

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CHARTER COMMUNICATIONS, INC.,
Petitioner,

v.

IARNACH TECHNOLOGIES, INC.,
Patent Owner.

Case IPR: 2024-XXXXX
U.S. Patent No. 8,942,378

DECLARATION OF GEORGE ROUSKAS, Ph.D.

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I. INTRODUCTION

1. My name is George Rouskas. I have been retained as an expert witness to provide my independent opinions in regards with matters at issue in the inter partes review of U.S. 8,942,378 (“the ’378 Patent”).

2. I have been retained by Charter Communications, Inc. (“Charter”), the Petitioner. The Patent Owner is Iarnach Technologies, Inc. (“PO”).

3. Unless otherwise noted, the statements made herein are based on my personal knowledge, and if called to testify about this declaration, I could and would do so competently and truthfully.

4. A detailed record of my professional qualifications including cases in which I was an expert is attached as Exhibit 1 and is summarized in Section II, *infra*.

5. I am not a legal expert and offer no opinions on the law. However, I have been informed by counsel of the various legal standards that apply, and I have applied those standards in arriving at my conclusions.

6. I am being compensated for the time I spend on this matter at my standard hourly rate for such assignments and my rate is in no way contingent on the outcome of these proceedings.

II. QUALIFICATIONS

7. Since 1994, I have been a Professor in the Department of Computer Science at North Carolina State University (“NC State”). I am currently an Alumni Distinguished Graduate Professor with Tenure in that department.

8. I have also served as the Director of Graduate Programs for NC State’s Department of Computer Science from January 2014 to June 2024.

9. I have held visiting positions on the faculties of a number of international universities, including positions as a Distinguished Scientist at King Abdulaziz University (Saudi Arabia, 2013-2021); Visiting Professor at the Laboratoire d’Informatique University of Paris 6 (France, October 2012); Visiting Professor at the Universidad Tecnica Federico Santa Maria (Chile, December 2008); and Visiting Professor at the Laboratoire de Méthodes Informatiques University of Evry (France, July 2006, December 2002, June 2000).

10. I am an experienced researcher and educator in the field of computer networking, with expertise in optical networks, Internet architectures and protocols, virtualization and cloud computing, mobile devices, network devices, network security and security protocols, in a variety of applications including providing for the protection of information transmitted between devices within and among networks.

11. I have thirty-five years of experience in computer networking. In 1989, I received my bachelor's degree in Computer Engineering from the National Technical University of Athens. In 1991, I was awarded a Masters of Science in Computer Science from the Georgia Institute of Technology. In 1994, I was awarded a doctorate in Computer Science from the Georgia Institute of Technology.

12. In my tenure as a professor of computer science, I have taught undergraduate courses on computer networks and Internet protocols, and graduate courses on data structures, computer performance evaluation, Internet Protocols, Network survivability, and Optical Networks. In 2001, I developed an advanced graduate level course on Optical Networks in which, among other topics, I cover in detail passive optical networks (PONs), including the EPON and GPON standards.

13. I supervised the research of numerous doctoral candidates, including those whose studies were directed to (i) routing and spectrum assignment in elastic optical networks, (ii) efficient decomposition techniques for traffic grooming in optical networks, (iii) routing and wavelength assignment in WDM networks, (iv) provisioning bandwidth and demand services using optical network design and SILO network architecture, (v) congestion control and quality of service (QOS) provisioning for optical burst switched networks, (vi) topology design of large-scale optical

networks, (vii) dynamic reconfiguration in broadcast WDM networks, among others.

14. A number of my graduate students have been recognized for this research. Two have received Ph.D. dissertation awards, one has received an NSF Career award, one became an NSA Fellow, and one has been inducted in the NC State Computer Science Alumni Hall of Fame. Three of my former Ph.D. students became Assistant Professors upon graduation, and the rest joined significant technology companies or research institutes, including RENCi (UNC-Chapel Hill), IBM Research, Google, Facebook, Cisco, Oracle, Ericsson, Riverbed Technologies, Sprint, and Sierra Wireless, among others.

15. I have received numerous accolades for my contributions to computer networking, including being elected as Fellow of the IEEE in 2012. Other accolades include the Outstanding Technical Achievement Award from the Optical Networking Technical Committee (ONTC) of the IEEE Communication Society (2024) for “pioneering research in the design, implementation, operation, and control of fiber optic networks;” the Person of Exceptional Performance Award from the Department of Computer Science, NC State (2024); the Outstanding Service Award from the ONTC (2019); the Joyce Hatch Service Award from the NC State Chapter of the

Association for Computing Machinery/Association of Information Technology Professionals (ACM/AITP) (2018); the title of Distinguished Lecturer in the IEEE (2010-2012); an IBM Faculty Award (2007); the Best Paper Award for the International Workshop on End-to-End Virtualization and Grid Management (EVGM) (2007) (with C. Castillo and K. Harfoush); the Best Paper Award for the International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP) (2006) (with B. Chen and R. Dutta); the ALCOA Foundation Engineering Research Achievement Award, NC State College of Engineering (2004); the Alumni Outstanding Research Award, NC State (2003); the CAREER Award from the National Science Foundation (1997); and the Graduate Research Award from the Georgia Tech College of Computing (1994).

16. In 2000-2001, while on Sabbatical from NC State, I worked as Network Architect for Vitesse Semiconductor, where I was responsible for the design of a state-of-the-art 2.5 Gbps network processor.

17. I have received funding from numerous agencies, foundations and companies for research on network design and communication. The sources of funding for this research include the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), the National Security Agency (NSA), Microsoft, IBM and Cisco.

18. I have served in a number of leadership roles for the IEEE, including as Chair of the IEEE Communications Society's Distinguished Lecturer Selection Committee (2016-2017); Vice Chair of the IEEE Communications Society's Technical and Educational Activities Council (2016-2017); and Chair of the IEEE Communications Society's Optical Networking Technical Committee (2016-2017).

19. I have served in various founding, editorial and leadership positions for publications in my field, including as founding Editor-in-Chief of IEEE Networking Letters (2018-2021); founding Editor-in-Chief, Elsevier Optical Switching and Networking Journal (2004-2017); OFC Steering Committee Member (2017-2023), Co-Guest Editor, IEEE/Optica Journal of Communications and Networking, Special issue on "Benchmarking in Optical Networks," 2024, Associate Editor, IEEE/Optica Journal of Communications and Networking (2010-2012); Co-Guest Editor, JCM Journal of Communications, Special Issue on the "Advances in Communications and Networking," vol. 6, no. 9, December 2011; Associate Editor, IEEE/ACM Transactions on Networking (2000-2004); Associate Editor, Computer Networks (2001-2004); Associate Editor, Optical Networks (2000-2004); and Co-Guest Editor, IEEE Journal on Selected Areas in Communications, Special Issue on "Protocols for Next Generation Optical WDM Networks," vol. 18, no. 10, October 2000.

20. During the course of my career, I have had more than 200 scientific articles, three books, and ten book chapters published, which have collectively received more than 9,950 citations (Google Scholar, July 23, 2024). These are summarized in my attached curriculum vitae. Ex. 1.

III. BASES OF OPINIONS

21. In the course of conducting my analysis and forming my opinions, I have reviewed at least the items listed below:

- a. U.S. Patent No. 8,942,378
- b. Prosecution History of U.S. Patent No. 8,942,378
- c. JP2004-343243A
- d. Certified English Translation of JP2004-343243A
- e. RFC 1112
- f. RFC 4601
- g. U.S. Patent Appl. 2002/0150097 A1 (“Yen”)

IV. APPLICABLE LEGAL STANDARDS

22. **Ordinary Skill in the Art.** My opinions in this declaration are based on the understandings of a person of ordinary skill in the art, which I understand is sometimes referred to as an “ordinary artisan” or by the acronyms “POSA”

(person of ordinary skill in the art), as of the time of the invention, which I understand is here is assumed to be at least as early as January 25, 2010, the filing date of Chinese Patent Application 201010102646 to which the '378 Patent claims priority.

23. I understand that the person of ordinary skill in the art is a hypothetical person who is presumed to have known the relevant art at the time of the invention.

24. I understand that, in assessing the level of skill of a person of ordinary skill in the art, one should consider the type of problems encountered in the art, the prior solutions to those problems found in the prior art references, the rapidity with which innovations are made, the sophistication of the technology, the level of education of active workers in the field.

25. Based upon the above criteria and my own experience working with those of skill in the art at the time of the invention, I have concluded that a person having ordinary skill in this art ("POSA") would have at least a bachelor's degree in electrical engineering, computer science or comparable degree or 2-3 years industry experience designing and/or maintaining back-end networking equipment.

26. **Claim Construction.** I understand that claims of the '378 Patent are generally interpreted according to their ordinary and customary meaning taking into consideration the so-called "intrinsic evidence" of the patent consisting of (1) the claim language; (2) the specification; and (3) the prosecution history. I understand

that the Board has discretion to take into consideration so-called “extrinsic evidence” including certain other references as well as definitions from dictionaries and treatises.

27. I understand that claim terms may be explicitly defined in the patent specification, or they may be implicitly defined through consistent usage in the specification. I also understand that the scope of claim terms may be limited by statements in the specification or prosecution history where the applicant clearly disavows or disclaims subject matter in a clear and unmistakable manner.

28. In offering my opinions, I have relied upon the ordinary and customary meanings of the terms used in the claims as they would have been understood by a POSA as of the priority date in light of the intrinsic evidence.

29. In particular, I have construed the term “**common key**” to mean “a key used to both encrypt and decrypt communications.” The term is nowhere found in the specification. *See generally* EX1001 (referring only to use of a “public” key). And, as initially filed, the claims also only used the term “public” key. EX1002, 129-131.

30. However, during prosecution the examiner noted that the “key” recited in the claims and described in the specification was not a “public” key as generally understood. As the examiner commented,

The term “public key” in claims 1-13 is used by the claim to mean “common key”, while the accepted meaning is of the term “public key” in the art is one of the pair of public/private keys in asymmetric encryption. One key lock or encrypts the plaintext, and the other unlocks or decrypts the ciphertext. **Neither key can perform both functions by itself.** The public key may be published without compromising security, while the private key must not be revealed to anyone not authorized to read the messages.

EX1002, 207.

31. I agree with the examiner that the key described in the specification of the '378 Patent is not what a POSA would understand to be a “public” key. Instead, the key described in the specification is a “key” used to both encrypt and decrypt the communication. In other words, it is “common” to these operations.

32. In response to the examiner’s observations, the Applicant replaced the term “public key” recited in the original claims with the term “common key.”
EX1002, 313-316.

33. In view of the specification and this exchange with the Examiner, as well as the use in the claims of the term “common key” to describe a key that encrypts and decrypts the communications, a POSA would understand that the claimed “common key” is “a key used to both encrypt and decrypt communications.”

34. I have construed the term “bearer channel” to include “a logical channel of the PON that can be a LLID or GEM.” The Applicant chose to define the term in

the '378 Patent. The specification discloses that the claimed “bearer channel is a logical channel of the PON, and it can be the general encapsulation model (GEM) channel born by the GPON port or the logical link identification (LLID) channel of the EPON port[.]” EX1001, 4:4-8. In view of this disclosure, a POSA would understand that the claimed “bearer channel” encompasses “a logical channel of the PON that may be a LLID *or* GEM.”

35. **Obviousness (35 U.S.C. § 103).** I have been informed that a patent may be invalid if the claimed invention considered as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art. I have been informed that the following factors must be evaluated to determine whether Petitioner has met its burden of proof on obviousness: (1) the scope and content of the prior art; (2) the level of ordinary skill in the art; and (3) the differences between the claimed subject matter and the prior art. Based on these factual inquiries, it must then be determined, whether or not the claimed subject matter as a whole would have been obvious to one of ordinary skill in the art at the time the alleged invention was made.

36. I understand that a finding of obviousness requires a showing that as of the date of the invention (a) the prior art teaches or suggests each of the limitations of the claim; (b) there exists an apparent reason or motivation to combine and/or

modify the prior art as proposed; and (c) a person of ordinary skill would have a reasonable expectation of success, including that the proposed combination and/or modification of the prior art would operate for its intended purpose.

37. I have been informed that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I have been informed that it is important in the obviousness inquiry to identify whether a reason existed at the time of the invention that would have given a POSA motivation to combine and/or modify the prior art references in the manner proposed by the Petitioners so as to arrive at the claimed invention. Put another way, a finding of obviousness should be supported by an apparent reason to combine and/or modify the prior art references as proposed by the Petitioners.

38. I also understand that the obviousness inquiry should guard against hindsight bias or hindsight reconstruction where after-the-fact reasoning is applied to combine prior art elements using the claimed invention as a template, without establishing that, as of the date of the invention, there exists a motivation to combine or apparent reason to combine and/or modify the prior art as proposed.

39. In assessing obviousness, I have been instructed to consider both the ordinary creativity and common sense of the person of ordinary skill in the art. I also

understand that it is impermissible for common sense to be applied so as to fill gaps in prior art that fails to teach or suggest a limitation of the claim.

40. In assessing obviousness, I have been instructed that, in order to qualify as proper prior art for an obviousness analysis, a reference must qualify as analogous art. I have been informed that a reference qualifies as analogous art with respect to the claims if it is either: (1) from the same field or endeavor as the patent; or (2) the reference is reasonably pertinent to the particular problem addressed by the invention. I have also been informed that in order for a reference to be reasonably pertinent, it must logically have commended itself during the ordinary course of development to an inventor's attention in considering his problem.

V. OVERVIEW OF '378 PATENT AND PROSECUTION

41. The '378 Patent is directed to securing communications, specifically point to multipoint (*i.e.* multicast) communications in which multiple recipients receive the same data from a single point.

42. The '378 Patent issued from U.S. Patent Application No. 13/257,731, filed November 10, 2010, and claims priority to Chinese Patent Application 201010102646 filed January 25, 2010. I am advised that based on PO's claim of priority, the '378 Patent would be evaluated under the rules preceding the adoption of the America Invents Acts with respect to what constitutes prior art.

43. The '378 Patent describes a conventional method for encrypting multicast service data in a passive optical network (PON) system. The '378 Patent correctly acknowledges that the structure of a PON system was known and that various mechanisms for encrypting service data in a PON system existed in the art. EX1001, 1:14-19, 32-39.

44. For example, the '378 Patent explains that a PON system was known to employ a plurality of optical network units (ONU) associated with users. EX1001, 1:14-19. These ONUs received data packets sent from an upstream Optical Line Terminal (OLT), after they interconnected with the PON and were authorized to receive such communications. *Id.*

45. The '378 Patent further acknowledges that encryption mechanisms were known. EX1001, 1:32-39. The '378 Patent illustrates the OLT's use of a key to encrypt the multicast communication before their transmission to one or more ONUs. For this purpose, the OLT unsurprisingly generates a key (*i.e.*, step 110). EX1001, Fig. 1. The OLT then encrypts the multicast data to be sent (*i.e.*, step 120). *Id.*

46. ONUs power on and access the PON network, registering with the network and applying for multicast service (*i.e.*, step 130). *Id.* The '378 Patent acknowledges that the procedures for registration and authorization were previously fully

described in published industry protocols, and for that reason, asserts that it need not provide details to explain that process further to POSAs. EX1001, 4:51-53.

47. In response, the OLT shares the key used to encrypt the multicast communication with the ONU authorized to receive it (*i.e.*, step 140). EX1001, Fig. 1. The key both encrypts and decrypts the multicast data (*i.e.*, the key is common to both processes).

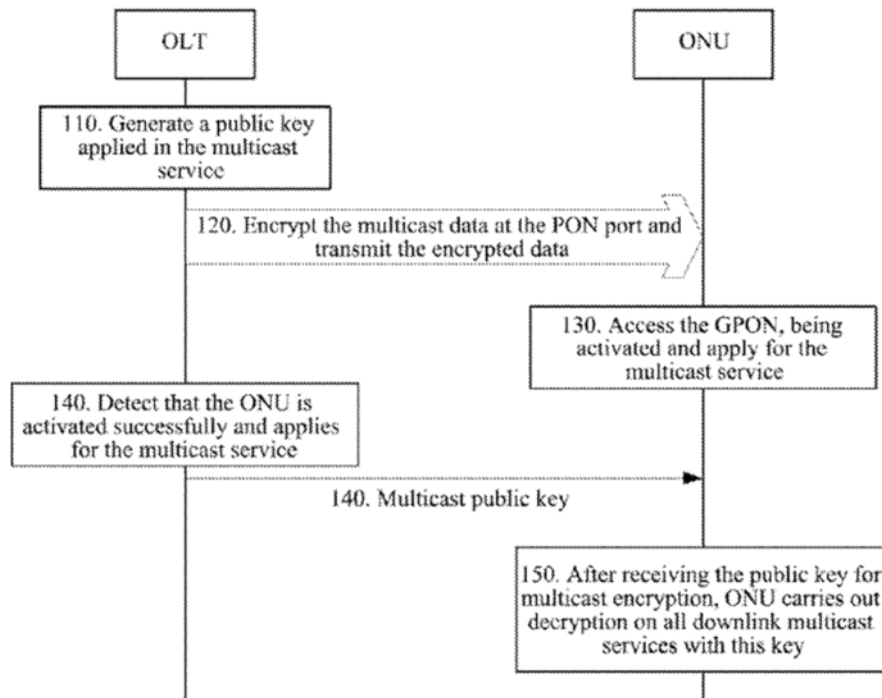


FIG. 1

EX1001, Figure 1.

48. Figure 2 further depicts use of a key valid for only a limited period of time. The OLT generates a common key and sets a timer (T1) (*i.e.*, step 210).

EX1001, Fig. 2. Use of this key proceeds as described above. However, upon expiration of the timer, the OLT regenerates a new common key and resets the timer (i.e., step 270).

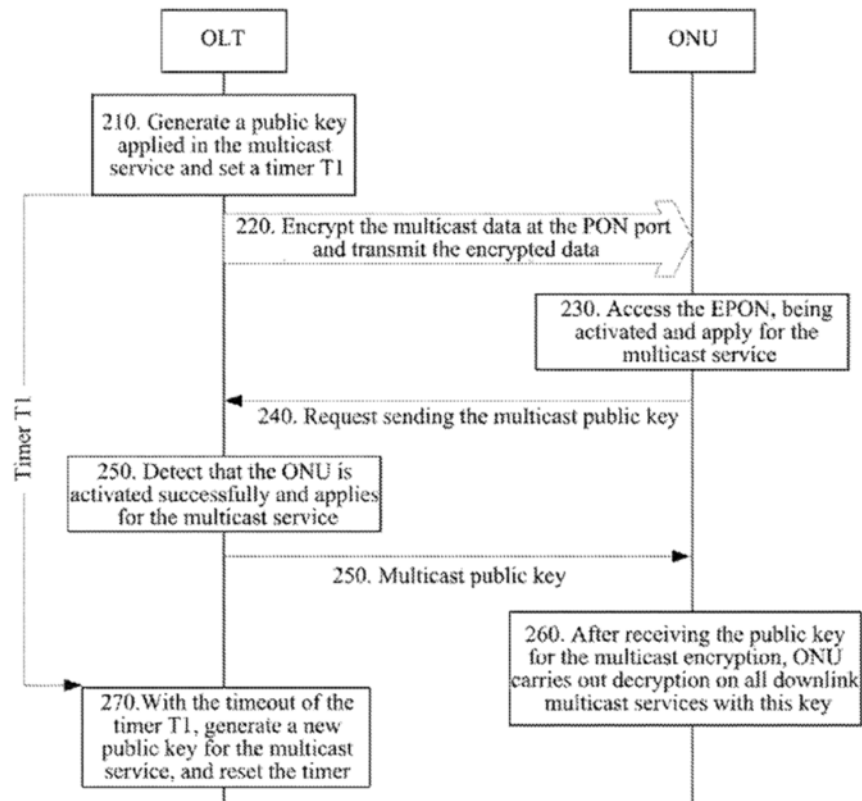


FIG. 2

EX1001, Figure 2.

49. In my review of the prosecution history for the '378 Patent, I noted that the claims of the application were initially rejected as anticipated by Chinese Patent No. 1855834 ("He") dated November 1, 2006. EX1002, 208-10. The examiner de-

terminated that He taught a method for encrypting multicast services in a passive optical network system in which an optical line terminal (OLT) generated a common key, used that key to encrypt multicast service data sent in a bearer channel, and then sent that key via a separate management control channel to an optical network unit (ONU) that is activated successfully and applies to receive said multicast service data, after which it is used to decrypt the encrypted data. *Id.* The examiner noted that He also taught the remaining elements of certain of the remaining dependent claims. *Id.* (observing that He taught use of the key to decrypt the multicast communications, that the key is sent once the ONU is detected/judged to have been activated successfully and to have applied to receive the key, that the OLT sent the ONU an identifier for the bearer channel, as well as the various independent/dependent apparatus claims drawn to the same method).

50. The examiner further concluded claims remaining that regenerated the key following expiration of an aging time, were obvious in light of He in further view of Chinese Patent No. 1866857 (“Jiang”) dated November 22, 2006. EX1002, 210-12. The examiner determined that He and Jiang were analogous art because they were from the same field, namely the provision of secure communications between computer systems. *Id.* The examiner noted that Jiang taught the application of an expiration time to a key and the generation of a new key following expiration. *Id.*

51. In response to the examiner’s rejection, the applicant contended that He described the encryption of a multicast “bit-stream,” and argued that He did not disclose the encryption of multiple multicast communications in a bearer channel with the common key. EX1002, 321-24 (arguing that a bearer channel differed from a multicast bit-stream, asserting that multiple multicast bit-streams could be carried in a single bearer channel). The applicant did not otherwise dispute the examiner’s reading of He, nor his application of the timing disclosures present in Jiang.

52. The examiner rejected the applicant’s efforts to distinguish He. The examiner noted that based on He, he had rejected a dependent claim (then Claim 6) that recited the encryption of all multicast service data in a bearer channel with the common key. EX1002, 328-31.

53. The applicant responded by amending the claims to positively recite that the common key was used to encrypt “all multicast services in a bearer channel” and that “all multicast services in the same one bearer channel use a same common key to carry out encryption.” EX1002, 341-44. The applicant again argued that He disclosed the transmission of only a single data stream and failed to disclose examples involving transmission of more than one data stream. EX1002, 351-54 (“HE’s invention provides a method for realizing multicast in PON, in which the OLT allo-

cates the multicast service which is applied for to occupy one downlink service channel, and the OLT generates one key for this multicast service.”). Again, the applicant did not otherwise dispute the examiner’s application of He and/or Jiang.

54. The examiner responded that the amended claims remained obvious in light of the disclosures in He and Jiang. The examiner noted that Jiang disclosed the encryption of all multicast services in a bearer channel, rendering the claims obvious in light of He’s remaining disclosures. EX1002, 373-78 (noting that Jiang disclosed that “BS in the same MBS zone use the same key for encrypting the same MBS program”).

55. To gain allowance, the applicant again amended its claims. The applicant required that a common key be used to encrypt multicast service data “of all different multicast services in a same bearer channel[.]” EX1002, 416-19. The examiner ultimately issued the claims after concluding that the prior art then of record did not explicitly disclose that data of “different” multicast services on a single bearer channel would be encrypted with the same common key. EX1002, 436-40.

VI. PRIOR ART

A. JP2004-343243A (“Murakami”) (EX1004, EX1005 (Certified English Translation))

56. Entitled “Method and Central Office Unit for Multicast Communication in PON System,” Murakami was published December 2, 2004. EX1005, 1(54), 1(43).

57. Murakami is concerned with the same field of endeavor as inventions claimed in the '378 Patent. Specifically, both the invention and Murakami are concerned with securing communications, particularly multicast communications made in passive optical networks.

58. Murakami’s disclosures are also reasonably pertinent to the problems which the application sought to solve, such that Murakami would have logically commended itself to an inventor's attention in considering his problem. Murakami discloses a method of securing multicast communications to prevent unauthorized access.

B. RFC 1112 (EX1006)

59. Entitled “Host Extensions for IP Multicasting,” RFC 1112 is an internet standard that was not cited or discussed by the Examiner during prosecution. RFC 1112 was published in August 1989. EX1006, 1.

60. RFC 1112 is concerned with the same field as the '378 Patent. RFC 1112 “specifies the extensions required of a host implementation of the Internet Protocol (IP) to support multicasting” and “is the recommended standard for IP multicasting in the Internet.” EX1006, 1. RFC 1112 is relevant to problems which inventors of the '378 Patent sought to solve.

C. RFC 4601 (EX1007)

61. Entitled “Protocol Independent Multicast – Sparse Mode IPIM-SM): Protocol Specification (Revised),” RFC 4601 discloses a multicast routing protocol. EX1007, 1. RFC 4601 was published in August 2006. *Id.* RFC4601 was not cited or discussed by the Examiner during prosecution. *See* 1001, 1(56).

62. RFC 4601 is concerned with the same field as the '378 Patent. The '378 Patent concerns the content of multicast communications in a bearer channel and the encryption of those communications. RFC 4601 describes source data forming multicast communications, and protocols for delivering them to users. RFC 4601 “specifies an Internet standards track protocol” (*i.e.*, Protocol Independent Multicast – Sparse Mode (PIM-SM)), which “is a multicast routing protocol.” EX1007, 1.

63. RFC 4601 is also relevant to problems which inventors of the '378 Patent sought to solve. The '378 Patent addresses multicast communications consisting of more than one multicast service. RFC 4601 describes systems and methods for constructing such multicast communications.

D. U.S. Patent Appl. 2002/0150097 A1 (“Yen”)

64. U.S. Patent Appl. 2002/0150097 A1 (“Yen”), entitled “Method and apparatus for secured multicasting,” was published October 17, 2002. EX1008, 1(54), 1(43).

65. Yen describes a method and apparatus for conducting secured multicast communications in a passive optical network having an optical line terminal (“OLT”), and multiple network devices, such as optical network terminals (“ONT”). Yen describes using a multicast encryption key to encrypt multicast data. ONTs employ the same key to decrypt those communications. Yen describes an OLT that periodically updates this multicast encryption key. EX1008, 1(57).

66. Yen is concerned with the same field of endeavor as the inventions claimed in the '378 Patent. Specifically, both the invention and Yen are concerned with securing communications, particularly multicast communications made in passive optical networks.

67. Yen’s disclosures are also reasonably pertinent to the problems which the application sought to solve, such that Yen would have logically commended it-
self to an inventor's attention in considering his problem. Yen discloses a method
of securing multicast communications to prevent unauthorized access.

VII. IDENTIFICATION OF HOW THE CLAIMS ARE UNPATENTABLE

A. Claims 1-2, 4, 6-10, 12-13 are Obvious in light of JP2004-343243A in view of RFCs 1112 and 4601 and the knowledge of persons of skill in the art

1. Independent Claim 1

68. Murakami explicitly discloses all but one element of independent
Claim 1 (*i.e.*, “all **different** multicast services”). EX1001, Claim 1 (emphasis
added). This remaining element is implicitly disclosed by Murakami and would have
been obvious to a POSA at the time of Murakami’s publication based upon Mura-
kami’s disclosures, particularly in view of RFCs 1112 and 4601 and in light of his
knowledge.

a. Element 1 [preamble]

A method for encrypting multicast service in a passive optical network system, the method comprising:
--

69. To the extent the preamble is deemed a limitation, Murakami discloses
this element.

70. Murakami discloses “[a] method for multicast communication in a PON system,” which “distribute[s] encryption keys for use in the multicast communication.” EX1005, Claim 1; *see also* EX1005, 1(57) (“ONUs and OLT 10 are connected via an optical transport medium so as to transmit and receive data between the ONUs and OLT 10 . . . [and] OLT 10 snoops IGMP¹ messages so as to control the setting of logical links for multicasting according to the result of the snooping and **distribute encryption keys for use in multicast communications.**”) (emphasis added).

Element 1[a]: an optical line terminal (OLT) generating a common key,

71. Murakami discloses this element. Murakami discloses that “**OLT 10 generates a new encryption key** used in this multicast communication[.]” EX1005, [0031] (emphasis added).

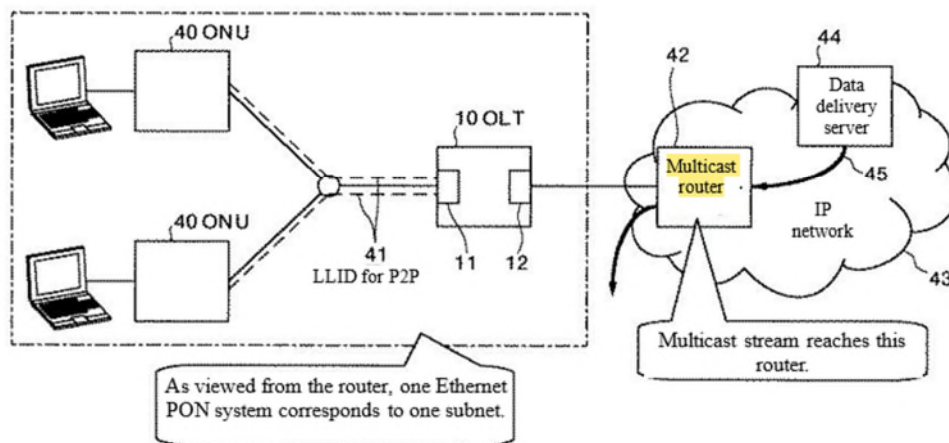
Element 1[b]: and using the common key to encrypt multicast service data of all different multicast services in a same bearer channel and then sending encrypted data,

¹ “IGMP” refers to the Internet Group Management Protocol. “Snooping” is a process by which network switches eavesdrop on conversations between hosts (*i.e.*, customer premises equipment) and routers to map which links need which multicast transmissions. “Snooping” prevents hosts from receiving traffic for a multicast group they have not joined. EX1003, ¶1004, n.4.

72. Murakami discloses this element. Murakami discloses use of a bearer channel in the form of a logical link. EX1005, 1(57) (disclosing “a PON system in which communications are carried out through the use of logical links”).

73. Murakami explains its OLT is equipped with a service node interface (SNI) 12 that connects to an IP network via multicast router 42. EX1005, [0026]. Multicast data from delivery servers on the IP network are routed through the Multicast Router 42 to OLTs for subsequent broadcast to ONUs and their associated subscribers. *Id.* This arrangement is depicted in Figure 4, below:

Figure 4



EX1005, Fig. 4 (yellow annotation added).

74. Communications in Murakami’s PON system are carried out through “logical links.” EX1005, 1(57). Using PON interface 11, the OLT connects with one

or more ONUs via optical fiber and a passive optical splitter. EX1005, [0020]. Murakami describes communicating with ONUs through logical links. EX1005, 1(57). Murakami describes the establishment of logical links 120 for both point-to-point **and multicast communications**. EX1005, [0018] (“LLID 120 can be specified for point-to-point or multicasting, the only difference is mode bit 121, as shown in Figure 10[.]”).

75. Murakami discloses that ONUs comprising a multicast group can receive multicast services on a downstream logical link. For example, in Figure 3, Murakami illustrates two ONUs belonging to a multicast group, each connected to the OLT’s physical port 2, receiving multicast data communications via a downstream logical link having LLID 100:²

² Multicast Management Table 19 also illustrates a separate logical channel is established between the physical ports on the OLT and each ONU individually for point-to-point communications (indicated by “LLIDs for P2P” 1, 2, 3, and 5). EX1005, Fig. 3.

Figure 3

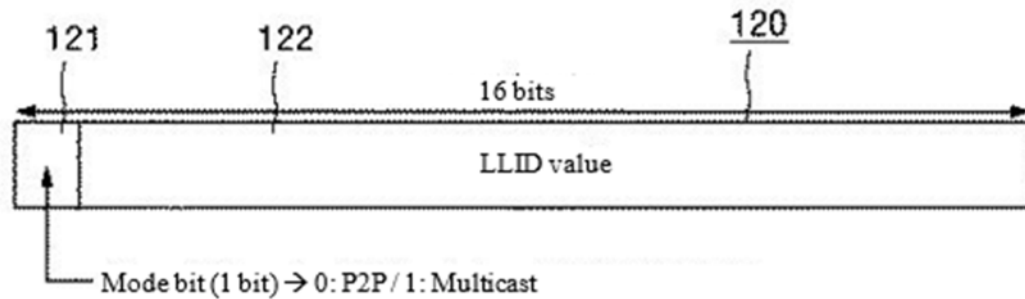
Multicast Management Table 19

Multicast Address (IP Group Address)	Access Port	ONU (LLID for P2P)	LLID for multicasting	Encryption key
yyy.yyy.yyy.yyy	2	1	100	# 1
		3		
	4	2	110	# 3
		5		
⋮	⋮	⋮	⋮	⋮

EX1005, Fig. 3.

76. “A logical link is identified by an LLID value, which is a unique identifier in PON.” EX1005, [0018]. “The LLID is defined in the preamble for the MAC frame and consists of 16 bits that include a mode bit, as shown in Figure 10.” *Id.* Murakami’s Figure 10 depicts this data structure:

Figure 10

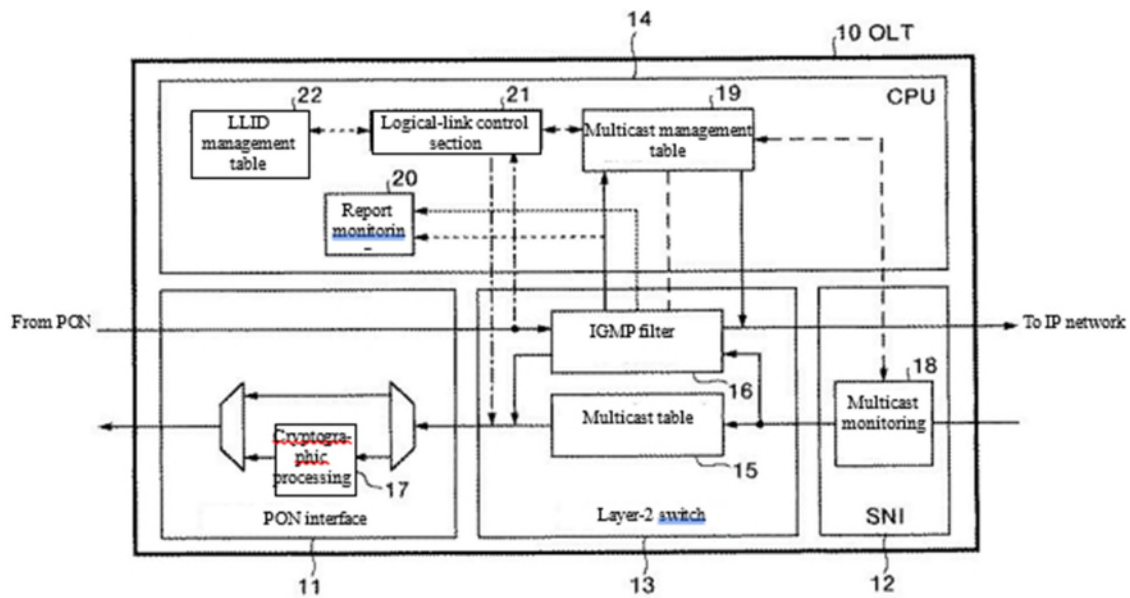


EX1005, Fig. 10.

77. These logical links are bearer channels. They bear the multicast communications downstream to ONUs. The '378 Patent acknowledges that a “logical channel” identified by a “logical link identification (LLID)” constitutes a “bearer channel.” EX1001, 4:4-8 (“Said bearer channel is a logical channel of the PON, and it can be the general encapsulation model (GEM) channel born by the GPON port **or the logical link identification (LLID) channel** of the EPON port[.]”) (emphasis added).

78. Murakami further discloses encrypting multicast service data of all multicast services communicated in this bearer channel. According to Murakami, “PON interface 11 is provided with cryptographic processing section 17 for encrypting multicast data.” EX1005, [0023]. The structure of the OLT, with its PON interface, is depicted in Figure 1:

Figure 1



EX1005, Fig. 1.

79. The OLT encrypts all data of all multicast services communicated in a particular bearer channel (*i.e.* logical link) with a key. Murakami describes encrypting all multicast frames received from the IP-network and destined for a particular multicast group with a key before transmitting them via the logical links. “[M]ulticast data arriving from SNI interface 12 are forwarded to the access port . . . , **encrypted with the encryption key corresponding to the multicast communication**

concerned (the encryption key corresponding to the encryption key index³ in the entry whose destination IP address matches the IP multicast address in the multicast management table), and then transmitted to PON interface 11.” EX1005, [0034] (emphasis added); *see also* EX1001, Claim 7. “Multicast management table 19” is stored on the OLT and managed by its CPU 14 using “report monitoring section 20.” EX1005, [0024], [0031], Fig. 1.

80. The Multicast Management Table 19 records information for each multicast group denoted by a unique IP Group address. EX1005, [0025]. For each multicast group, Multicast Management Table 19 associates the ONUs in that group with the OLT physical ports to which they are connected, with the logical link on that port over which multicast communications are made to each particular ONU, and with the encryption key used to encrypt the multicast communications on that link. EX1005, [0025], Fig. 3.

81. An example of Multicast Management Table 19 is shown in Murakami’s Figure 3. Murakami explains “there are two access ports (ports 2 and 4) for the multicast communication with the destination IP address of ‘yyy.yyy.yyy.yyy,’

³ The value recorded in Table 19 for the encryption key is an “index,” with the actual encryption key being managed by cryptographic processing section 17 of PON interface 11. EX1005, [0025].

allowing access by a total of four ONUs[.]” EX1005, [0025]. “For port 2, the LLID of the multicast logical link is 100, and the encryption key is #1,” and “[f]or port 4, the LLID of the multicast logical link is 110, and the encryption key is #3.” *Id.*

Figure 3

Multicast Management Table 19

Multicast Address (IP Group Address)	Access Port	ONU (LLID for P2P)	LLID for multicasting	Encryption key
yyy-yyy-yyy-yyy	2	1	100	#1
		3		
	4	2	110	#3
		5		
⋮	⋮	⋮	⋮	⋮

EX1005, Fig. 3.

82. In other words, all data for the different group multicast services communicated via link 100 to ONUs 1 and 3 (as denoted by their point-to-point LLIDs) is encrypted with encryption key #1 and all multicast data for all services communicated via link 110 to the remaining two ONUs is encrypted with encryption key #3. A POSA would understand that Murakami discloses that all multicast data for all

different multicast services transmitted on the same bearer channel (LLID 100 or 110) to ONUs that are members of a multicast group is encrypted with the same encryption key.

83. To the extent Murakami does not explicitly disclose encryption of multicast service data relating to *different* multicast services, RFCs 1112 and 4601 teach that (1) a multicast group is defined by an IP multicast address, (2) the content of communications to each such multicast group can be drawn from different services, and (3) all data packets from these different services are sent to members of the group. RFCs 1112 and 4601 are prior art. Each was published more than one year before the earliest claimed priority date for the '378 Patent.

84. RFCs 1112 and 4601 are both from the same field of endeavor as the '378 Patent and Murakami. The '378 Patent relates to the field of multicast communications, as does Murakami. EX1001, 1:7-10 (noting that invention relates to communication of multicast service data); EX1005, [0001] (“The invention pertains to a method and central office unit for multicast communication in a PON system[.]”). Both RFCs relate to the composition of multicast communications and protocols relating to its transmission. EX1006, 1 (RFC 1112 describing “IP multicasting”); EX1007, 4 (describing a protocol for routing communications to multicast groups).

85. RFC 1112 further describes what a POSA would understand to be version 1 of the Internet Group Management Protocol (IGMP). EX1006, 11-15. IGMP Version 2 is defined in similar terms in the successor RFC 2362. EX1010. RFC 4601 specifically implements the service model initially described in RFC 1112. EX1007, 6 (“Like all multicast routing protocols that implement the service model from RFC 1112[3], PIM-SIM must be able to route data packets from sources to receivers without either the sources or receivers knowing a priori of the existence of the others.”). Murakami expressly notes that it employs IGMP, including the versions then available as of the date of its publication, versions 1 and 2. EX1005, [0027].

86. Consistent with the ’378 Patent’s disclosures, RFC 1112 also characterizes “IP multicasting” as the transmission of an “IP datagram” to a “‘host group,’ a set of zero or more hosts **identified by a single IP destination address.**” EX1006, 1 (emphasis added); *compare* EX1001, Fig. 3 (showing members of multicast group identified by single IP group address). RFC 4601 expressly implements the service model described in RFC 1112. EX1007, 6.

87. RFC 1112 further explains that IP multicast datagrams are forwarded using “multicast routers.” EX1006, 1. RFC 4601 in turn describes an implementation of the model described in RFC 1112 in which multicast data is transmitted to a router that has been configured as a “root” for the multicast group. EX1007, 4-6

(describing multiple sources transmitting multicast data to a Rendezvous Point (RP)). As depicted above, Murakami similarly describes use of a multicast router 42 delivering multicast data to OLT 10 received from a data delivery server 45 in an IP network 43. EX1005, Fig. 4.

88. The RFCs are properly considered analogous art.

89. At least as early as August 1989, RFC 1112 disclosed to a POSA that multicast communications can be composed of data from a plurality of sources. As noted above, RFC 1112 confirmed that "IP multicasting" involves transmission of an IP datagram to "a single IP destination address" representing one or more recipients (*i.e.* hosts). EX1006, 1. Any number of sources may direct such IP datagrams to this single destination address. *See, e.g., id.* (noting that IP datagrams can be sent by sources other than those hosts constituting the members of the group).

90. RFC 4601 in turn further confirms that the implementation of the model described in RFC 1112 includes multicast data drawn from a plurality of sources. EX1007, 4 ("This document specifies a protocol for efficiently routing multicast groups that may span wide-area (and inter-domain) internets."). For example, hosts seeking to join a multicast group can issue a request to "join[] group G **for all sources to that group.**" *Id.* at 6 (emphasis added). Data sent by this plurality of sources is ultimately distributed to hosts (recipients) via a *shared tree*—"shared"

because it is employed “**by all sources sending to that group.**” EX1007, 6 (emphasis added).

91. Data from these different sources constitutes multicast service data of different multicast services, as recited in the claims. During prosecution of the '378 Patent, the applicant acknowledged that different multicast “data streams” equated to multicast service data of different multicast services. EX1002, 352 (arguing that nowhere did He encrypt “all multicast data streams” carried in a single bearer channel, as required by the claims). A POSA would understand, and it would have been obvious to such a person, that multicast data transmitted from a plurality of different sources can and would encompass data relating to different multicast services. In view of the RFC disclosures that *multiple different sources* (i.e., a plurality of different data streams) can send data packets to the *same* multicast group, a POSA would understand that Murakami’s multicasting communications can involve *different* multicast services sent to the *same* multicast group. Murakami’s OLT transmits all of these multicast services on the *same* multicast LLID/bearer channel, encrypting them with the same key.

92. Moreover, a POSA would have been motivated to employ the systems and methods described in Murakami to communicate multicast data encompassing different multicast services. I understand that a motivation to combine may be found

explicitly or implicitly in (i) market forces, (ii) design incentives, (iii) the interrelated teachings of multiple patents, (iv) any need or problem known in the field of endeavor at the time of invention and addressed by the patent, as well as (v) the background knowledge, creativity, and common sense of the person of ordinary skill.

93. Murakami described a system intended for the secure communication of multicast communications to multicast groups. Like these RFCs, Murakami's system employed the Internet Group Management Protocol (IGMP). EX1005, [0003]. Murakami did not suggest restricting its system to a single source of data and/or a single multicast service. Murakami's disclosures discuss the distribution to ONUs of conventional multicast communications addressed to a group IP address once received at the OLT. A POSA would have been motivated to employ such a system to communicate conventional configurations of multicast data, such as data drawn from different sources as described in these RFCs. A POSA would have been motivated to provide subscribers registered with a particular multicast group with data from more than one different multicast service to enhance the services offered to such subscribers and to deliver that data to a subscriber in a single bearer channel because to do so would be more efficient. A POSA would further employ Murakami's system to deliver encrypted data of all different multicast services in its bearer channel

because doing so would ensure compatibility with published standards protocols, such RFC 4601. *Id.* A POSA would also have been motivated to employ the IGMP protocol described in RFC 4601, with its ability for hosts to join all sources of different multicast services, because a POSA would have wished to take advantage of this and other advantages discussed below that are introduced by RFC 4601. As discussed below, Murakami's system and methods are compatible with multicast data consisting of different multicast services generated and used.

94. Indeed, a POSA would not have undertaken to differentiate multicast data comprised of data from a plurality of sources (as described in RFC 4601) based upon its source. Nor would a POSA have otherwise sought to differently encrypt that data based upon its original source. Murakami's disclosures (*e.g.* data entries reflected in Multicast Management Table 19) do not contemplate differentiating between sources of multicast data received by multicast router 42 and transmitted to OLT 10. Doing so would have required Murakami's system to monitor the source addresses of multicast communications and establish either unique logical links for each source, or different encryption keys therefor, or both. Such an arrangement would require establishing more than one logical channel for each port devoted to multicast content originating each different source, unnecessarily multiplying the number of logical channels, adding unneeded complexity to the establishment and

maintenance of such channels, and pointlessly increasing processing overhead. Alternatively, separately encrypting data based upon its source, multiplies the number of unique keys needed to encrypt these multicast communications, increases the complexity surrounding the generation, assignment, maintenance of the keys securing such communications, complicates the process of decryption that now must assess the data's origin to determine the proper key for decryption, and unnecessarily increases the processing overhead at both the OLT and ONU which must differentiate content based upon source and process differently with respect to the keys used to encrypt/decrypt.

95. A POSA would have reasonably expected success in combining data from these different services in the multicasting made to ONUs on a particular bearer channel, and in encrypting that data with the key disclosed in Murakami. I understand that a reasonable expectation is shown where POSA could have combined the elements as claimed by known methods with no change in their respective functions, and the combination would have yielded nothing more than predictable results.

96. Murakami describes an infrastructure that can receive multicast data from a plurality of sources for communication to ONUs. Consistent with the descriptions in RFC4601, Murakami explains that the IP network 43 streams multicast data from data delivery servers 45 to the multicast router 42, where it is passed to

the OLT. *Compare* EX1005, [0026] (“multicast data 45 from data delivery server 44 in IP network 43 reaches multicast router 42 connected to OLT 10”) *with* EX1007, 4, 6, and 8 (describing a “multicast receiver” that communicates with a “local router” that forwards “join messages” (*i.e.*, expressions of interest in receiving multicast traffic) to a router configured to be used as a root of the “non-source specific” distribution).

97. Murakami also employs the IGMP protocols incorporated in RFC 4601. EX1005, Fig. 4 and [0027]; EX1007, 6 (noting that the PIM-SM protocol routes packets from sources to receivers in a manner consistent with the service model described in RFC 1112). In fact, earlier versions of IGMP referenced by Murakami did not permit a receiver joining a multicast group to opt out of receipt of **all** multicast communications. EX1007, 7 (noting that expanded IGMPv3 now “permits a receiver to join a group and specify that it only wants to receive traffic for a group if that traffic comes from a particular source”).

98. Murakami’s encryption key is a “common key.” It is a single key used both to encrypt and decrypt the multicast data communicated on a particular bearer channel. This would have been evident to a POSA from Murakami’s discussion of sharing the key used to encrypt the information with the ONUs for purposes of decrypting that information.

99. Murakami explains that when an ONU registers with the OLT as a member of a multicast group, the OLT accesses the Multicast Management Table 19 to determine if there already exists an ONU communicating on the same physical port that is a member of this multicast group. EX1005, [0029]. If so, the OLT adds an entry to the Multicast Management Table 19 associating the newly registered ONU with the multicast group address. EX1005, [0035]-[0036]. The entry also associates the ONU with the physical port on which such multicast group communications are to occur. EX1005, [0037]. The LLID of the logical link on which it and the other previously registered ONUs are to receive the multicast data is denoted for the new ONU. *Id.* The entry made in the Multicast Management Table 19 also specifies the index number of the encryption key to be used for transmissions of multicast data on this logical link to the previously registered and newly registered ONUs. EX1005, [0039]. The OLT then “transmits [that encryption key] to the point-to-point logical link 41” connecting the OLT with the particular, newly registered ONU. *Id.* **The ONU uses the same encryption key to decrypt the received multicast data.** EX1005, Claim 5 (“after setting up the multicasting logical link, uses a point-to-

point logical link pre-set for the aforementioned subscriber-side unit to distribute an encryption key, which is to be used in the aforementioned multicast logical link”).⁴

100. Thus, Murakami discloses using a common key to encrypt multicast service data of all *different* multicast services in a same bearer channel and then sending the encrypted data, and/or a POSA would have considered it obvious to use a common key to encrypt multicast service data of all different multicast services in a same bearer channel and then send the encrypted data, based upon the disclosures in Murakami, RFCs 1112 and 4601, and his knowledge.

Element 1[c]: wherein the multicast service data of all different multicast services in the same one bearer channel use a same common key to carry out encryption; and

101. Murakami discloses this element and/or a POSA would have considered it obvious based upon the disclosures in Murakami, RFCs 1112 and 4601, and his knowledge. *See* Element 1[b], above.

Element 1[d]: said OLT sending the common key applied in encrypting the multicast service data via a management control channel to an optical network unit (ONU) that is activated successfully and applies to receive said multicast service data.

⁴ Murakami describes a similar process where the registering ONU is the first to register on a particular port as a member of a multicast group. EX1005, [0029]-[0031].

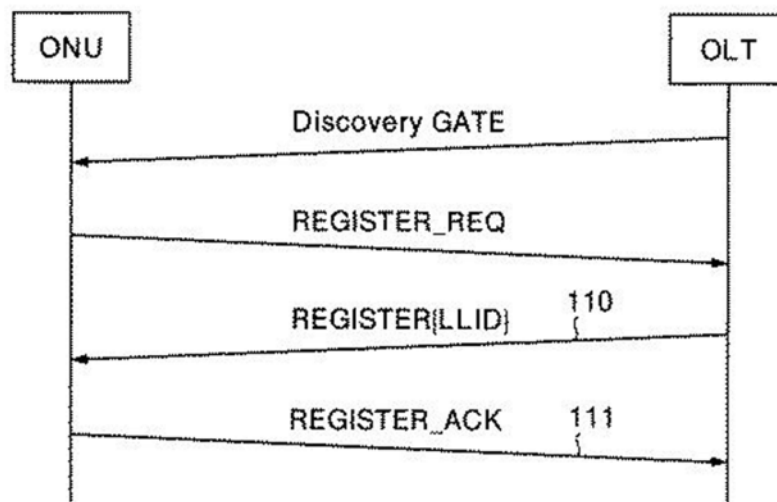
102. Murakami discloses this element. Murakami communicates the common key to an ONU only after it has been activated successfully and applies to receive the multicast service. See Element 1[b], above. Indeed, the applicant made no claim of novelty for this step. EX1001, 5:17-19 (“the specific procedure of registration and multicast service application has been defined relevantly in the EPON protocol and will be omitted here”) and 4:51-53 (“the specific procedure of registration and multicast service application has been defined relevantly in the GPON protocol and will be omitted here”).

103. For example, Murakami describes an OLT which receives a report message at interface 11 from an ONU. The OLT snoops this message using IGMP filter section 16. EX1005, [0045]. The OLT 10 snoops the message “to control the setting of logical links for multicasting” and to “distribute encryption keys for use in multicast communication.” EX1005, 1(57).

104. The OLT 10 captures “report messages” from the ONU which also have a MAC frame destination address that is a multicast address. EX1005, [0027]. In this manner, the ONU applies to receive multicast services via the OLT from the multicast router 42. “OLT 10 then sets up a multicast logical link for the ONU that has

made access.” EX1005, [0030]. The OLT transmits REGISTER message 110 containing said LLID to point-to-point logical link 41 of the ONU concerned. *Id.* at [0031] and Fig. 9. “The ONU concerned, upon receipt of the REGISTER message 110, uses the LLID stored in message 110 as the LLID of the multicast logical link and transmits REGISTER_ACK message 111”, confirming that REGISTER message 110 has been correctly received. EX1005, [0031]. These exchanges are illustrated in Figure 9, below:

Figure 9



EX1005, Fig. 9.

105. Only after the ONU has thus been activated successfully does the OLT now communicate the appropriate encryption key. EX1005, [0032] (“Now, said encryption key may be included in REGISTER message 110.”). The REGISTER message is encrypted to prevent the stored encryption key from being eavesdropped by another ONU not authorized to receive the multicast data. *Id.* The encryption key is communicated to the ONU on a point-to-point logical link established between the OLT and the particular ONU different from the logical link on which the OLT will communicate multicast data to the ONU. *Id.* A POSA would understand that this point-to-point logical link is “a management control channel.”

106. A POSA would understand in view of these disclosures that Murakami discloses that the OLT sends the common key applied in encrypting the multicast service data via a management control channel to an ONU *that is activated successfully* and who *applies to receive said multicast service data*.

107. The method recited in Claim 1 would have been obvious to a POSA at least as early as the date of RFC 4601’s publication.

2. Claim 2

The method of claim 1, further comprising: after obtaining the common key, said ONU using said common key to decrypt all the multicast service data, which the ONU applies to receive, in the bearer channel.

108. Murakami discloses this element. *See* Elements 1[b] and 1[d], above. To the extent that Murakami does not expressly disclose use of the common key to decrypt the multicast service data, such use would have been obvious to a POSA based upon Murakami's disclosures and the knowledge of a POSA.

109. A POSA would have understood that Murakami discloses a system in which an ONU is the terminus of communications with a subscriber receiving multicast communications. EX1005, [0057] (noting that an ONU may, but need not, accommodate multiple user network interfaces (*i.e.*, subscriber ports)). In such a case, the ONU must necessarily decrypt the multicast communication intended for the recipient associated with that ONU for the multicast communication to be of any use for that subscriber.

110. The method recited in Claim 2 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

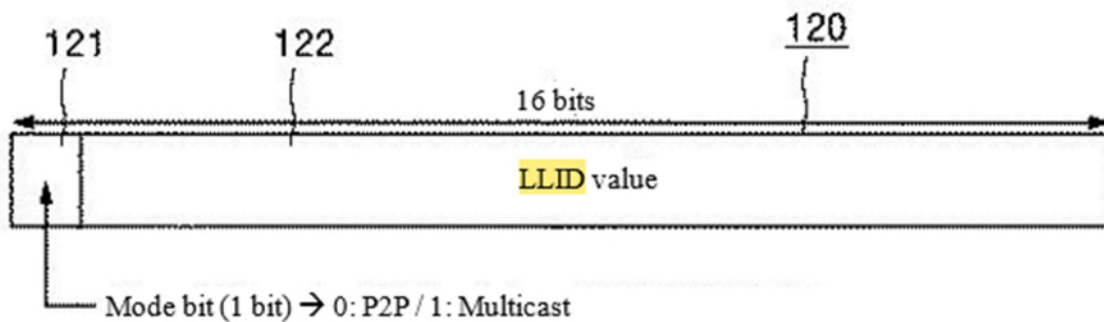
3. Claim 4

The method of claim 2, wherein: in the step of said OLT sending the common key to the ONU that is activated successfully and applies to receive said multicast service data, said OLT also sends the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key.
--

111. Murakami discloses this element. *See* Claim 2, above. Murakami discloses that the OLT sends the ONU a bearer channel identification of the bearer

channel where all multicast service data are encrypted with the common key. Murakami describes sending each successfully activated ONU who has applied to receive multicast service data a “REGISTER message 110 containing the LLID thus selected,” informing it of the bearer channel upon which multicast service data will be transmitted. EX1005, [0037]-[0038] (“upon receipt of the REGISTER message 110, [the ONU] uses the LLID stored in said REGISTER message 110 as the LLID of the multicast logical link”) and [0018] (“The LLID is selected in the OLT and notified to the ONU.”). The structure of the message sent by the OLT to the ONU is illustrated in Figure 10 and depicts the inclusion of the LLID identifying the bearer channel:

Figure 10



EX1005, Fig. 10 (yellow annotation added).

112. The method recited in Claim 4 would have been obvious to a POSA at least as early as the date of RFC 4601’s publication.

4. Claim 6

The method of claim 1, wherein: the step of said OLT sending the common key applied in encrypting the multicast service data to the ONU that is activated successfully and applies to receive said multicast service data comprises: the OLT judging that the ONU is activated successfully and applies to receive the multicast service data, and actively sending the common key applied in encrypting the multicast service data to said ONU; or the ONU sending a key request to the OLT, and said OLT detecting that the ONU is activated successfully and applies to receive the multicast service data, then the OLT sending the common key applied in encrypting said multicast service data to the ONU.

113. Murakami discloses the elements of Claim 6. Murakami describes the step of an OLT actively sending the common key applied in encrypting the multicast service data to the ONU that is activated successfully and applies to receive said multicast service data. *See* Element 1[d] and Claim 4, above.

114. Murakami discloses that this step may comprise ONU sending a key request to the OLT, and said OLT both judging and detecting that the ONU is activated successfully and applies to receive the multicast service data, then the OLT actively sending the common key applied in encrypting said multicast service data to the ONU. *See also* Element 1[d] and Claim 4, above.

115. The method recited in Claim 6 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

5. Claim 7

The method of claim 1, wherein: the multicast service data in different bearer channels use different common keys or the same common key.

116. Murakami discloses this element. Murakami discloses that different bearer channels (*e.g.* LLIDs 100 and 110) use different common keys (*e.g.* Encryption Key #1 and Encryption Key #3). *See* Element 3[d], above. The method recited in Claim 7 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

6. Claim 8

The method of claim 1, wherein: in the step of said OLT sending the common key to the ONU that is activated successfully and applies to receive said multicast service data, said OLT also sends the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key.

117. Murakami discloses this element. *See* Claim 4, above. The method recited in Claim 8 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

7. Claim 9

a. Element 9[a]

A device for encrypting multicast service in a passive optical network system, and the device comprising a key generation unit, an encryption unit and a sending unit, wherein: said key generation unit is configured to: generate a common key;

118. Murakami discloses this element. Murakami discloses a device for encrypting multicast service in a passive optical network system. *See* Element 1[a], above.

119. Murakami discloses such a system having an encryption unit and a sending unit. *See* Element 9[b]-9[c], below.

120. Murakami discloses such a system having a key generation unit configured to generate a common key. I understand that a claim term that fails to recite sufficiently definite structure or else recites function without reciting sufficient structure for performing that function, is to be construed as encompassing only that specific structure disclosed in the patent’s specification that is clearly linked with the performance of the recited function—so-called “mean-plus-function” limitations. I understand that the standard is whether the words of the claim are understood by POSAs to have a sufficiently definite meaning as the name for structure, although

that structure may cover a broad class of structures, such as filters, brakes, clamps, etc.

121. I understand that there is a presumption that the claim term is not means-plus-function limitation if it does not employ the term “means.” However, I understand that this presumption is overcome if the claim terms merely serve as a generic placeholder and thus does not limit the scope of the claim to any specific manner or structure for performing the claimed function.

122. The limitation “key generation unit” would not have been understood by a POSA at the time of the priority date as having a sufficiently definite meaning as a name for particular structure or class of structures. The limitation recites the function of key generation, without reciting sufficient structure for generating a key.

123. In the event a limitation is a “means-plus-function” limitation, I understand that the scope of that limitation is limited to the structure, material, or acts that are disclosed in the specification to perform that function. I understand that this determination is made from the point of view of a POSA and what they would understand from the specification constitutes the corresponding structure, material, or acts. I understand that the specification must nevertheless clearly link or associate the corresponding structure, material, or acts to the claimed function.

124. In the '378 Patent specification, the only structure explicitly linked to the performance of the key generating function is the OLT. EX1001, Abstract (“an Optical Line Terminal (OLT) generating a public key”), 1:66-67 (same), 2:13 (same), 3:48, 61-62 (same), Figs. 1-4 and accompanying discussion (same).

125. For purposes of my opinion, however, whether or not the limitation “key generating unit” is considered a “means-plus-function” limitation, the '378 patent specification acknowledges that at least an OLT will satisfy the limitation of a key generation unit.

126. As discussed above, Murakami discloses an OLT that generates a common key. *See* Element 1[a], above.

b. Element 9[b]

said encryption unit is configured to: encrypt multicast service data of all different multicast services born in a same one bearer channel with a same common key;

127. Murakami discloses this element.

128. In light of the principles discussed above, the term “encryption unit” is properly construed as a means-plus-function limitation. The limitation “encryption unit” would not have been understood by a POSA at the time of the priority date as having a sufficiently definite meaning as a name for particular structure or class of

structures. The limitation recites the function of encryption, without reciting sufficient structure for doing so.

129. In the '378 Patent specification, the only structure explicitly linked to the performance of the encrypting function is the OLT. EX1001, Abstract (“an Optical Line Terminal (OLT) generating a public key, and using the public key to encrypt the multicast service data in a bearer channel”), 1:66-2:1 (same), 2:13-16 (same), 3:48-49, 61-65 (same), Figs. 1-4 and accompanying discussion (same).

130. For purposes of my opinion, however, whether or not the limitation “encryption unit” is considered a “means-plus-function” limitation, the '378 patent specification nevertheless acknowledges that an OLT will satisfy this limitation.

131. As discussed above, Murakami discloses an OLT that encrypts multicast service data of all different multicast services borne in a same one bearer channel with a same common key. *See* Element 1[b], above.

c. Element 9[c]

said sending unit is configured to: send the encrypted multicast service data, and send the common key applied in encrypting the multicast service data via a management control channel to an optical network unit (ONU) that is activated successfully and applies to receive the multicast service data.

132. Murakami discloses this element.

133. In light of the principles discussed above, the term “sending unit” is properly construed as a means-plus-function limitation. The limitation “sending

unit” would not have been understood by a POSA at the time of the priority date as having a sufficiently definite meaning as a name for particular structure or class of structures. The limitation recites the function of sending, without reciting sufficient structure for doing so.

134. In the '378 Patent specification, the only structure explicitly linked to the performance of the sending function is the OLT. EX1001, Abstract (“an Optical Line Terminal (OLT) . . . transmitting the encrypted data . . . and said OLT sending the public key”), 1:66-2:4 (same), 2:13-18 (same), 3:47-52 (same), Figs. 1-4 and accompanying discussion (same).

135. For purposes of my opinion, however, whether or not the limitation “sending unit” is considered a “means-plus-function” limitation, the '378 patent specification acknowledges that at least an OLT will satisfy this limitation.

136. As discussed above, Murakami discloses an OLT that sends the encrypted multicast service data, as well as sends the common key applied in encrypting the multicast service data via a management control channel to an optical network unit (ONU) that is activated successfully and applies to receive the multicast service data. *See* Element 1[d], above.

137. The device recited in Claim 9 would have been obvious to a POSA at least as early as the date of RFC 4601’s publication.

8. Claim 11

The device of claim 9, wherein: said sending unit is configured to apply following methods to send the common key applied in encrypting the multicast service data to the ONU that is activated successfully and applies to receive the multicast service data: after judging that the ONU is activated successfully and applies to receive the multicast service data, actively sending the common key applied in encrypting the multicast service data to said ONU; or, after receiving a key request from the ONU, judging that the ONU is activated successfully and applies to receive the multicast service data, and then sending the common key applied in encrypting the multicast service data to the ONU.

138. Murakami discloses this element. Murakami discloses a device recited in Claim 9. *See* Claim 9, above.

139. Murakami describes the step of an OLT actively sending the common key applied in encrypting the multicast service data to the ONU that is activated successfully and applies to receive said multicast service data. *See* Claim 6 and Element 1[d], above.

140. Murakami discloses that this step may comprise an ONU sending a key request to the OLT, and said OLT both judging and detecting that the ONU is activated successfully and has applied to receive the multicast service data, then the OLT actively sending the common key applied in encrypting said multicast service data to the ONU. *See* Claim 6 and Element 1[d], above.

141. The device recited in Claim 11 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

9. Claim 12

The device of claim 9, wherein, said sending unit is also configured to: send the common key to the ONU which is activated successfully and applies to receive the multicast service data, and also send the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key.

142. Murakami discloses this element. Murakami discloses the device recited in Claim 9. *See* Claim 9, above.

143. Murakami discloses a device having a sending unit configured to send the common key to the ONU which is activated successfully and applies to receive the multicast service data. *See* Claim 11, above.

144. Murakami also discloses that the sending unit (OLT) sends the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key. *See* Claim 4, above.

145. The device recited in Claim 12 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

10. Claim 13

a. Element 13[a]

The device of claim 11, wherein, said sending unit is also configured to: send the common key to the ONU which is activated successfully and applies to receive the multicast service data, and

146. Murakami discloses this element. Murakami discloses the device recited in Claim 11. *See* Claim 11, above.

147. Murakami also discloses the device having a sending unit (OLT) configured to send the common key to the ONU which is activated successfully and applies to receive the multicast service data. *See* Claim 11, above.

b. Element 13[b]

also send the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key.

148. Murakami discloses this element. Murakami discloses the device's sending unit (OLT) is also configured to send the ONU a bearer channel identification of the bearer channel where all multicast service data are encrypted with the common key. *See* Claim 12, above.

149. The device recited in Claim 13 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

B. Claims 3, 8, 11 are Obvious in light of JP2004-343243A in view of RFCs 1112 and 4601 and knowledge of persons of skill, and in further view of U.S. Patent Appl. 2002/0150097 A1 ("Yen")

1. Claim 3

a. Element 3[a]

The method of claim 2, further comprising: said OLT generating the common key and setting an aging time for the common key, and

150. Murakami discloses the OLT generating the common key. *See* Elements 1[b] and 1[d], above. Murakami discloses the method recited in Claim 2, and/or such a method would have been obvious to a POSA at the time of Murakami’s publication. *See* Claim 2, above.

151. A POSA would have deemed it obvious to set an aging time for the common key based upon the disclosures in Murakami in view of Published U.S. Patent Appl. 2002/0150097 A1 (“Yen”). Yen was published October 17, 2002, and is analogous prior art. EX1008, 1(43). It is from the same field of endeavor as Murakami and the invention and is also reasonably pertinent to the particular problem with which the inventor is involved (*i.e.* securing multicast communications). EX1008, [0002] (“The present invention is directed to a method and apparatus for secured multicasting [in a PON].”). Yen describes a “multicasting churning key scheme [that] provides privacy against eavesdropping by unauthorized or potentially malicious third parties.” EX1008, [0018]; *compare* EX1001, 7:50-58 (describing invention’s concerns with malicious users stealing the multicast service content).

152. Yen’s churning key is the equivalent of the claimed common key. According to Yen, its churning key may be sent by the OLT to all ONUs authorized to receive the multicast broadcast for subsequent use by each ONU in descrambling the multicast communication. EX1008, [0027] (“However, prior to transmitting the

scrambled message to all the subscribing ONTs, the OLT preferably sends to all the other subscribing ONTs the group leader ONT's churning key.”) and [0029] (“OLT selects **a common, multicast, churning key** and sends the churning key to all the subscribing ONTs.”) (emphasis added).⁵

153. Yen further discloses setting a “key interval” at the time a churning key is distributed. EX1008, [0016] (teaching that a “churning key is then updated at a given churning **key interval**”) (emphasis added) and [0031] (noting that the key interval is set by the OLT)).

154. A POSA would have been motivated to add Yen’s key aging feature to Murakami’s system and method in order to further ensure secure communication. Murakami expressed concerns that subscriber authorizations could become stale and proposed, in that circumstance, that authorizations expire. EX1005, Claim 8, [0028] (describing the maximum response-time field that specifies the maximum amount of waiting time before a report message is received), and [0048] (explaining that

⁵ While Yen describes soliciting the churning key from the lead ONU, this distinction is irrelevant to Yen’s teachings of securing that distributed key against malicious users by means of predetermined obsolescence. In addition, while Yen includes embodiments in which the ONUs instead receive a value representing the difference between a churning key suggested by each ONU and that suggested by the lead ONU, by which each ONU is then able to calculate the lead ONU’s churning key, this represents merely an alternative embodiment.

system entries in Multicasting Management Table 19 are deleted for ONUs that have failed to respond within a particular interval).

155. A POSA would have been motivated to periodically change the common key to defeat efforts to hack the system to gain access. For example, sunseting decryption keys reduces the time available to hackers seeking to mount a successful brute-force attack.

156. The movie *The Imitation Game* provides an analogy. In that film, set during World War II, Alan Turing and his British colleagues attempt to break the German's enigma code. Their efforts to crack this code through typical cryptographic techniques proves futile, however, because each day the Germans reset the code, rendering the preceding progress towards breaking that code useless. In other words, the Germans set a twenty-four (24) hour aging time for the key where, after the aging time arrived, a new key was generated.

157. A POSA would have been motivated to incorporate Yen's key aging method to further protect the multicast communications against unauthorized interception, and to ensure that only ONU's in authorized communication with the OLT remain recipients of multicast communications.

158. Applying Yen’s aging method to the common key also necessitates that the key be regenerated once its aging time has elapsed, so that communications may continue with the multicast group.

159. A POSA would have reasonably expected that Murakami’s system and methods could have been modified to incorporate Yen’s sunsetting feature. Murakami describes a system capable of soliciting responses from ONUs concerning their authorization and desire to receive multicast communications (*i.e.* Query messages). EX1005, [0004] (noting that in widely used methods “[a] multicast router ***periodically*** multicasts query messages (Query messages) and acknowledges its members by the presence or absence of report messages (Report messages) from each host”) (emphasis added). A POSA would have known to schedule such a communication by the OLT upon the expiration of a pre-set interval, and to invoke its key generation process as if the ONUs were newly applying for access. Ex1005, [0027]-[0041] (describing process of populating Multicast management Table 19 with entries relating to members of multicast group and the generation of encryption keys for same).

b. Element 3[b]

after the aging time arrives, it regenerating a new common key, and

160. This element would have been obvious to a POSA in light of the disclosures in Murakami in view of Yen. Murakami discloses the ability of the OLT to generate new common keys for use in encrypting multicast communications. EX1005, [0027]-[0041] (“OLT 10 generates a new encryption key used in this multicast communication[.]”). Yen teaches the establishment of a key interval upon the expiration of which the OLT will establish a new “churning key” and distribute that key to all affected ONUs for use in decrypting multicast communications. EX1008, [0031]) (disclosing that upon the expiration of the key interval, the OLT establishes a new churning key and “then send[s] to all the subscribing ONTs the new churning key as the updated multicast key”) and 1(57) (“[T]he central network device [*i.e.* OLT] periodically updates the multicast encryption key[.]”).

161. For the reasons set for the above in connection with Element 3[a], a POSA would have been motivated to regenerate a new common key upon expiration of the aging time and would have expected that such a facility could have been incorporated into the system/method disclosed in Murakami.

c. Element 3[c]

using the new common key to encrypt the multicast service data in the bearer channel, and

162. This element would have been obvious to a POSA in light of the disclosures in Murakami in view of Yen. As noted above, Murakami discloses the use of a common key to encrypt multicast services data in the bearer channel. *See* Elements 1[a]-1[d]. Yen teaches the establishment of a time for updating such a key. *See* Elements 3[a]-3[b].

d. Element 3[d]

sending the new common key to the ONU that is activated successfully and applies for the multicast service data.

163. This element would have been obvious to a POSA in light of the disclosures in Murakami in view of Yen. As noted above, Murakami discloses sending a common key to ONUs that are successfully activated and who apply to receive the multicast service data. *See* Elements 1[a]-1[d]. Yen similarly teaches the updating of such a key and its distribution to ONUs that have been activated successfully and who have applied to receive multicast service data. *See* Elements 3[a]-3[b].

164. For the reasons set for the above in connection with Element 3[a], a POSA would have been motivated to send the new common key to the ONU that is activated successfully and applies for the multicast service data in order that such an ONU could decrypt those communications. *See* Claim 2, above.

165. The method recited in Claim 3 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

2. Claim 5

a. Element 5[a]

The method of claim 1, further comprising: said OLT generating the common key and setting an aging time for the common key, and

166. Murakami discloses this element. *See* Element 3[a], above.

b. Element 5[b]

after the aging time arrives, it regenerating a new common key, and

167. Murakami discloses this element. *See* Element 3[b], above.

c. Element 5[c]

using the new common key to encrypt the multicast service data in the bearer channel, and

168. Murakami discloses this element. *See* Element 3[c], above; *see also* Element 1[b], above.

d. Element 5[d]

sending the new common key to the ONU that is activated successfully and applies for the multicast service data.

169. Murakami discloses this element. *See* Element 3[d], above.

170. The method recited in Claim 5 would have been obvious to a POSA at least as early as the date of RFC 4601's publication.

3. Claim 10

The device of claim 9, wherein, said device also comprises an aging time setting unit, and said aging time setting unit is configured to: set an aging time for the common key, and when the aging time arrives, notifying said key generation unit to regenerate a common key.

171. Murakami discloses this element. Murakami discloses a device recited in Claim 9. *See* Claim 9, above.

172. Murakami discloses such a system having an aging time setting unit configured to set an aging time for the common key, and when the aging time arrives, notifying said key generation unit to regenerate a common key.

173. In light of the principles discussed above, the term “aging time setting unit” is properly construed as a means-plus-function limitation. The limitation “aging time setting unit” would not have been understood by a POSA at the time of the priority date as having a sufficiently definite meaning as a name for particular structure or class of structures. The limitation recites the function of setting an aging time, without reciting sufficient structure for doing so.

174. In the '378 Patent specification, the only structure explicitly linked to the performance of the aging time setting function is the OLT. EX1001, 2:13 (“said

OLT generating the public key and setting an aging time for the public key”), 3:61-63 (same), Fig. 2 and accompanying discussion (same).

175. For purposes of my opinion, however, whether or not the limitation “aging time setting unit” is considered a “means-plus-function” limitation, the ’378 patent specification nevertheless asserts that an OLT will satisfy this limitation.

176. As discussed above, Yen discloses an OLT sets an aging time or the common key. *See* Element 3[a], above.

177. As further discussed above, it would have been obvious to a POSA based upon the disclosures in Murakami and Yen to have an OLT that is notified of the expiration of an aging time in order that it regenerates a common key. *See* Element 3[a]-[b], above.

178. The method recited in Claim 10 would have been obvious to a POSA at least as early as the date of RFC 4601’s publication.

VIII. CONCLUSION

179. For the reasons discussed above, a POSA would have viewed Claim 1-13 of the ’378 Patent to have been obvious at least as early as the date of RFC 4601’s publication.

Signature Page Follows.

This declaration and my opinions herein are made to the best of my knowledge and understanding, and based on the material available to me, at the time of signing this declaration. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. (28 U.S.C. §1746).



Date: August 9, 2024

GEORGE ROUSKAS, PH.D.

EXHIBIT 1

VITA

George N. Rouskas

Alumni Distinguished Graduate Professor

Department of Computer Science
North Carolina State University
Raleigh, NC 27695-8206
<http://rouskas.csc.ncsu.edu/>

July 2024

Education

Ph.D.	1994	Georgia Institute of Technology	Computer Science
M.S.	1991	Georgia Institute of Technology	Computer Science
B.S.	1989	National Technical University of Athens	Computer Engineering

Employment History

Alumni Distinguished Graduate Professor (Professor 2002-2018 Associate Professor 1999-2002 Assistant Professor 1994-1999)	Department of Computer Science North Carolina State University Raleigh, NC	1994-present
Director of Graduate Programs	Department of Computer Science	January 2014-June 2024

Visiting Positions

Distinguished Scientist	King Abdulaziz University, Saudi Arabia	2013-2021
Visiting Professor	Laboratoire d'Informatique University of Paris 6, France	October 2012
Visiting Professor	Universidad Tecnica Federico Santa Maria, Chile	December 2008
Visiting Professor	Laboratoire de Méthodes Informatiques University of Evry, France	July 2006 December 2002 June 2000
Network Architect (Sabbatical)	Vitesse Semiconductor	August 2000-May 2001

Honors and Awards

OUTSTANDING TECHNICAL ACHIEVEMENT AWARD, ONTC, IEEE Communications Society, 2024
PERSON OF EXCEPTIONAL PERFORMANCE (PEP) AWARD, Department of Computer Science, 2023-24
CARLA SAVAGE AWARD, Department of Computer Science, October 2020
OUTSTANDING SERVICE AWARD, Optical Networking Tech. Cmte (ONTC), IEEE Commun. Society, 2019
ALUMNI DISTINGUISHED GRADUATE PROFESSOR, NC State, 2018
JOYCE HATCH SERVICE AWARD, NC State Chapter of ACM/AITP, 2015

MOST RECEPTIVE GRADUATE PROFESSOR AWARD, NC State Chapter of ACM/AITP, 2014
FELLOW, INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE), 2012
CAROL MILLER GRADUATE LECTURER AWARD, NC State Chapter of ACM/AITP, 2012
IEEE DISTINGUISHED LECTURER, 2010-2011
OUTSTANDING SERVICE AWARD, IEEE GLOBECOM, 2010
IBM FACULTY AWARD, 2007
BEST PAPER AWARD, *EVGM Workshop*, 2007 (with C. Castillo and K. Harfoush)
BEST PAPER AWARD, *CSNDSP Symposium*, 2006 (with B. Chen and R. Dutta)
ALCOA FOUNDATION ENGINEERING RESEARCH ACHIEVEMENT AWARD, CoE, NC State, 2004
ACADEMY OF OUTSTANDING TEACHERS, NC State, 2004
ALUMNI OUTSTANDING RESEARCH AWARD, NC State, 2003
BEST PAPER AWARD, *SPIE Conference on All-Optical Networking*, 1998 (with I. Baldine)
CAREER AWARD, NATIONAL SCIENCE FOUNDATION (NSF), 1997
OUTSTANDING NEW TEACHER AWARD, Department of Computer Science, NC State, 1995
GRADUATE RESEARCH AWARD, College of Computing, Georgia Institute of Technology, 1994

I. Teaching and Mentoring

Courses Taught

- CSC 316 – DATA STRUCTURES (undergraduate)
- CSC 401 – COMPUTER NETWORKS (undergraduate)
- CSC/ECE 573 – INTERNET PROTOCOLS (graduate)
- CSC/ECE 579 – INTRODUCTION TO COMPUTER PERFORMANCE EVALUATION (graduate)
- CSC/ECE 772 – SURVIVABLE NETWORKS (graduate)
- CSC/ECE 778 – OPTICAL NETWORKS (graduate)

Visiting Scholars

4. DR. KAMAL JAMBI, 2018-19 (King Abdulaziz University, Jeddah, Saudi Arabia)
Research: *Machine Learning Applications to Network Control Plane*
3. DR. YU XIONG, 2016-2017 (Chongqing University of Posts and Telecommunications (CUPT), China)
Research: *Optical and Datacenter Networks*
2. DR. OMAR BATARFI, 2014-2015 (King Abdulaziz University, Jeddah, Saudi Arabia)
Research: *Visible Light Communications*
1. DR. EVRIPIDIS BAMPIS, 2005-2006 (Paris VI University, France)
Research: *Packet Scheduling*

Post Doctoral Fellows

3. DR. EMRE YETGINER, 2008-2009
Research: *Traffic Grooming for Green Optical Networking*
2. DR. A. HALIM ZAIM, 2001-2002
Research: *Implementation of Signaling Protocols for Optical Burst-Switched Networks*
1. DR. SRIDHAR RAMESH, 1999-2000
Research: *Performance Analysis of Wavelength Routed Networks*

Ph.D. Students Supervised – Graduated

25. LINGNAN GAO, 2019
Dissertation: *Resource Allocation in Virtual Network Environments*
Outstanding Research Award, 2019
Outstanding Teaching Assistant Award, 2016
24. SHIREESH BHAT, 2017
Dissertation: *Network Service Orchestration within the ChoiceNet Architecture*
23. RAMESH KRISHNAMURTHY, 2016
Dissertation: *A Framework for Evaluating Server Performance: Application to SIP Proxy Servers*

22. SAHAR TALEBI, 2015
Dissertation: *On Routing and Spectrum Assignment in Elastic Optical Networks*
21. AHMET CAN BABAOGLU, 2014
Dissertation: *Verification Services for the Choice-Based Internet of the Future*
20. HUI WANG, 2013
Dissertation: *Efficient Decomposition Techniques for Traffic Grooming Problems in Optical Networks*
19. ZEYU LIU, 2012
Dissertation: *On Routing and Wavelength Assignment in WDM Networks*
18. MOHAN IYER, 2010
Dissertation: *Providing Bandwidth on Demand Services Using Optical Network Design and the SILO Network Architecture*
Outstanding Teaching Assistant Award, 2009
17. QIAN LV (2010)
Dissertation: *Economic Models for Internet Tiered Services*
16. ANJING WANG, 2010
Dissertation: *Optimization of Silo Services for the Future Internet*
Outstanding Teaching Assistant Award, 2009
15. ZYAD DWEKAT 2009
Dissertation: *Practical Fair Queueing Schedulers: Simplification Through Quantization*
14. CLARIS CASTILLO, 2008
Dissertation: *Scheduling and Resource Management in Grids*
College of Engineering Nancy G. Pollock PhD Dissertation Award, 2008
Google Anita Borg Scholarship, 2007
Outstanding Teaching Assistant Award, 2006
13. LI YANG, 2006
Dissertation: *Congestion Control and Quality of Service (QoS) Provisions for Optical Burst Switched Networks*
12. BENSONG CHEN, 2005
Dissertation: *Hierarchical Traffic Grooming in Large-Scale WDM Networks*
Outstanding Teaching Assistant Award, 2004
11. JING TENG, 2004
Dissertation: *A Study of Optical Burst Switched Networks with the Jumpstart Just-In-Time Signaling Protocol*
10. LAURA E. JACKSON, 2003
Dissertation: *The Directional p-Median Problem with Applications to Traffic Quantization and Multi-processor Scheduling*
GAANN Fellow, 2000-2003
College of Engineering Nancy G. Pollock PhD Dissertation Award, 2004
9. YUFENG XIN, 2002
Dissertation: *Topology Design of Large-Scale Optical Networks*
8. LISONG XU, 2002
Dissertation: *Performance Analysis of Optical Burst Switched Networks*
NSF CAREER Award, 2007

7. RUDRA DUTTA, 2001
Dissertation: *Virtual Topology Design for Traffic Grooming in Optical WDM Networks*
6. A. HALIM ZAIM, 2001
Dissertation: *Computing Call Blocking Probabilities in LEO Satellite Networks*
5. YUHONG ZHU, 1999
Dissertation: *Computation of Blocking Probabilities in Wavelength Routing Networks*
4. ILYA BALDIN, 1998
Dissertation: *Dynamic Reconfiguration in Broadcast WDM Networks*
3. ZEYDY ORTIZ-LAUREANO, 1998
Dissertation: *Techniques to Support Multicast Traffic in Single-Hop WDM Optical Networks*
NSA Fellow, 1994-1998
2. M. WILLIAM (BILL) MCKINNON, 1997
Dissertation: *Performance Analysis of a Class of Photonic Interconnection Architectures*
1. SUPRIYA S. SHARMA, 1997
Dissertation: *Optimal Buffer Management for Shared Buffer ATM Switches*

Visiting Ph.D. Students

5. FENGXIAN TANG, 2019-2020 (Soochow University, China)
Research: *Optical Network Optimization*
4. WENZHE LI, 2017-2018 (Beijing University of Posts and Telecommunications, China)
Research: *Optical Networks on a Chip (ONoC)*
3. XIAOMIN LIU, 2011-2012 (Beihang University, China)
Research: *Ethernet Passive Optical Networks*
2. CHANG CAO, 2010-2011 (Beijing University of Posts and Telecommunications, China)
Research: *p-Cycle Protection in MPLS Networks*
1. ARUN VISWANATH, 2007-2008 (University of New South Wales, Australia)
Research: *Buffer Sizing in High-Speed Routers*

M.S. Students Supervised – Graduated

12. MANOJ VELLALA, 2008
Thesis: *Stack Composition for SILO Architecture*
11. SRIKRISHNA GIRISH KHARE, 2008
Thesis: *Linux Implementation of Tiered Service Fair Queueing (TSFQ) Scheduling Disciplines*
10. AJAY BABU AMUDALA BHASKER, 2006
Thesis: *Tiered-Service Fair Queueing (TSFQ): A Practical and Efficient Fair Queueing Algorithm*
9. NIKHIL BARADWAJ, 2005
Thesis: *Traffic Quantization and its Application to QoS Routing*
Graduate School Nancy G. Pollock MS Thesis Award, 2006

8. VIJAY IYER, 2002
Thesis: *A Simulation Study of Wavelength Assignment and Reservation Policies with Signaling Delays*
7. MRUGENDRA SINGHAI, 2002
Thesis: *Helios 2: An All-Optical Broadcast Local Area Network*
6. SUDHIN BENGARI, 2001
Thesis: *Differentiated Services Support for the Helios Optical WDM Testbed*
5. DHAVAL THAKER, 2001
Thesis: *Multicasting in a Partially Tunable Broadcast WDM Network*
4. JEFFREY J. STUCKEY, 1998
Thesis: *Worst-Case Cell Delay in an ATM Switch Using EDF Scheduling*
3. BRIAN K. HABERMAN, 1997
Thesis: *Cost, Delay, and Delay Variation Conscious Multicast Routing*
2. ILYA BALDIN, 1995
Thesis: *Multicast Routing With End-to-End Delay and Delay Variation Constraints*
1. VIJAY SIVARAMAN, 1995
Thesis: *TDM Schedules For Broadcast WDM Networks With Arbitrary Tuning Latencies*

II. Research and Scholarship

Books

3. ROUSKAS, G.N., RAMAMURTHY, B., SIVALINGAM, K.M. (editors). Next-Generation Internet Architectures and Protocols. Cambridge University Press, 2011.
2. ROUSKAS, G.N. Internet Tiered Services: Theory, Economics, and Quality of Service. Springer, 2009.
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6. DUTTA, R., KAMAL, A.E., ROUSKAS, G.N., "Introduction to Traffic Grooming." In Rudra Dutta, Ahmed E. Kamal, and George N. Rouskas (editors), *Traffic Grooming for Optical Networks: Foundations, Techniques, and Frontiers*, Springer, 2008.
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4. ROUSKAS, G.N., "Optical Network Engineering." In Sudhir Dixit (editor), *IP over DWDM: Building the Next Generation Optical Internet*, John Wiley & Sons, Hoboken, New Jersey, pp. 299-327, 2003.
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87. LI, W., YUAN, G., WANG, Z., TAN, G., ZHANG, P., ROUSKAS, G.N., "Fast and Scalable All-Optical Network Architecture for Distributed Deep Learning." *IEEE/Optica Journal of Optical Communications and Networking*, vol. 16, no. 3, pp. 342-357, March 2024.
86. ROUSKAS, G.N., GUPTA, S., SHARMA, P. "Symmetry-Free Algorithm for Spectrum Allocation: Parallel Implementations and Evaluation [Invited]." *IEEE/Optica Journal of Optical Communications and Networking*, vol. 15, no. 10, pp. E40-E50, October 2023.
85. ROUSKAS, G.N. "A Symmetry-Free Spectrum Allocation Heuristic for Elastic Optical Networks." *Optical Switching and Networking*, vol. 49, May 2023.
84. ROUSKAS, G.N., BANDIKATLA, C., "Recursive First Fit: A Highly Parallel Optimal Solution to Spectrum Allocation." *IEEE/Optica Journal of Optical Communications and Networking*, vol. 14, no. 4, pp. 165-176, April 2022.
83. TANG, F., SHEN, G., ROUSKAS, G.N., "Crosstalk-Aware Shared Backup Path Protection in Multi-Core Fiber Elastic Optical Networks." *IEEE/OSA Journal of Lightwave Technology*, vol. 39, no. 10, pp. 3025-3036, May 15, 2021.
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Conference Proceedings (invited)

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9. ROUSKAS, G.N., DUTTA, R., BALDINE, I. “A New Internet Architecture to Enable Software Defined Optics and Evolving Optical Switching Models.” *Proceedings of the 8th Workshop on Optical Burst/Packet Switching (WOBS 2008)*, September 8, 2008, London, UK.
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Tutorials

4. ROUSKAS, G.N., “Tutorial on Network Virtualization.” Presented at the *OFC 2012* Conference, March 2012, Los Angeles, California.
3. ROUSKAS, G.N., “Tutorial on Traffic Grooming and Multigranular Switching in Optical WDM Networks.” Presented at the *NETWORKING 2004* Conference, May 9, 2004, Athens, Greece.
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Keynotes, Distinguished Lectures, and Panels

- Distinguished Lecture (virtual), Institute of Broadband Research and Innovation, Soochow University, China, October 2021.
- Distinguished Lecture (virtual), Istanbul Commerce University, Turkey, May 2021.
- Distinguished Lecture (virtual), Department of Computer and Information Sciences, Temple University, February 2021.
- Distinguished Lecture (virtual), School of Science, Beijing University of Posts and Telecommunications, Beijing, China, September 2020.
- Distinguished Lecture, CE Department, National Technical University of Athens, June 2019
- Distinguished Lecture, CSE Department, University at Buffalo, April 2019
- Panel on “Innovation Opportunities in Transport Networks from Network Analytics and Machine Learning.” OFC 2019, March 2019.
- Panel on “Future Directions for IoT.” IEEE MASS 2018, October 2018.
- Distinguished Lecture, East Carolina University, April 2017

- Distinguished Lecture, National Conference for Colleges of Computing (NC3), Jeddah, Saudi Arabia, February 2016
- Distinguished Lecture, King Abdulaziz University, Saudi Arabia, April 2015
- Distinguished Lecture, King Abdulaziz University, Saudi Arabia, February 2014
- Distinguished Lecture, King Abdulaziz University, Saudi Arabia, May 2013
- CS Distinguished Lecture, Iowa State University, April 2012
- Panel on “Future Internet: Do We Need Fundamentally New Designs?.” IEEE LANMAN workshop, Chapel Hill, NC, October 2011
- Keynote, ICIIS Conference, Kandy, Sri Lanka, August 2011
- IEEE Distinguished Lecture, University of Colombo, Sri Lanka, August 2011
- IEEE Distinguished Lecture, University of Moratuwa, Sri Lanka, August 2011
- IEEE Distinguished Lecture, The University of West Indies, Kingston, Jamaica, May 2011
- IEEE Distinguished Lecture, IEEE Communications Society Chapter, Orlando, FL, May 2011
- IEEE Distinguished Lecture, University of Alabama at Huntsville, Huntsville, AL, May 2011
- IEEE Distinguished Lecture, University of Alabama at Birmingham, Birmingham, AL, October 2010
- IEEE Distinguished Lecture, Verizon, Temple Terrace, FL, October 2010
- IEEE Distinguished Lecture, IEEE Communications Society Chapter, Orlando, FL, October 2010
- IEEE Distinguished Lecture, AT&T Research, Middletown, NJ, August 2010
- IEEE Distinguished Lecture, DRS Technologies, Gaithersburg, MD, August 2010
- IEEE Distinguished Lecture, IEEE Communications Society Chapter, Baltimore, MD, August 2010
- Keynote, INFORMS Telecom, Montreal, Canada, May 2010
- Panel, OFC Conference, San Diego, CA, March 2010
- Keynote, Euro-NGI Conference, Aveiro, Portugal, July 2009
- Distinguished Lecture, Universidad Tecnica Federico Santa Maria, Valparaiso, Chile, November 2008
- Distinguished Presentation, IEEE ICCCN Conference, Saint Thomas, August 2008
- Keynote, 5th Workshop on Optimization of Optical Networks, Montreal, Canada, May 2008
- Panel, ONDM Conference, Vilanova i la Geltru, Spain, March 2008
- Panel, BROADNETS conference, San Jose, CA, October 2006
- Distinguished Lecture, University of Evry, France, July 2006
- Panel, UNC Teaching and Learning with Technology (TLT) conference, Chapel Hill, NC, March 2006
- Distinguished Lecture, Carleton University, Canada, December 2005
- Distiguished Lecture, National Technical University of Athens, Greece, June 2004
- Distiguished Lecture, Athens Institute of Technology, Greece, June 2004
- Distiguished Lecture, University of Patras, Greece, May 2004

Funded Research Proposals and Grants

CNS Core:Small:On Parallelizing Optical Network Design Problems:Towards Network Optimization as a Service (PI: Rouskas)
National Science Foundation
Amount: \$440,000, October 2019-September 2022

Graduate Industrial Traineeships (PI: Rouskas)
SAS, Genworth, RENCI
Amount: \$460,000, June 2014-May 2020

Cisco Internship Program (PIs: Rouskas, Ning)
Cisco
Amount: \$160,000, May 2011-December 2012

NeTS: Large: Collaborative Research: ChoiceNet: Network Innovation Through Choice (NC State PIs: Rouskas, Dutta)
National Science Foundation
Amount: \$643,917 (total budget: \$2.732M), September 2011-December 2015

NeTS: Small: Computationally Scalable Aware Optical Network design (PI: Rouskas)
National Science Foundation
Amount: \$430,000, August 2011-July 2016

SURFnet GigaPort3 Research Plan (PIs: Rouskas, Karmous-Edwards)
SURFnet
Amount: \$280,000, July 2009-May 2012

GENI IMF: Integrated Measurement Framework and Tools for Cross Layer Experimentation (PIs: Dutta, Rouskas)
GENI Program Office
Amount: \$420,000, October 2009-September 2012

Edge Reconfigurable Optical Networks (ERONs) for High-Performance Applications (PIs: Rouskas, Reeves)
DARPA
Amount: \$250,000, July 2008- December 2009

CPATH-CB: Computing Across Curricula
National Science Foundation
Amount: \$275,000, July 2007-June 2010

An Intelligent Second-Life VCL-Based Computing Lab (PIs: Rouskas, Young)
IBM Faculty Award
\$30,000, July 2007

Lambda Scheduling for Grid Applications
NC State Center for Advanced Computing and Communication (CACC)
Amount: \$40,000, July 2007-June 2008

Learning with In-class Technology (LIT): The 15-Minute Learning Module Approach
NC State LITRE
Amount: \$8,000, June 2006-May 2007

Collaborative Research: NeTS-FIND: The SILO Architecture for Services Integration, controL, and Optimization for the Future Internet (PIs: Rouskas, Dutta)
National Science Foundation
Amount: \$228,000 (total budget: \$408,000), September 2006-May 2010

Integration of Network Survivability Concepts in an MS in Computer Networking Curriculum (PIs: Dutta, Rouskas)
 Microsoft Trustworthy Computing Curriculum
 Amount: \$50,000, January 2006-December 2006

Traffic Quantization: A Formal Approach To Scalability in Packet-Switched Networks
 National Science Foundation
 Amount: \$357,000, September 2004-August 2009

A Formal Approach to Traffic Grooming in Optical Networks with General Topologies (PIs: Rouskas, Dutta)
 National Science Foundation
 Amount: \$405,000, September 2003-August 2006

Transparent Optical Network Management and Routing with Just In Time Signaling (PIs: Rouskas, Perros)
 NSA LTS
 Amount: \$327,000 (total budget: \$1,350,000), January 2003-December 2004

Optical Network Lab Equipment
 MCNC-RDI
 Amount: \$640,000 (six Optera WDM switches with SONET and Gigabit Ethernet interfaces), August 2003

Engineering Online Student Access to Internet Lab
 NC State DELTA
 Amount: \$10,000, January 2003-June 2003

Access Protocols for Multicasting in an Optical Burst Switching Metro Ring (PIs: Perros, Rouskas)
 Alcatel
 Amount: \$45,000, January 2002-September 2003

Performance Analysis and Alternate Routing for Just In Time Optical Burst Switching Networks (PIs: Rouskas, Perros, Franzon)
 NSA LTS
 Amount: \$437,000 (total budget: \$1,500,000), January 2002-June 2003

Performance Evaluation of IPv6 Tunneling
 IBM Faculty Award (PIs: Devetsikiotis, Rouskas)
 Amount: \$40,000, July 2001

Research in Optical Burst Switching (PIs: Perros, Rouskas)
 NC State Center for Advanced Computing and Communications (CACC)
 Amount: \$43,000, July 2001-June 2002

Multicast Support for Just In Time Optical Burst Switching Networks (PIs: Rouskas, Perros)
 NSA LTS
 Amount: \$70,000 (total budget: \$500,000), October 2000-March 2001

Project: Optical Burst-Switched Ring Networks (PIs: Perros, Rouskas)
 NC State Center for Advanced Computing and Communications (CACC)
 Amount: \$35,000, July 2000-June 2001

Regional Testbed Optical Access Network for IP, Multicast, and Differentiated Services
 DARPA Next Generation Internet (NGI) Program
 Amount: \$214,000 (total budget: \$1,800,000), March 2000-March 2002

Networking Lab Equipment

HP U.S. University Equipment Grants

Amount: \$159,190 (50 HP Kayak workstations and 3 laser printers), December 1999

Internet Teaching Lab

CAIDA Internet Teaching Laboratories (ITL) Initiative

Amount: \$100,000 (4 Cisco Routers), October 1999

Performance Analysis of Wavelength Routed Wide Area Networks (PIs: Rouskas, Perros)

National Science Foundation

Amount: \$255,000, September 1998-August 2002

MTCP: TCP-like Congestion Control for Reliable Multicast (PIs: Rhee, Rouskas)

NC State Center for Advanced Computing and Communications (CACC)

Amount: \$78,000, July 1998-June 2000

Towards an All-Optical Network Infrastructure: Interconnection of Photonic WDM Broadcast-and-Select Local Area Networks

National Science Foundation (CAREER)

Amount: \$200,000, September 1997-August 2002

All-Optical Solutions to ATM Switching

NC State Center for Advanced Computing and Communications (CACC)

Amount: \$40,000, July 1995-June 1996

Multicasting for Multimedia Applications

NC State Faculty Development and Research Support

Amount: \$5,000, January 1995-June 1995

III. Leadership and Service

Society Memberships

FELLOW, Institute of Electrical and Electronics Engineers, Communications Society

MEMBER, Association for Computing Machinery, also Special Interest Group on Computer Communications

IEEE Leadership

CHAIR, IEEE Communications Society Distinguished Lecturer Selection Committee, 2016-2017

VICE CHAIR, IEEE Communications Society Technical and Educational Activities Council, 2016-2017

VICE CHAIR, IEEE Communications Society TCs Recertification Committee, 2016-2017

CHAIR, IEEE Communications Society Optical Networking Technical Committee (ONTC), 2016-2017

VICE CHAIR, IEEE Communications Society Optical Networking Technical Committee (ONTC), 2014-2015

SECRETARY, IEEE Communications Society Optical Networking Technical Committee (ONTC), 2012-2013

Technical Journal Leadership

FOUNDING EDITOR-IN-CHIEF, *IEEE Networking Letters*, 2018-2021

FOUNDING EDITOR-IN-CHIEF, *Optical Switching and Networking*, Elsevier, 2004-2017

Conference Committee Leadership

AWARDS CHAIR, *IEEE GLOBECOM 2023*, Kuala Lumpur, Malaysia, December 4-8, 2024.

EXECUTIVE CHAIR, *ICCCN 2023*, Honolulu, Hawaii, July 24-26, 2023.

MEMBER, STEERING COMMITTEE, *OFC Conference*, 2018-2023

EXECUTIVE CHAIR, *ICCCN 2022*, Honolulu, Hawaii (virtual conference), July 25-27, 2022.

TPC CO-CHAIR, *DRCN 2022*, Vilanova, Spain, March 28-31, 2022.

TPC CO-CHAIR, *IEEE MeditCom 2021*, Athens, Greece, September 7-10, 2021.

GENERAL CHAIR, *ICCCN 2021*, Athens, Greece (virtual conference), July 19-22, 2021.

CHAIR, STEERING COMMITTEE, *IEEE LANMAN*, 2015-2018

GENERAL CO-CHAIR, *IEEE MASS 2018*, Chengdu, China, October 9-12, 2018.

PROGRAM CO-CHAIR, *IEEE ICC 2017, Optical Networks and Systems (ONS) Symposium*, Paris, France, May 21-25, 2017.

GENERAL CO-CHAIR, *IEEE ICNP 2014*, Raleigh, NC, October 21-24, 2014.

GENERAL CHAIR, *ICCCN 2013*, Nassau, Bahamas, July 30-August 2, 2013.

PROGRAM CO-CHAIR, *ICCCN 2011*, Maui, Hawaii, August 1-4, 2011.

PROGRAM CO-CHAIR, *IEEE Globecom 2010, Optical Networks and Systems (ONS) Symposium*, Miami, FL, November 28-December 3, 2010.

PROGRAM CO-CHAIR, *ICCCN 2009, Internet Services, Systems and Applications (ISSA) Track*, San Francisco, CA, August 2-6, 2009.

GENERAL CO-CHAIR, *International Conference on Broadband Communications, Networks, and Systems (BROADNETS 2007)*, Raleigh, NC, September 10-13, 2007

GENERAL CO-CHAIR, *14th IEEE Workshop on Local and Metropolitan Area Networks (LANMAN 2005)*, Chania, Crete, Greece, September 18-21, 2005.

PROGRAM CO-CHAIR, *Workshop on Traffic Grooming (WTG 2004)*, October 29, 2004, San Jose, CA

TECHNICAL PROGRAM CHAIR, *13th IEEE Workshop on Local and Metropolitan Area Networks (LANMAN 2004)*, April 25-28, 2004, San Francisco, CA

TECHNICAL PROGRAM CO-CHAIR, *IFIP Networking 2004*, May 9-14, 2004, Athens, Greece

Editorial and Review Work for Technical Journals and Publishers

ASSOCIATE EDITOR, *IEEE/OSA Journal of Communications and Networking*, 2010-2012

CO-GUEST EDITOR, *JCM Journal of Communications*, Special Issue on the “Advances in Communications and Networking,” vol. 6, no. 9, December 2011.

ASSOCIATE EDITOR, *IEEE/ACM Transactions on Networking*, 2000-2004

ASSOCIATE EDITOR, *Computer Networks*, 2001-2004

ASSOCIATE EDITOR, *Optical Networks*, 2000-2004

CO-GUEST EDITOR, *IEEE Journal on Selected Areas in Communications*, Special Issue on “Protocols for Next Generation Optical WDM Networks,” vol. 18, no. 10, October 2000.

REVIEWER, Morgan Kaufmann, John Wiley and Sons, Cambridge University Press, Springer, IEEE Transactions on Networking, IEEE Transactions on Computers, IEEE Transactions on Communications, IEEE/OSA Journal of Lightwave Technology, IEEE/OSA Journal of Optical Communications and Networking, IEEE Journal on Selected Areas in Communications, Computer Networks Journal, International Journal of Performance Evaluation, European Transactions on Telecommunications, Photonic Network Communications Journal, IEEE Computer Magazine, IEEE Communications Magazine, IEEE Network Magazine, and numerous conferences

PROPOSAL REVIEW PANELIST, National Science Foundation – on numerous occasions

Conference Program Committees

IEEE GLOBECOM: 2003-2023

IEEE ICC: 2003-2023

IEEE LANMAN: 2007-2023

IEEE INFOCOM: 2007-2013, 2004, 1996-1998
ONDM: 2014-2023, 2009, 2005
IFIP NETWORKING: 2023, 2019, 2005-2012
OSA NETWORKS: 2017-2019
OFC/NFOEC: 2008-2010
Euro NGI: 2008-2011
EuCNC: 2015-2017
ACM CoNEXT Cloud Assisted Networking: 2016-2017
TEMU: 2012-2016
Networks: 2008-2016
DRCN: 2019-2021, 2015, 2011
NOC: 2014-2015
IEEE NFV-SDN: 2015
ITC: 2013
IEEE ICNP: 2013, 2008, 1997
ICCCN: 2012, 2006
ICNC: 2020, 2012
IEEE ANTS: 2011, 2009, 2008
RNDM: 2010-2011
ACP: 2010
ReArch Workshop: 2009-2010
INFORMS Telecom: 2010
WOBS: 2009, 2003-2005
BROADNETS: 2004-2006
IEEE HPSR Workshop: 2019, 2003-2005
OPTiCOMM: 2000-2003
SPIE Conference on All-Optical Networking: 1998-1999

NC State: University Committees

MEMBER, Administrative Board of the Graduate School (ABGS), 2016-2018
JUDGE, Graduate Student Research Symposium, 2018, 2014
MEMBER, Microsoft Research Faculty Fellowship Review Committee, 2012-2013
MEMBER, DELTA IDEA grant review committee, 2004-2005
MEMBER, DELTA Advisory Committee, 2003-2005
CHAIR, DELTA Subcommittee on Intellectual Property, 2003-2005
MEMBER, Alumni Outstanding Research Awards Selection Committee, 2004

NC State: College of Engineering Committees

MEMBER, University Faculty Scholar Selection Committee, 2012-2014
MEMBER, ALCOA Awards Committee, 2012-2013
MEMBER, College Reappointment, Promotion, and Tenure (RPT) Committee, 2008-2011
textscMember, College Research Committee, 2007-2008
MEMBER, CSC Head Search Committee, 2004-2006
MEMBER, Engineering Online Advisory Committee, 2003-2005
MEMBER, CSC Review Survey Committee, 1998-1999
MEMBER, Admissions Standards Committee, MS in Computer Networking, 1998-1999

NC State: Department of Computer Science Committees

CHAIR, Networking faculty search committee, 2021-2022
MEMBER, Reappointment, Promotion, and Tenure (RPT) Committee, 2017-present
CHAIR, Strategic Planning Committee, 2009-2012
MEMBER, Graduate Student Admissions Committee, 2011-2012
MEMBER, Awards Committee, 2009-2012
MEMBER, Faculty Recruiting Committee, 2008-2009
COURSE COORDINATOR, CSC 316 (Data Structures), 2005-2017
MEMBER, Computing Infrastructure Committee, 2006-2010
CHAIR, Minority Recruiting Committee, 2006-2007
MEMBER, Committee for External Evaluation Visit, Fall 2004
MEMBER, Strategic Planning Committee, 2003-2004
MEMBER, Research Productivity Committee, 2003-2004

MEMBER, Strategic Planning Committee, 2002-2005

CHAIR, Faculty Recruiting Committee, 2001-2002

CHAIR, Faculty Recruiting Committee, 2000-2001

PEER EVALUATOR, 23 teaching evaluations, 1999-present

MEMBER, Graduate Student Admissions Committee, 1996-1998

MEMBER, PhD Qualifying Exam Committee, 1994-1996

NC State: Operations Research and ECE Committees

MEMBER, OR Graduate Student Admissions Committee, 2012-2013, 2005-2007

MEMBER, ECE Faculty Recruiting Committee, 1999-2000

Other National and International Activities

MEMBER, International Advisory Committee, Scuola Superiore Sant'Anna, Pisa, Italy, 2013-2014

MEMBER, Committee of Visitors (CoV), DoE Networking Research Program, 2011

MEMBER, Best Paper Award Committees

IEEE ICC, 2021

IEEE/OSA Journal of Optical Communications and Networking, Charles Kao Award, 2015-2017

IEEE ICC, 2016

ICNC, 2015

ACP, 2012, 2009

IEEE INFOCOM, 2011

IEEE ANTS, 2010

IEEE FELLOW NOMINATOR, four cases, 2018-present

IEEE FELLOW REFERENCE, 19 cases, 2012-present

EXTERNAL REVIEWER for the promotion to Full Professor, 26 cases, 2004-present

EXTERNAL REVIEWER for the promotion to Associate Professor with tenure, 29 cases, 2000-present