. 3 depicts a flow chart illustrating the operation of a stationary node according to the invention. The stationary node receives a packet (Step T1). The geographic location of the packet's destination is carried within the packet. The stationary node reads this information and determines if the packet is addressed to the stationary node or to a device that is directly connected to the stationary node (Step T2). If the packet is addressed to the stationary node or to a device that directly connected to it, the stationary node delivers the packet and processing of that packet is terminated (Step T3). If the packet is not addressed directly to the stationary node, the stationary node determines if the packet is addressed to a device within its wide area network (WAN)(Step T4). If the packet is not addressed to a device within the WAN of the stationary node, the packet is forwarded to the next node in the direction of the destination node's coordinate location (Step T5).

If the packet is addressed to the current stationary node's WAN, the stationary node determines if the packet is addressed to a device or roaming node which it serves (Step T6). If the packet is not addressed to a device or roaming node which the stationary node serves, an error has occurred and the stationary node process the packet according to its error-handling instructions (Step T7). In one embodiment, the stationary node processes a packet error by asking the name server for an address for the ultimate destination of the packet. The stationary node then routes the packet to the address provided by the name server. In another embodiment, the stationary node processes a packet error by discarding the packet and sending a message to the source of the packet that delivery was not successful.

If the packet is addressed to a device or roaming node which the stationary node serves, the stationary node determines if the address is for a roaming node listed in the stationary node's "forward" table (Step T8). If the destination is not listed in the stationary node's "forward" table, the stationary node will attempt to deliver the packet to the destination roaming node (Step T9). If delivery is successful, packet processing ends. If delivery is not successful, the stationary node processes the packet as an error (Step T7). If the destination is listed in the stationary node's "forward" table, the stationary node will forward the packet to the WAN listed in the forward table (Step T5).

In a specific embodiment of the invention discussed in detail in the Baran patent, the identifier for the roaming node is transmitted through the network as part of the Layer 3 header.

The invention has now been explained with reference to specific embodiments. Other embodiments will be apparent to those of ordinary skill in the art. It is therefore not intended that this invention be limited except as indicated by the appended claims.

What is claimed is:

1. In a packet communication network with a plurality of stationary nodes, a method by which a roaming node may establish a communication link with said network comprising the steps of:

transmitting a link acquisition packet to one or more of said stationary nodes;

receiving a response packet from each of said stationary nodes that successfully receives said link acquisition packet;

determining from data in said received response packets the one of said stationary nodes that provides the best communication link;

selecting the one of said stationary nodes that provides the best communication link by transmitting to said selected stationary node a packet informing said selected stationary node that said selected stationary node is a current parent node for said roaming node; and

transmitting data packets to nodes in the network using an identifier of said parent node as part of the return identifier for said roaming node.

2. The method according to claim **1**, further permitting said roaming node to change its network communication link to a new parent node in response to changed conditions and further including the steps of:

monitoring each received data packet from said current parent node to determine whether said communication link is still good;

intermittently transmitting link acquisition packets to one or more of said stationary nodes to determine the quality of the possible communication link with them;

receiving a response packet from each of said stationary nodes that successfully receives said link acquisition packet;

selecting from said received response packets one of said stationary nodes to be a new parent node when the link with said current parent node is no longer good;

transmitting to said current parent node a packet informing said current parent node that said current parent node is no longer the current parent node and that said new parent node is a current parent node for said roaming node; and

transmitting to said new parent node a packet informing said new parent node that said new parent node is a current parent node for said roaming node.

3. A method for transmitting packet data between a plurality of stationary nodes and at least one roaming node comprising the steps of:

assigning a unique stationary node identifier to each stationary node;

assigning a unique roaming node identifier to said roaming node;

providing communication means between individual stationary nodes forming a network such that each stationary node can communicate directly with at least one other stationary node and such that any stationary node can communicate with any other stationary node by relaying data through any number of stationary nodes and identifying said data with said unique stationary node identifier for the receiving stationary node;

receiving at any number of stationary nodes a link acquisition packet from said roaming node and transmitting a response packet to said roaming node from each stationary node that received said link acquisition packet;

receiving from said roaming node a packet designating a single stationary node as the current parent node for that roaming node;

receiving at said parent node from said roaming node data packets which include said unique stationary node identifier for said parent node as part of the source address and transmitting said packets to other stationary nodes;

accepting at said parent node from any of said plurality of stationary nodes data packets for said roaming node;

transmitting said data packets to said roaming node from said parent node.

4. The method according to claim **3**, further comprising the steps of:

receiving at said parent node from said roaming node a packet designating said parent node as an old parent node and informing said parent node of the identifier of a new parent node;

accepting at said old parent node data packets for said roaming node addressed to said old parent node;

forwarding said data packets to said new parent node for delivery to said roaming node.

5. The method according to claim **3**, further comprising the steps of:

periodically receiving at a name server packets from said roaming node indicating the unique identifier of the current parent node and storing that information;

transmitting from said name server to any of said nodes in said network said identifier of said current parent node for said roaming node in response to a query from any of said nodes.

6. The method according to claim **5**, further comprising the steps of:

receiving at said parent node from said name server a packet designating said parent node as an old parent node and informing said parent node of the identifier of a new parent node;

accepting at said old parent node data packets for said roaming node addressed to said old parent node;

forwarding said data packets to said new parent node for delivery to said roaming node.

* * * * *