IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIENA CORPORATION,
Petitioner,

v.

K.MIZRA LLC,
Patent Owner.

U.S. Patent No. 10,735,320

Title: APPLICATION WIRE

Inter Partes Review No.: IPR2025-01364

DECLARATION OF DR. A.L. NARASIMHA REDDY IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 10,735,320

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4. Detailed Application of *Murphy* in Combination with *Taguchi* to the Challenged Claims 49

Claim 1 49

[1pre] A method comprising: 49

[1a] at a node associated with a multiprotocol label switching system (MPLS) network, performing: 49

[1b] identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow; 51

[1ci] in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through the MPLS network, ... 57

[1cii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and 64

[1d] communicating data related to the sending device application via at least one of the plurality of pseudowires. 69

Claim 2 70

[2] The method of claim 1, wherein the stored data defines an application wire for use by the sending device application, the application wire configured to communicate particular data from a particular application flow of the sending device application to an edge node 70

Claim 3 73

[3] The method of claim 1, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires. 73

Claim 4 74

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[4] The method of claim 1, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network. 74

Claim 5 74

[5] The method of claim 1, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device. 74

Claim 7 77

[7] The method of claim 1, wherein the stored data maps the application flow to the plurality of pseudowires to create an application wire. 77

Claim 8 78

[8pre] A device comprising: 78

[8a] a processor; and a memory that stores instructions executable by the processor to: 79

[8b] identify information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow; 79

[8ci] in response to identifying the information, and based on stored data mapping application flows to pseudowires, determine a plurality of pseudowires as paths through a multiprotocol label switching (MPLS) network for the application flow, ... 80

[8cii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and 80

[8d] communicate data associated with the sending device application via at least one of the plurality of pseudowires. 80

Claim 9 81

[9] The device of claim 8, wherein the stored data defines an application wire for use by the sending device application, the application wire

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configured to communicate particular data from a particular application flow of the sending device application to an edge node.....81

Claim 10 81

[10] The device of claim 8, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires. 81

Claim 11 81

[11] The device of claim 8, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network. 81

Claim 12 81

[12] The device of claim 8, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device. 81

Claim 14 82

[14] The device of claim 8, wherein the stored data maps the application flow to the plurality of pseudowires to create an application wire. 82

Claim 15 82

[15pre] A computer-readable non-transitory medium storing instructions that are executable by a processor to initiate or perform: 82

[15a] identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow; 82

[15bi] in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through a multiprotocol label switching system (MPLS) network, ...83

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[15bii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and 83

[15c] communicating data related to the sending device application via at least one of the plurality of pseudowires. 83

Claim 16 83

[16] The computer-readable non-transitory medium of claim 15, wherein the instructions are executable to perform the identifying, the determining, and the communicating at a node associated with the MPLS network. 83

Claim 17 84

[17] The computer-readable non-transitory medium of claim 15, wherein the stored data defines an application wire for use by the sending device application, the application wire configured to communicate particular data from a particular application flow of the sending device application to an edge node. 84

Claim 18 84

[18] The computer-readable non-transitory medium of claim 15, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires. 84

Claim 19 84

[19] The computer-readable non-transitory medium of claim 15, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network. 84

Claim 20 85

[20] The computer-readable non-transitory medium of claim 15, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device. 85

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1. Booth (EX-1016)....85

2. Detailed Application of *Murphy* in Combination with *Taguchi* and *Booth* to the Challenged Claims....87

Claim 6 87

[6pre] The method of claim 1, ...87

[6i] wherein the application flow includes data packets transmitted and received by the sending device application, wherein the data is communicated via the at least one of the plurality of pseudowires, ...87

[6ii] and further comprising assigning, at an edge node, sequence numbers to ingress data packets in an order in which they are received by the node....90

Claim 13 92

[13pre] The device of claim 8,....92

[13i] wherein: the application flow includes data packets transmitted and received by the sending device application, the data is communicated via the at least one of the plurality of pseudowires, ...93

[13ii] and the instructions are executable by the processor to cause assigning, at an edge node, of sequence numbers to ingress data packets in an order in which they are received by the node....93

CONCLUSION AND DECLARATION

APPENDIX A – MATERIALS RELIED UPON

APPENDIX B – *CURRICULUM VITAE*

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I, Dr. A.L. Narasimha Reddy, declare as follows:

I. INTRODUCTION

1. I am over the age of eighteen (18) and otherwise competent to make this declaration.

2. I have been retained by Ciena Corporation (Petitioner) as an independent expert consultant in this proceeding before the United States Patent and Trademark Office. Although I am being compensated at my rate of $650 per hour for the time I spend on this matter, no part of my compensation depends on the outcome of this proceeding, and I have no other interest in this proceeding. To the best of my knowledge, I have no financial interest in Petitioner.

3. This Petition for *inter partes* review involves U.S. Patent No. 10,735,320 (the "'320 Patent") (EX-1001), titled "APPLICATION WIRE" and listing Ping Pan and Richard D. Gitlin as the inventors.

4. For the purposes of this *inter partes* review as discussed later, I have been instructed to assume that the effective filing date of the claims of the '320 Patent challenged by the Petitioner in this *inter partes* review is no earlier than October 7, 2005, the filing date of provisional application 60/725,038.

5. I understand that according to USPTO records, the '320 Patent is currently assigned to K.MIZRA LLC ("K.MIZRA" or "Patent Owner").

6. The ’320 Patent is directed to systems and methods for transferring data across computer networks. I am familiar with the technology described in the ’320 Patent as of the earliest possible priority date of October 7, 2005.

7. In preparing this Declaration, I have reviewed the ’320 Patent (EX-1001), the file history of the ’320 Patent (EX-1002), and each of the documents cited herein, and I have considered these documents in light of the general knowledge in the art as of October 7, 2005. In formulating my opinions, I have relied upon my experience in the relevant art. I have also considered the viewpoint of a person of ordinary skill in the art (“POSITA”) in the relevant field, as of October 7, 2005, who I describe below (§IV.E). For convenience, the materials I considered in forming my opinion are listed in Appendix A.

8. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. The findings presented herein are made to a reasonable degree of scientific certainty. I have made every effort to accurately and completely investigate all areas of concern identified during our investigation.

9. I have been asked to provide my technical expertise, analysis, insights, and opinions regarding the ’320 Patent and relevant references that form the basis of the arguments set forth in the accompanying Petition for *inter partes*

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review of the ’320 Patent. As described in detail below, I offer the following opinions in this Declaration:

- A POSITA would have found Claims 1-5, 7-12, and 14-20 of the ’320 Patent obvious over *Murphy* in view of *Taguchi*.
- A POSITA would have found Claims 6 and 13 of the ’320 Patent obvious over *Murphy* in view of *Taguchi* and *Booth*.

II. MY BACKGROUND AND QUALIFICATIONS

10. I am currently the Truchard Foundation Chair Professor of Electrical and Computer Engineering at Texas A&M University in College Station, Texas. I have over 30 years of experience in a wide variety of technologies and industries relating to computer networks, data communications, storage systems, and distributed systems, including packet-switched network communications.

11. My academic credentials include a Bachelor of Technology degree in Electronics and Electrical Communications Engineering from the Indian Institute of Technology, Kharagpur, India, in August 1985. I then earned a Master of Science and a Ph.D. in Computer Engineering from the University of Illinois at Urbana-Champaign in May 1987 and August 1990, respectively.

12. For over three decades, I have worked in the field of Computer Engineering. My primary focus and research interest has been on computer networks, storage systems, multimedia systems, and computer architecture. I have

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authored and co-authored over a hundred technical papers and several book chapters related to several of these interests, including on such topics as multipath routing, route control, high-speed networks, network congestion, packet management, quality of service regulation, network security, network modeling, differentiated services, storage system enhancements, caching strategies, and multimedia system enhancements to name a few examples. I am listed as an inventor on six U.S. patents in the field of multi-node communication networks and computer systems.

13. My employment history following my graduation from the University of Illinois at Urbana-Champaign began at the IBM Almaden Research Center in San Jose, California in 1990. At IBM, I worked on projects related to disk arrays, multiprocessor communication, hierarchical storage systems and video servers.

14. In 1995, I joined the faculty of the department of Electrical Engineering at Texas A&M University initially as an Associate Professor and was later promoted to full, tenured Professor. At Texas A&M, during 2016-21, I was the Associate Agency Director for Strategic Initiatives and Centers for the Texas A&M Engineering Experiment Station (TEES), which engages in engineering and technology-oriented research and educational collaborations. Further, I also served as Associate Dean for Research in the College of Engineering during 2016-21.

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15. At Texas A&M, I have taught dozens of courses related to computer networking and communications, as well as computer architecture, multimedia systems and networks, topics in networking security, multimedia storage and delivery, as well as networking for multimedia applications. I have also served on various committees for the benefit of the scientific community and the Texas A&M University community.

16. I am a member of a number of professional societies, including the Institute of Electrical and Electronic Engineers (IEEE), where I have been elevated to an IEEE Fellow, and the Association for Computing Machinery (ACM). I have been responsible for chairing or co-chairing numerous conferences and programs, as well as presenting research at major IEEE and ACM conferences. For example, I served as program co-chair for the 2008 5th International Conference on Broadband Communications, Networks and Systems, panels co-chair for the 2008 3rd International Conference on Communication Systems Software & Middleware, and panel chair of the IEEE Conference of High Performance Computer Architecture.

17. My presentations include a Keynote speech at International Conference on Information Technology-New Generations in 2013, a Keynote speech at IEEE International Symposium on Computers and Communications 2010, and several invited talks including at Georgia Tech (2013), COMSNETS

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Conference (2013), Int. Conf. on Networking and Communications (2012), Samsung (2011), Korea University (2011), Aijou University (2011), Catedra Series at University of Carlos III, Madrid (2009), Thomson Research, Paris (2009), Telefonica Research, Barcelona (2009), and a Distinguished Seminar at IBM Austin Research Lab (2008).

18. I have received multiple awards in the field of networks and computer architecture. I received the NSF Career Award from 1996-2000. I received an outstanding professor award by the IEEE student branch at Texas A&M during 1997-1998, an outstanding faculty award by the department of Electrical and Computer Engineering during 2003-2004, a Distinguished Achievement award for teaching from the former students' association of Texas A&M University, and a citation "for one of the most influential papers" from the 1st ACM Multimedia conference.

19. My curriculum vitae, which includes a more detailed summary of my background and experience, is attached as Appendix B.

III. RELEVANT LEGAL STANDARDS

20. I am not a lawyer and do not provide any legal opinions in this Declaration. Although I am not a lawyer, I have been informed and understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims. I have been asked to

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provide my opinions regarding whether the claims of the ’320 Patent are anticipated or would have been obvious to a person having ordinary skill in the art at the time of the alleged invention, in light of the prior art.

21. I have been informed and understand that a patent claim is not patentable under 35 U.S.C. § 103 if the differences between the patent claim and the prior art are such that the claimed subject matter as a whole would have been obvious at the time the claimed invention was made to a person having ordinary skill in the relevant art. Obviousness, as I have been informed and understand, is based on the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in the art, and, to the extent that they exist, certain objective indicia of non-obviousness.

22. I understand that objective indicia can be important evidence regarding whether a patent is obvious or nonobvious, if it has an appropriate nexus to the claimed invention, i.e., is a result of the merits of a claimed invention (rather than the result of design needs or market-pressure advertising or similar activities). Such indicia include: commercial success of products covered by the patent claims; a long-felt need for the invention; failed attempts by others to make the invention; copying of the invention by others in the field; unexpected results achieved by the invention as compared to the closest prior art; praise of the invention by the infringer or others in the field; the taking of licenses under the

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patent by others; expressions of surprise by experts and those skilled in the art at the making of the invention; and the patentee proceeded contrary to the accepted wisdom of the prior art.

23. I have been informed that whether there are any relevant differences between the prior art and the claimed invention is to be analyzed from the view of a person of ordinary skill in the relevant art at the time of the invention. As such, my opinions below as to a person of ordinary skill in the art are as of the time of the invention, even if not expressly stated as such; for example, even if stated in the present tense.

24. In analyzing the relevance of the differences between the claimed invention and the prior art, I have been informed that I must consider the impact, if any, of such differences on the obviousness or non-obviousness of the invention as a whole, not merely some portion of it. The person of ordinary skill faced with a problem is able to apply his or her experience and ability to solve the problem and also look to any available prior art to help solve the problem.

25. I have been informed that a precise teaching in the prior art directed to the subject matter of the claimed invention is not needed. I have been informed that one may take into account the inferences and creative steps that a person of ordinary skill in the art would have employed in reviewing the prior art at the time of the invention. For example, if the claimed invention combined elements known

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in the prior art and the combination yielded results that were predictable to a person of ordinary skill in the art at the time of the invention, then this evidence would make it more likely that the claim was obvious. On the other hand, if the combination of known elements yielded unexpected or unpredictable results, or if the prior art teaches away from combining the known elements, then this evidence would make it more likely that the claim that successfully combined those elements was not obvious.

26. I have been informed and understand that there are recognized, exemplary, rationales for combining or modifying references to show obviousness of claimed subject matter. Some of the rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to yield predictable results; use of a known technique to improve a similar device (method or product) in the same way; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and some teaching, suggestion, or motivation in the prior art that would have led one of

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ordinary skill to modify the prior art reference or to combine prior art teachings to arrive at the claimed invention.

IV. OVERVIEW

27. The ’320 Patent is directed to an edge node that addresses quality of service (QoS) for “application flows” by forwarding the flow as Multi-Protocol Label Switching (MPLS) packets along one or more pseudowires.

28. Specifically, the ’320 Patent discloses “Application Wires” that map the “application flows” to pseudowires in the MPLS network. “Application flows” transfer data between an application running on clients, such as a voice over IP (VoIP) or Video-on-Demand (VoD) application running on client device 204 communicating with client device 214:

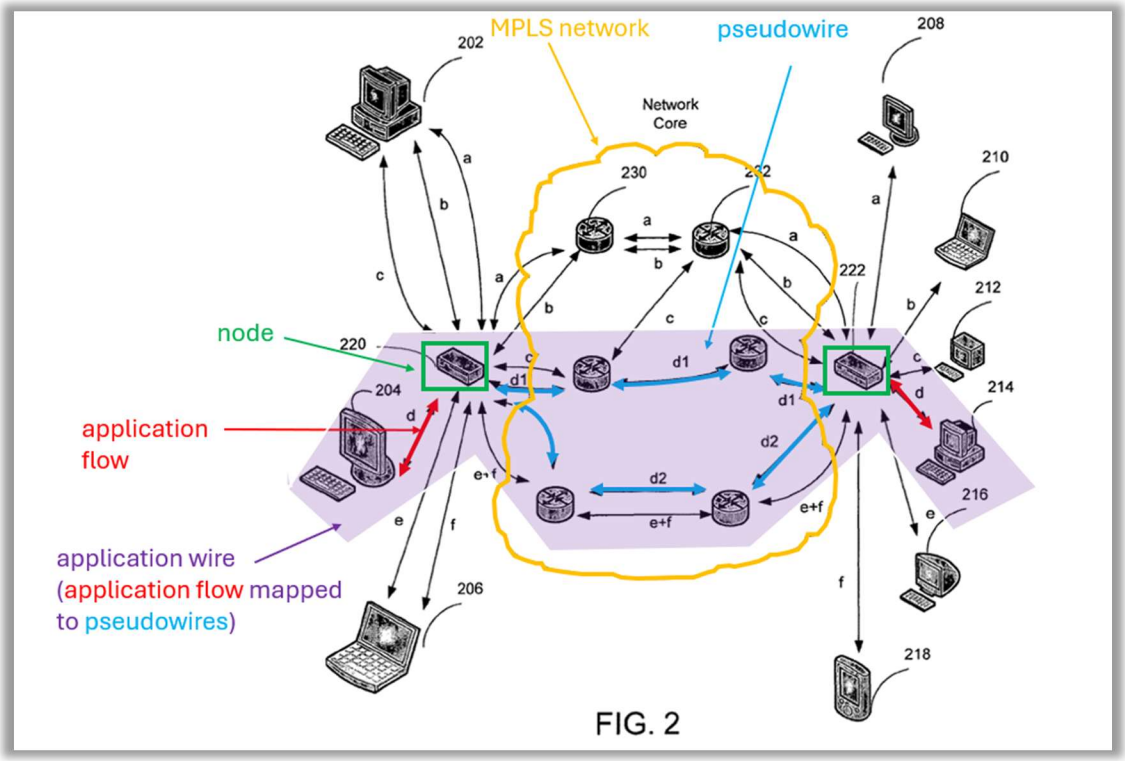


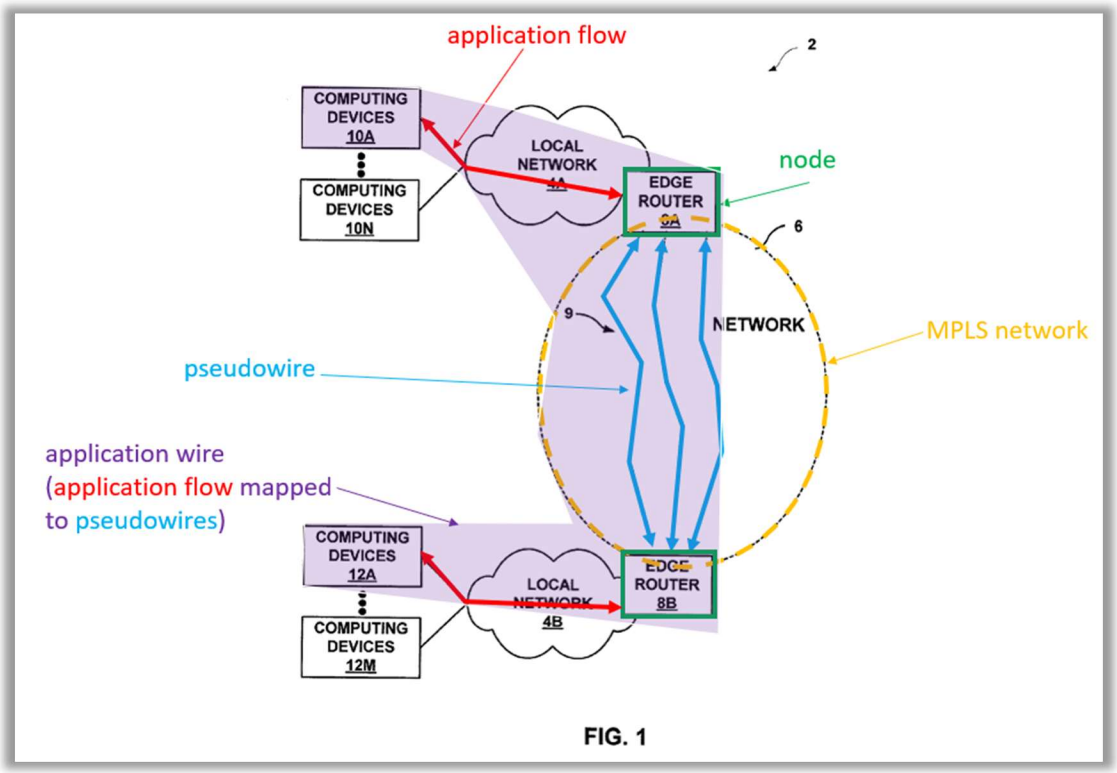
FIG. 2

EX-1001 FIG. 2 (annotated).

29. Application data originating from client device 204 produces an application flow (red) sent to a first edge node (green) of the MPLS network (orange). The node identifies information associated with the application flow (such as a protocol or port number) and maps the flow to one or more pseudowires (blue). The node encapsulates the packets of the application flow as MPLS formatted packets with header information corresponding to the pseudowires. The node then forwards the MPLS packets along the pseudowires toward a second edge node (green). The patent contemplates three types of mappings of application flows-to-pseudowires: (1) one-to-one; (2) many-to-one (an aggregation); and (3) one-to-many (distributed mapping). Of these mapping schemes, the Challenged Claims require distributed mapping.

30. However, the use of mapping of application flows to pseudowires, including distributed mapping, was well known in the prior art. For example, *Murphy* disclosed a nearly identical system for providing QoS to application flows communicated along MPLS pseudowires. *Murphy's* system is illustrated below (elements in common with the '320 Patent annotated in common color):

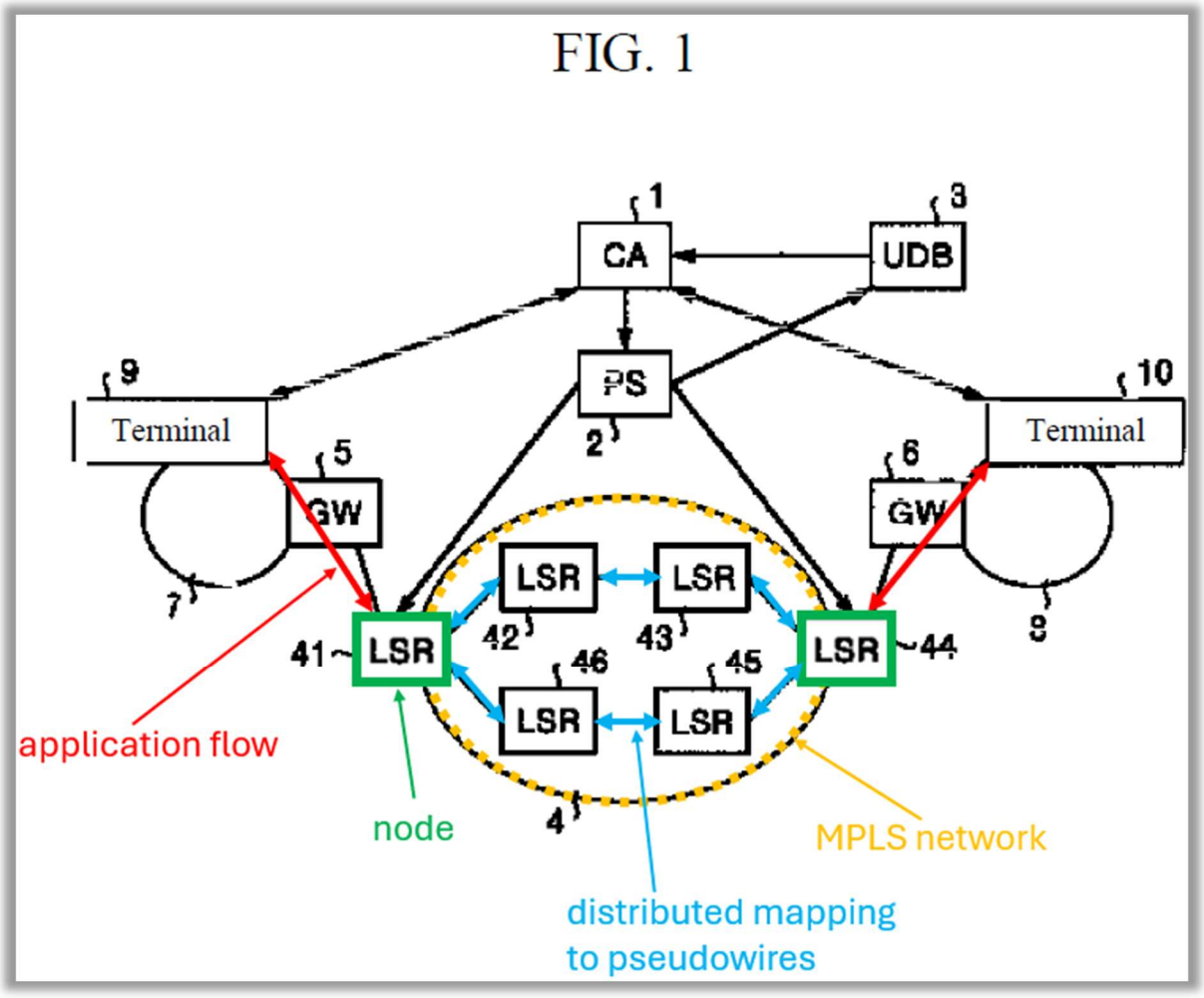
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EX-1005 FIG. 1 (annotated).

31. *Murphy's* edge routers (green) of an MPLS network (orange) received application flows (aka "packet flows" in *Murphy*) (red) from computing devices. The edge routers identified information associated with the packet flows (red), such as protocol and port numbers, mapped the packet flows to pseudowires comprising label switched paths (LSPs) (blue) of the MPLS network (orange) according to various mapping schemes. The edge router encapsulated the packets of the application flow (red) as MPLS packets using MPLS headers. The edge router (green) then forwarded the MPLS packets along the pseudowires to a second edge router (green) according to the mapping scheme. Thus, *Murphy* taught mapping of application flows to pseudowires in various mapping schemes.

32. *Taguchi* taught a distributed mapping scheme readily applicable to Murphy. *Taguchi* also mapped application flows (*e.g.*, voice streams) to pseudowires and taught that it was beneficial to distribute an application flow over two or more pseudowires. For example, *Taguchi* disclosed a policy server 2 in communication with edge label switched routers (LSRs) (green) that determined the number of LSPs (blue), including multiple LSPs, in the MPLS network (orange) for routing the application flow (red) in a distributed manner:



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EX-1006 FIG. 1 (annotated). As illustrated above, a single application flow (red) is distributed over two pseudowires (blue), i.e., pseudowire LSR41-LSR42-LSR43-LSR44 and pseudowire LSR41-LSR46-LSR45-LSR44.

33. Thus, as described in the Grounds below, the Challenged Claims are obvious over *Murphy* in view of *Taguchi*.

A. Summary of the '320 Patent

34. The '320 Patent is directed to systems and methods for transferring data across computer networks. Ex-1001 Abstract.

35. The '320 Patent acknowledges that prior networks were managed using MPLS technology, which provided QoS, redundancy, Operations Administration and Maintenance ("OAM"), and Virtual Private Network ("VPN") services and was deployed in "most backbone networks." Ex-1001 1:22-28.

36. The '320 Patent also states that MPLS networks previously used "pseudowires"[1] to map Layer-1 or Layer-2 traffic into "virtual circuits," where pseudowires were associated with an "MPLS label" that determined packet forwarding. EX-1001 1:33-45. Thus, MPLS allowed prior art pseudowires to provide emulation of a "Layer-1 or Layer-2 native service" over a network. EX-

[1] The '320 Patent includes several instances, including the claims, that pseudowire is misspelled. This Declaration uses the correct spelling.

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1001 1:35-37. According to the specification, however, MPLS networks previously allowed only Layer-1 or Layer-2 connections to be mapped to pseudowires, and that mapping was in a one-to-one relationship, MPLS purportedly could not guarantee QoS for "individual applications," such as the delay or packet loss requirements of voice and video applications, at least not "typically." EX-1001 1:46-57.

37. While the '320 Patent recognized that other solutions addressed "the QoS requirement associated with applications," it stated that issues remained with these other solutions. EX-1001 1:58-60. For example, one solution, "IntServ/RSVP," identified application flows based on source and destination ports and IP addresses, as well as protocol types, thus requiring deep packet inspection to implement IntServ/RSVP's "extensive QoS mechanisms to satisfy the service parameters for each flow." EX-1001 1:60-2:3. Another solution, "DiffServ," purportedly addressed application QoS using "traffic classes" rather than handling QoS on a "per flow basis." EX-1001 2:6-20.

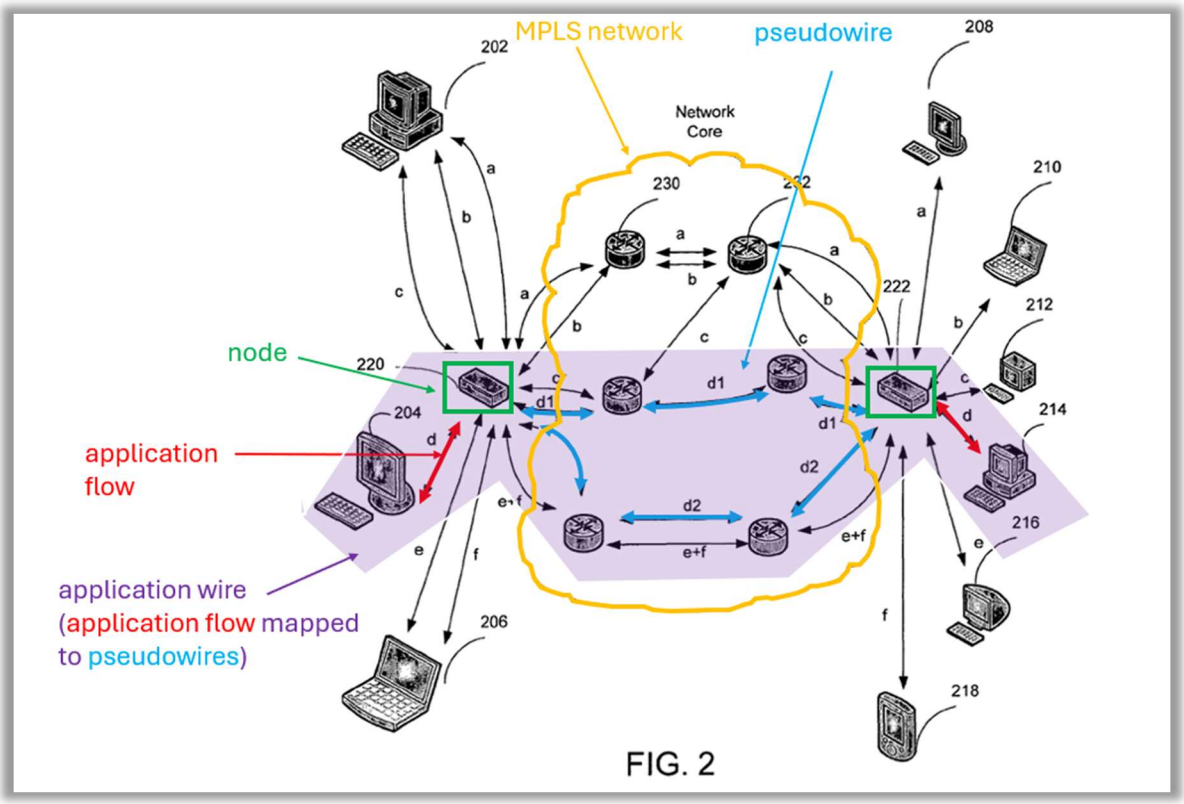
38. Thus, the '320 Patent sought to provide "QoS guarantee…at per-application flow level" while "manag[ing] application traffic over a carrier network without requiring changes to the intermediate nodes." EX-1001 2:21-26.

39. The '320 Patent discloses using "Application Wires" in place of prior art pseudowire uses. EX-1001 4:7-8. Rather than mapping Layer 1/2 traffic

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indiscriminately to pseudowires, an Application Wire instead maps "application flows" to pseudowires. EX-1001 3:20-23, 3:42-61. As described, "an application flow" is "a set of packets exchanged between two or more devices for accomplishing a specific function," and can "include[] data associated with [OSI] Layer-4 or above." EX-1001 3:23-28. Thus, the "Application Wire" provided a "virtual circuit," or a transparent wire, for transferring "application flows." EX-1001 3:18-20, 1:33-37.

40. FIG. 2 illustrates a network that supports "Application Wires":



EX-1001 FIG. 2 (annotated); EX-1001 4:8-9. The network includes client devices 202-206 that communicate with client devices 208-218 and edge nodes 220, 222 (green) that transfer application flows (red), labelled "a-f," between client devices

through the MPLS network core (orange) comprising standard MPLS devices. EX-1001 4:9-21, 4:46-50. Edge nodes 220, 222 map the application flows to pseudowires (blue) through the MPLS network. EX-1001 4:29-31. The '320 Patent explains that an application wire (purple) is formed by mapping an identified application flow (red) to one or more pseudowires (blue). EX-1001 4:61-65.

41. The '320 Patent lists a number of schemes for mapping application flows to pseudowires, including: (1) a one-to-one mapping; (2) an aggregation of multiple application flows to one pseudowire; and (3) a "distributed mapping" "where an application flow is mapped to multiple Pseudowires." EX-1001 4:31-35. For example, FIG. 2 illustrates that (1) application flows "a" and "b" are one-to-one mapped to separate pseudowires ("a" and "b," respectively), (2) application flows "e" and "f" are aggregated to a single pseudowire ("e + f"), and (3) application flow "d" is distributed to pseudowires ("d1" and "d2"). EX-1001 4:29-39.

42. After the application flow's pseudowire(s) are determined, the edge node encapsulates the flow's packets with a pseudowire header and transmits the packets through the MPLS/IP network's pseudowires. EX-1001 6:13-16; *see also* EX-1001 4:29-39. The pseudowire header includes "packet label information,

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which has the same format as…an MPLS packet." EX-1001 6:19-20. Thus, "the resulting packet is an MPLS formatted packet." EX-1001 6:37-40.

43. To identify application flows, edge nodes extract data from packet header fields. EX-1001 5:2-4. For example, data in packet header 502 (brown) can be used to identify an application flow:

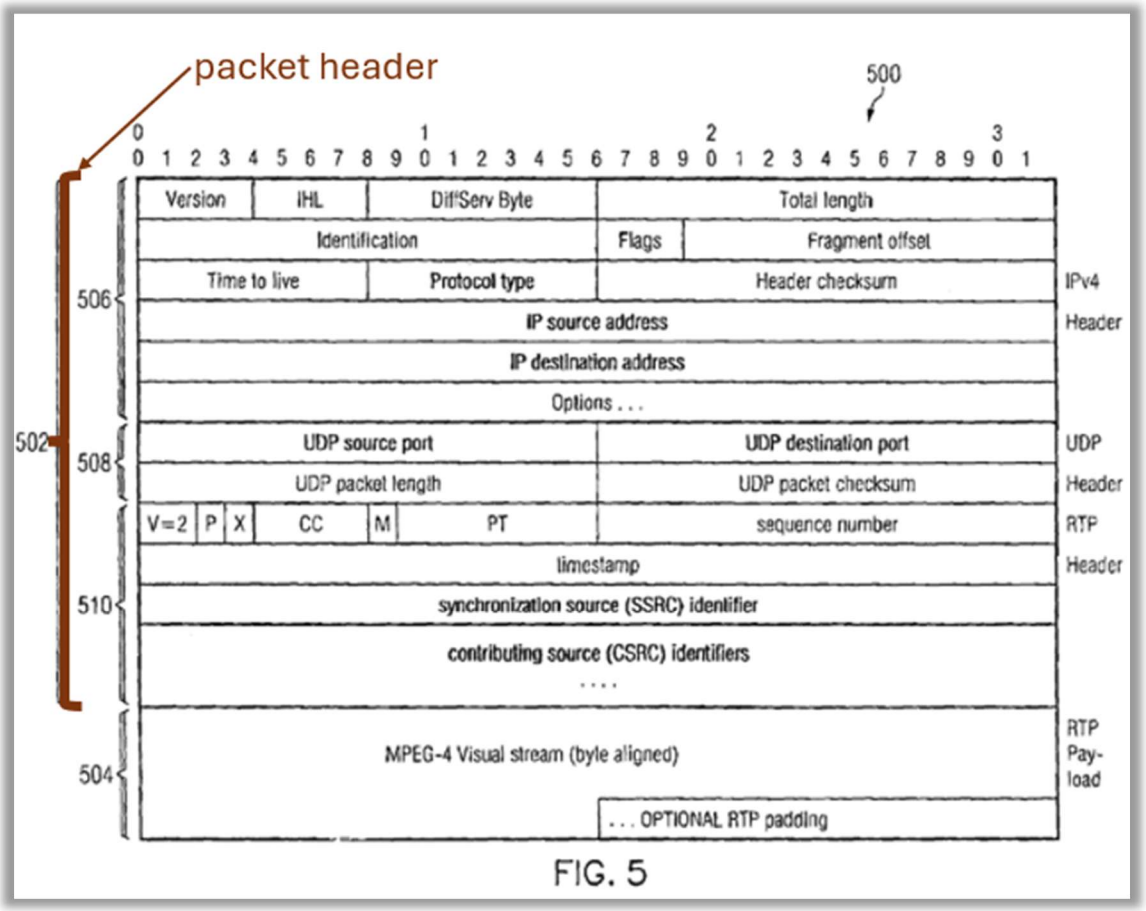


FIG. 5

EX-1001 FIG. 5 (annotated), 5:15-31. The fields identifying an application flow can include the IP source and destination addresses, "protocol type," "source port," and "destination port." EX-1001 5:21-27. The patent admits that the prior art identified application-level connections (*i.e.*, application flows) based on these five

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parameters, known as the "5-tuple." EX-1001 1:60-64. The '320 Patent nonetheless states that all header fields are not required to identify an application flow and that other headers and fields may be used. EX-1001 5:27-31.

44. Claim 1 is representative:

[1pre] *A method comprising*:

[1a] *at a node associated with a multiprotocol label switching system (MPLS) network, performing:*

[1b] *identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow;*

[1ci] *in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through the MPLS network, [1cii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and*

[1d] *communicating data related to the sending device application via at least one of the plurality of pseudowires.*

45. However, mapping "application flows" to pseudowires was already known in the art as demonstrated by this Declaration.

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B. Prosecution History of the ’320 Patent

46. I have been informed that the ’320 Patent issued from application 16/536,103, filed August 8, 2019. EX-1001 (21-22). I have been informed that, during examination, the Patent Office issued a single office action without providing a prior art rejection. EX-1002 058-064. I have been informed that the applicant overcame the rejections and the claims were allowed. EX 1002 0021-0034; 0007-0014

47. I have been informed that the Examiner’s reasons for allowing the ’320 Patent were identical to the reasons that the same Examiner allowed the parent US 10,411,999 Patent. EX-1002 0007-0014; EX-1004 0024-0033. I have been informed that the US 10,411,999 was allowed over prior art rejections after an Examiner’s Amendment added the “distributed mapping of the application flow via at least one of the plurality of pseudowires” found in limitation [1cii] of the ’320 Patent:

21. (Currently amended) A method comprising:

at an ingress node associated with a multiprotocol label switching system (MPLS) network , performing:

identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow; ~~and~~

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in response to identifying the information, and based on stored data mapping application flows with psuedowires, determining a plurality of pseudowires as paths through the MPLS network for the application flow, wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of psuedowires; and

communicating data associated with the application via at least one of the pseudowires.

EX-1004 0029-0030, 0087-0094; EX-1001 claim 1.

48. It is my opinion however, as shown by this Declaration, distributed mapping of application flows to pseudowires was also already known.

C. Claim Construction

49. I have been informed and understand that in order to properly evaluate the ’320 Patent, the terms of the claims must first be interpreted.

50. I have been instructed to give each claim term in the Challenged Claims its plain and ordinary meaning in this proceeding. It is my opinion that the prior art I have relied upon meets each of the claim terms under any reasonable construction. Thus, I understand that no specific construction of any claim term is required.

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D. Priority Date of Claims

51. For the purpose of this *inter partes* review, I have been instructed to assume that the effective filing date of each of the Challenged Claims is no earlier than the filing date of provisional application 60/725,038, October 7, 2005.

E. Person of Ordinary Skill in the Art (POSITA)

52. I am familiar with the knowledge and capabilities of one of ordinary skill in the art. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art as of October 7, 2005, the earliest possible effective filing date of the '320 Patent.

53. I have been informed and understand that a Person of Ordinary Skill in the Art ("POSITA") is a hypothetical person who is presumed to be aware of all pertinent prior art, thinks along conventional wisdom in the art, and is a person of ordinary creativity.

54. With respect to the '320 Patent, a POSITA in October 2005 would have been someone knowledgeable and familiar with computer networking and, in particular, MPLS networks. A POSITA would have gained knowledge of these concepts through a mixture of training and work experience, such as by having at least a Bachelor's degree in electrical engineering, computer science, or related field, and at least two to three years of training or additional work experience in the area of computer networking, or a related field. Additional hands-on and design

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experience could compensate for less formal education, and vice versa. The knowledge and skill of a POSITA is further reflected in the prior art references themselves, as well as the State of the Art (§V), discussed below.

55. I have been informed and understand that a POSITA may work as part of a multi-disciplinary team and draw upon not only his or her own skills, but also take advantage of certain specialized skills of others on the team to solve a given problem.

V. State of the Art

56. This section presents my opinions as to the state of the art as of the Priority Date. This section, and the documentary evidence cited, provide additional factual support for my opinions, including the general knowledge, common understanding and skill of a POSITA at the Priority Date. This section provides additional factual support and foundation for my opinions on the motivation to modify and combine the teachings in the references, and further demonstrates why doing so would involve a reasonable expectation of success.

1. Application Flows

57. It was well known in the art that applications communicated using flows of packets identifiable using packet header attributes, such as source and destination addresses, protocol, and source and destination port numbers. For example, "[a]pplication[s]" were "software program[s] that carrie[d] out some

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useful task", such as "communications packages." EX-1012, 57. Applications, and the traffic flows containing the applications, were known to be identified using packet header information, such as the source and destination IP addresses, the transport protocol, and the source and destination ports ("5-tuple"). EX-1019, 33; EX-1001 1:58-64. "Port[s]" were "used by Internet transport protocols to distinguish among multiple simultaneous connections to a single destination host." EX-1012, 615.

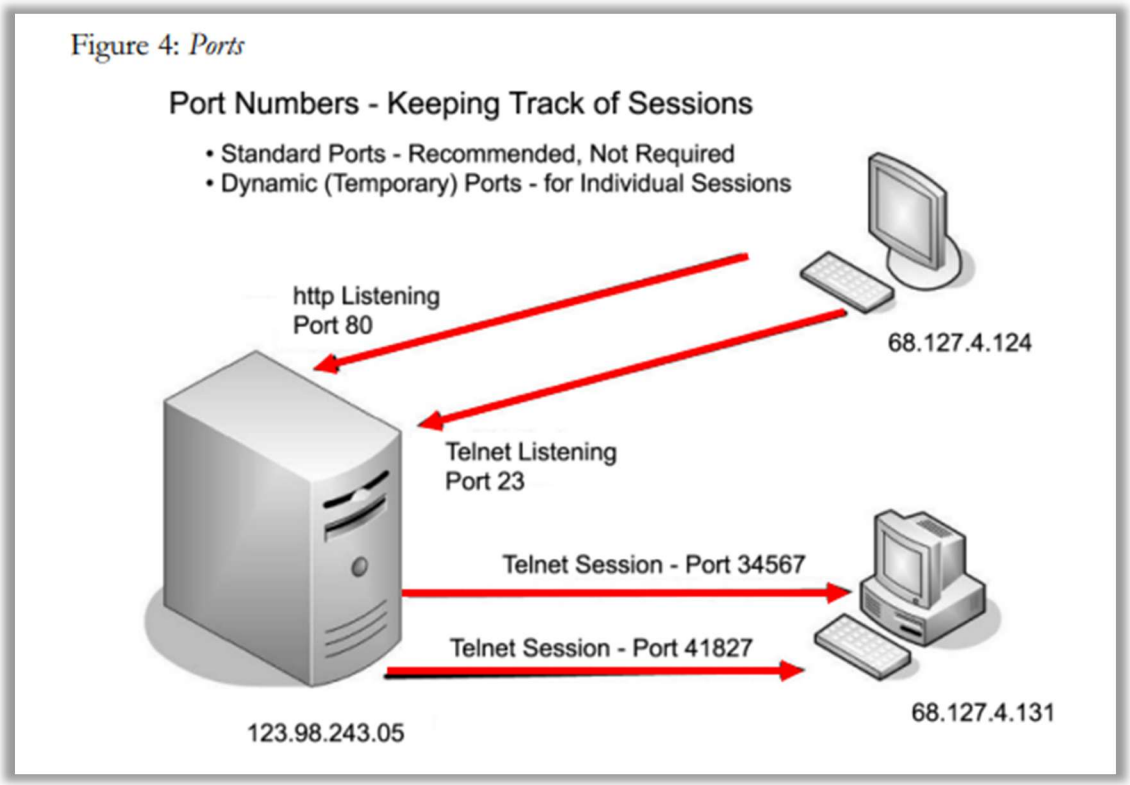
58. In one example, Cisco System's NetFlow services provided network administrators "flow" information including "fine-grained metering for highly flexible and detailed resource usage" within their networks. EX-1013, 2. These, flows were packets having common properties, "such as **IP addresses**, packet and byte counts, timestamps, Type of Service (ToS), **application ports**, input and output interfaces, **etc.**"[2] EX-1013, 2. This flow information was used for network monitoring, security analysis, and "**application** monitoring and profiling, user monitoring and profiling." EX-1013, 2-3.

59. As discussed in *Basel*, packets of a traffic flow were identified using the source and destination IP addresses, IP protocol, service type, and port number. EX-1014, 8. Ports were specifically used to manage each two-way conversation,

[2] Throughout this Declaration, all emphasis is added unless otherwise stated.

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or sessions (*i.e.*, traffic flows). EX-1014, 8. Each of the flows were sorted based on the port number specified in the header of each of the packets. EX-1014, 8; *see also* EX-1013, 2 (a flow is defined as a sequence of packets with common properties that pass through a network device, wherein "flow records include details such as IP addresses, packet and byte counts, timestamps, Type of Service (ToS), **application ports**, input and output interfaces, etc."). For example, as illustrated below, a request for a web page (red) was directed to port 80 and a request for a telenet session (red) was directed to port 23:



EX-1014, 8, FIG. 4 (annotated).

60. Such port numbers were used, and often standardized, because "each computer may have many different **programs**," aka, applications, "running at the

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same time." EX-1014, 8. Further, "*port[s]* referr[ed] to the number that helps manage communication sessions," and network management used IP headers, including port numbers, "to decide how to handle" "packets." EX-1014, 8. Thus, many port numbers were synonymous with the applications they serviced (*e.g.*, HTTP on port 80).

61. Thus, a POSITA was well aware that applications flows, including identifying them using IP source and destination addresses, the protocol, **and** the port numbers, were fundamental to network management and the routing and handling of packets of application flows.

2. Pseudowires Using MPLS and Traffic Engineering

62. Transferring data using MPLS pseudowires was already well understood.

63. First, MPLS networks were well known, having been recognized as moving beyond merely expedited packet forwarding to providing "fundamental advancements" in networks, allowing the transition of the internet from "best effort" to "a true **multiservice** infrastructure." EX-1007, 111. Indeed, one of the first major applications of MPLS was "traffic engineering" that enabled optimization of network performance and "QoS objectives such as low delay, low delay variation, high throughput, low packet loss, and predictable service." EX-1007, 112. Thus, "the essential goals" of MPLS traffic engineering, like all

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Internet traffic engineering, "[were] to optimize traffic oriented performance characteristics while simultaneously minimizing network costs through efficient utilization of network resources." EX-1007, 112.

64. It was known that MPLS included attaching a label to packets at the ingress point of an MPLS network (orange) by edge routers (green) and forwarding the traffic according to the label:

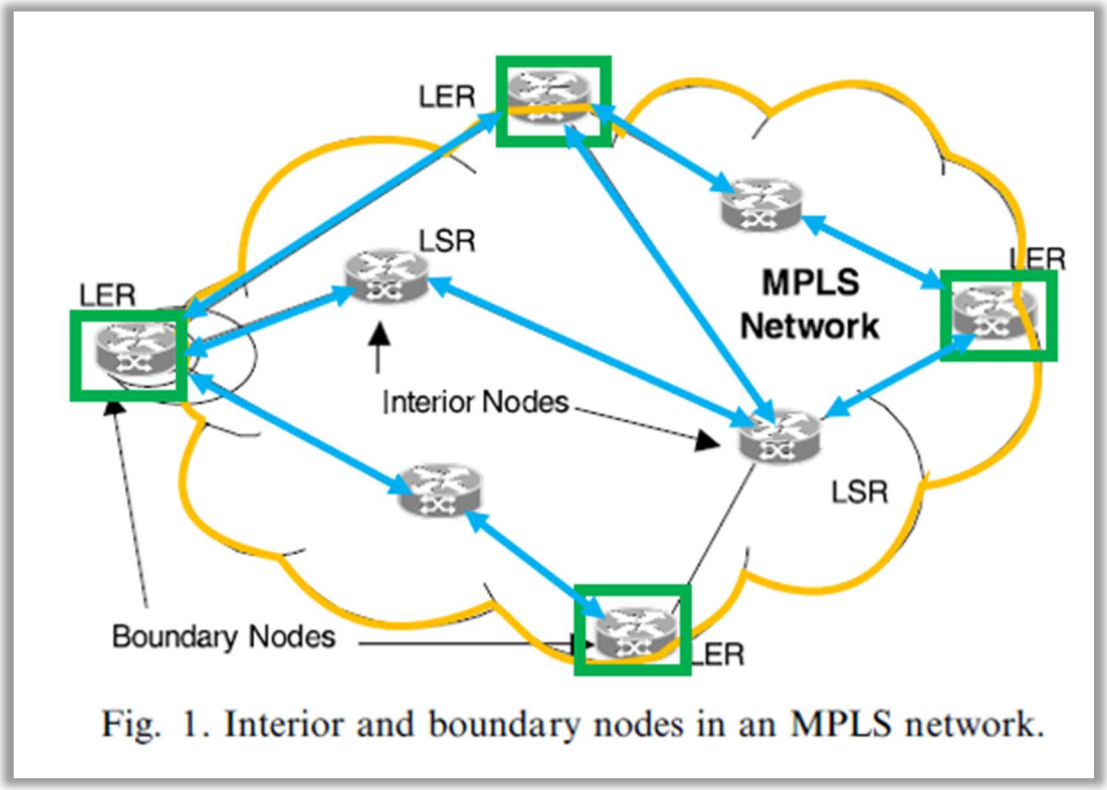


Fig. 1. Interior and boundary nodes in an MPLS network.

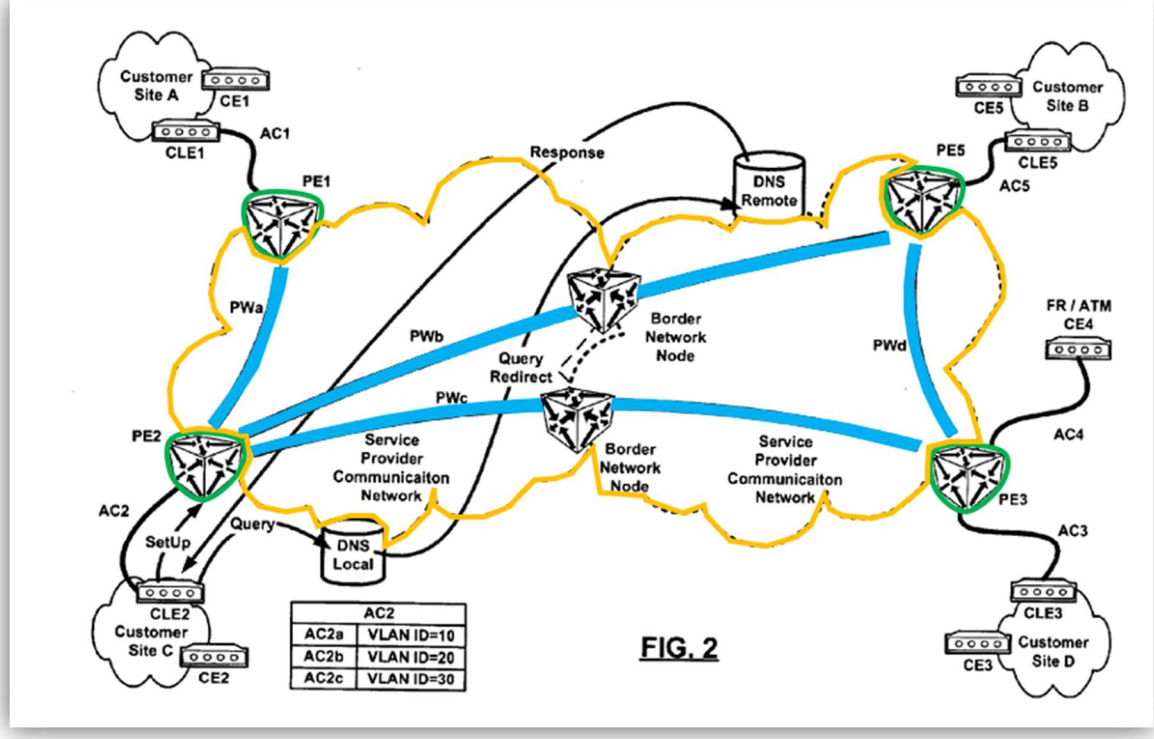
EX-1007, 113-14, FIG. 1 (annotated). The path traveled by the packets are label switched paths (LSPs) (blue). EX-1007, 113. Signaling protocols, such as RSVP-TE and CR-LDP, were used to create LSPs. EX-1007, 114.

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65. In MPLS networks, traffic engineering often dealt with "traffic trunks," which included routed traffic traversing one or multiple paths. EX-1007, 120. As used in the art, the term "LSP-tunnels" referred to both the traffic trunk and the explicit LSP that the traffic trunk traverses through. EX-1007, 120. LSP-tunnels were established at the originating router and configured based on the endpoints and the desired performance or behavior attributes. EX-1007, 121. Once the path was identified, the LSR used the signaling protocol (*e.g.*, RSVP-TE, CR-LDP, etc.) to establish the LSP-tunnel. EX-1007, 121.

66. MPLS LSPs were also known to provide "point-to-point connections," which were also known as "tunnels." EX-1008 ¶15. These MPLS LSPs (point-to-point connections) were pseudowires ("PW"). EX-1008 ¶¶15, 31, 67; EX-1015 ¶¶10-11, 27, cls. 24 and 40 (pseudowires comprised MPLS tunnels); EX-1016 ¶¶21, 25 (pseudowires connected PE nodes across an MPLS core); EX-1017 ¶24 (packets transmitted over PWs, the PWs included tunnels selected from a group of tunnels including MPLS tunnels). For example, *Lee '600* used MPLS network's (orange) LSPs to "provision the point-to-point tunnel(s)" such as the "PWa," "PWb," and "PWc" (blue) running between edge nodes (green) to provide an emulated LAN service, assigning PWs based on VLAN IDs:

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EX-1008 ¶¶15, 31, 67, FIG. 2 (annotated).

67. Thus, transferring data using MPLS pseudowires to provide QoS for flows was already well understood.

3. Distributed Mapping and Load Balancing

68. Distributed mapping of application flows, including across pseudowires including in the context of multiple LSPs, was a well-known technique also known to provide efficient use of network resources and more bandwidth. EX-1007, 122 (traffic sent across multiple LSPs when traffic between two endpoint exceeded the capacity of a link); EX-1009, 4-5 (traffic sent along multiple links enhanced efficiency of network resources); EX-1010, 3, 24-25

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(fragmenting and sequencing IP packets); EX-1020, 18 (aggregate traffic divided into sub-streams and routed through multiple paths between two nodes when one single link could not carry the load). Distributed mapping enhanced the efficiency of the network resources by breaking up (*e.g.*, partitioning or fragmenting) the flows such that they do not exceed the capacity of a link. EX-1007, 122 (arriving traffic partitioned and assigned onto parallel LSPs according to a network performance objective); EX-1009, 5 (packet-specific load balancing using multiple links instead of a single link); EX-1020, 18.

69. One use of distributed mapping was load balancing. EX-1007, 122 (partitioned traffic load balanced across multiple LSPs); EX-1009, 4-5 (packet-specific load balancing using multiple links instead of a single link); EX-1020, 18 (load balancing included dividing aggregate traffic into sub-streams and routing the sub-streams through multiple paths between nodes). The "basic concept" behind load balancing is to partition the arriving traffic and assign the partitioned traffic onto the parallel LSPs. EX-1007, 122; EX-1020, 18 ("divid[ing] the aggregate traffic into sub-streams and rout[ing] the sub-streams through multiple paths between the two nodes."). For example, load balancing was previously used in MPLS networks having multiple LSPs between various nodes, such as the three LSPs (blue) between nodes A, Z (green) of an MPLS network (orange):

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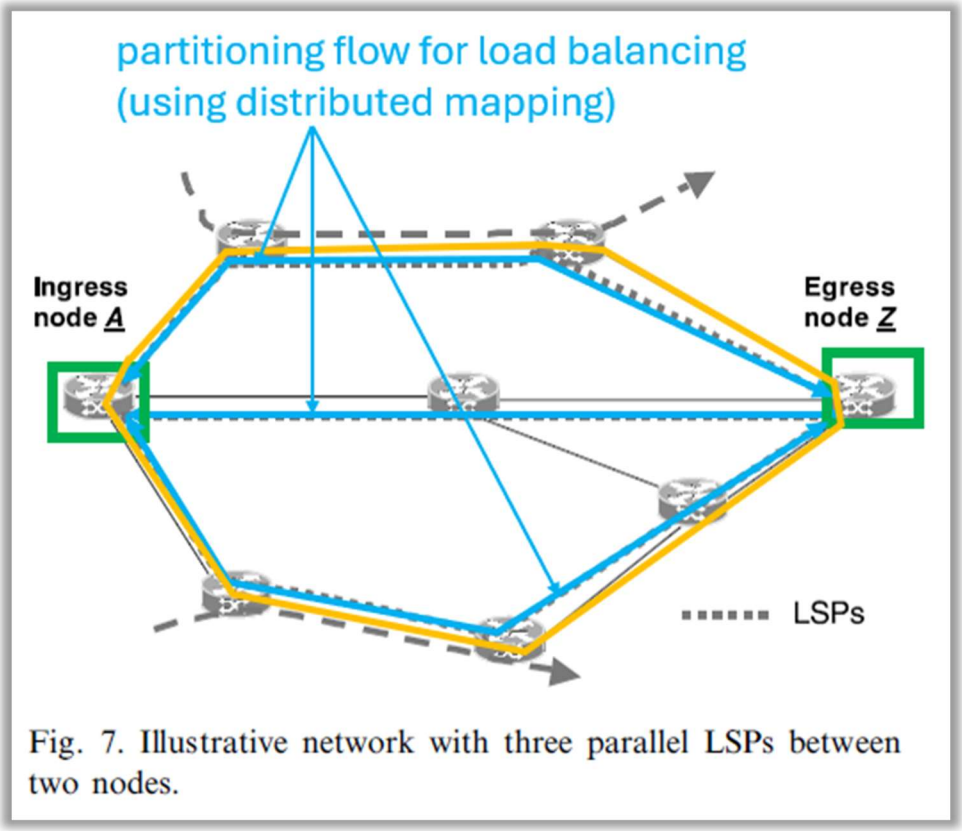
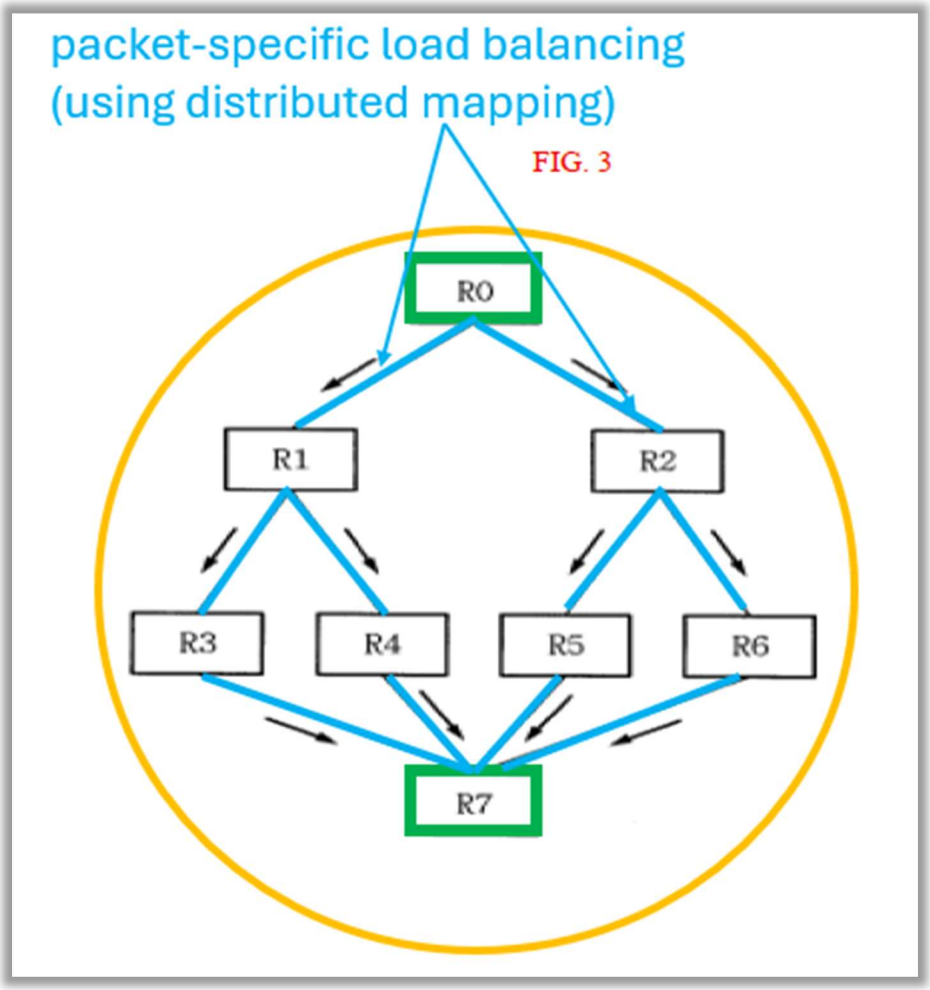


Fig. 7. Illustrative network with three parallel LSPs between two nodes.

EX-1007 FIG. 7 (annotated). If the traffic exceeded capacity of one LSP, it was "partitioned" and forwarded by the node A along a separate, parallel LSP based on dynamic or static considerations. EX-1007, 122.

70. It was also well known that various mechanisms allowed "packet-specific," *i.e.*, packet-by-packet, "load balancing across multiple links" such that the traffic associated with the packets were mapped in a distributed manner. EX-1009 Abstract. For example, *Lee '938* implemented load balancing for packets transmitted between LSRs RO and R7 (green) over various LSPs (blue):



EX-1009, 4, FIG. 3 (annotated). Various paths would be chosen, *e.g.*, R0→R1→R3→R7, R0→R1→R4→R7, R0→R2→R5→R7, and R0→R2→R6→R7, based on load balancing. EX-1009, 4 ("if load balancing according to the present invention is implemented, IP packets are transmitted through all four paths: R0→R1→R3→R7, R0→R1→R4→R7, R0→R2→R5→R7, and R0→R2→R6→R7, as depicted in FIG. 3, thereby enabling the efficient usage of network resources").

71. Thus, load balancing and distributed mapping, across pseudowires, including MPLS LSPs, for traffic flows and packets was well understood by a POSITA before October 2005.

4. Packet Sequencing/Fragmentation

72. A POSITA also understood the need for, and technical mechanisms to implement (*e.g.*, using "sequence" numbers), packet sequencing in a variety of scenarios, including when an application flow was distributed over a variety of paths, including MPLS pseudowires. As discussed in *Stewart*, if application flows were fragmented, the packets should be assigned a sequence number such that they could be reassembled sequentially at the receiver. EX-1011, 9-10, 23 ("[w]hen a user message is fragmented into multiple chunks, the TSNs are used by the receiver to reassemble the message. This means that the TSNs for each fragment of a fragmented user message **MUST be strictly sequential**"). Sequence numbers were also specifically used to track the order of delivery of packets over a pseudowire in the context of MPLS; indeed, such sequence numbers were "[c]onventional." EX-1016, ¶19.

73. Thus, using sequence numbers to order application-flow packets distributed across MPLS PWs was well understood by a POSITA before October 2005.

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VI. IDENTIFICATION OF HOW THE CLAIMS ARE UNPATENTABLE

A. Ground 1: Claims 1-5, 7-12, and 14-20 Are Obvious over *Murphy* in View of *Taguchi*

1. Murphy (EX-1005)

74. U.S. 7,477,657 to Murphy et al. ("*Murphy*," EX-1005) is directed to "Aggregated End-to-End QoS Signaled Packet Flows Through Label Switched Paths." EX-1005 (10), (75), (54). I have been informed that *Murphy* qualifies as prior art.

75. *Murphy* provided application-specific QoS using an "end-to-end" resource reservation "using MPLS." EX-1005 Abstract, 1:7-9, 2:66-3:4.

76. *Murphy* stated that conventional Resource Reservation Setup Protocol (RSVP) systems allowed reservation of network resources "for packet flows from a source device to a destination device." EX-1005 1:13-16. *Murphy* observed that typical "RSVP-enabled routers" used RSVP requests to "establish a defined route within the network able to commit the resources to satisfy the request…[for] transmission of real-time data," such as "video" and "voice data" over packet-based networks. EX-1005 1:19-24. However, like the '320 Patent, *Murphy* explained that resource reservation protocols, such as RSVP, are disadvantageous because they can "introduce significant overhead within a network." EX-1005 1:25-29. This is because routers in the network "must continually monitor resource allocation and maintain significant state data related to the route" making

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it difficult to support these types of protocols in networks. EX-1005 1:29-36. Thus, *Murphy* sought a solution to these problems.

77. *Murphy's* solution used edge routers 8A, 8B (green) to route the reservation request and subsequent packet flows (*i.e.*, application flows) (red) over the pseudowires (blue) of an MPLS Network (orange):

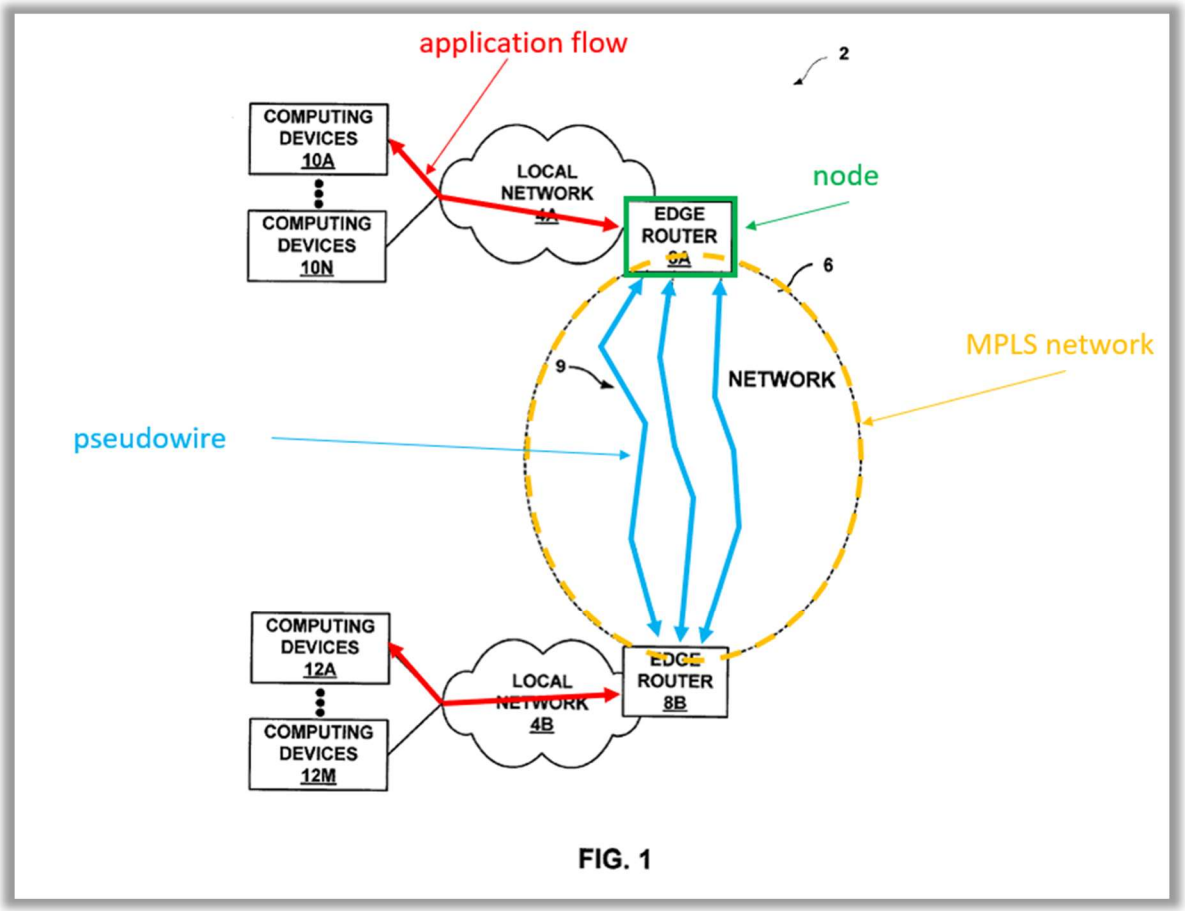


FIG. 1

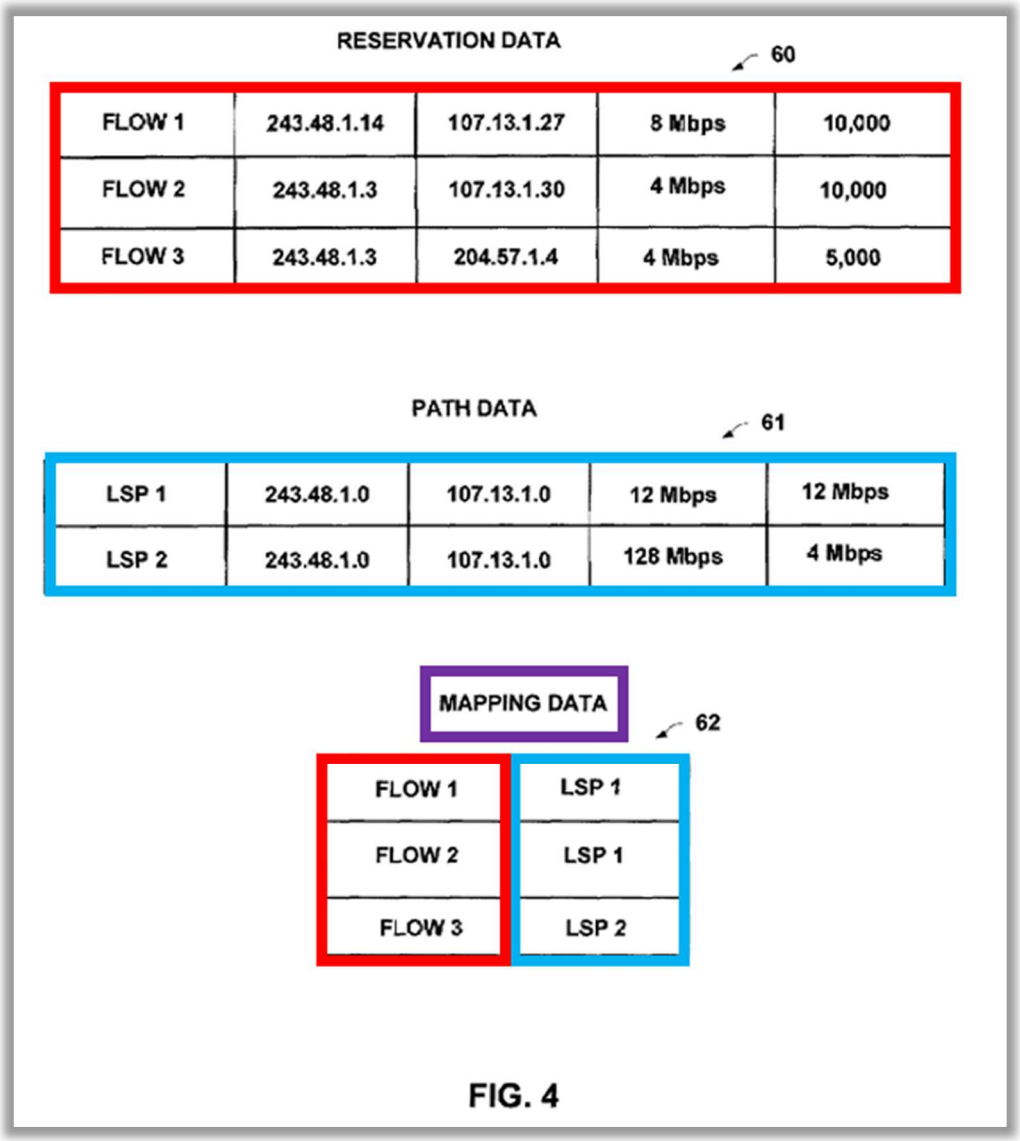
EX-1005 3:50-4:10, FIG. 1 (annotated). *Murphy* described that these edge routers (*node*)[3] encapsulated data packets from end-to-end packet flows or streams (*application flow*) (red) produced by computing devices 10A-10N and 12A-12M and forwarded the encapsulated packets through an *MPLS network* 6 (orange) over LSPs 9 (*pseudowires*) (blue). EX-1005 4:44-51. *Murphy* disclosed end-to-end packet flows for particular types of applications, including "real-time data, such as video or voice data." EX-1005 2:66-3:4. *Murphy* also disclosed that the LSPs carried encapsulated MPLS packets such that the packet flows are "opaque" to the network, obviating the need to "monitor and support information associated with the individual end-to-end packet flows." EX-1005 1:57-67, 4:39-58. Further, *Murphy* disclosed that edge routers may be coupled with a second LSP such that there is bidirectional communication between the edge routers. EX-1005 5:19-33.

78. *Murphy* disclosed that reservation data 60 (red) represented the requests "to reserve resources for a particular packet flow, e.g., FLOW 1, FLOW 2 and FLOW 3," and included packet flow information, such as source and destination addresses, the protocol, protocol port numbers, the type-of-service

[3] Throughout this Declaration, I use italics to indicate claim language of the Challenged Claims.

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(ToS) byte, the DiffServe Code Point (DSCP), the required bandwidth, and the burst size:



EX-1005 6:58-7:8, FIG. 4 (annotated).

79. *Murphy* further disclosed that mapping data 62 (purple) associated each of the flows identified in the reservation data 60 (red) to an LSP identified in the path data 61 (blue). EX-1005 7:16-20. As an example, FLOW 3 was mapped

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to LSP 2—a "one-to-one" mapping. EX-1005 7:18-20. FLOW 1 and FLOW 2 were "aggregated" to LSP 1. EX-1005 7:18-26. *Murphy* also disclosed that the path data can identify a primary LSP and one or more backup LSPs the packet flows can be mapped to. EX-1005 8:41-46.

80. *Murphy* identified attributes (*e.g.*, protocol and port numbers) of the packet flows (*applications flows*) and mapped those flows to LSPs (*pseudowires*). Thus, *Murphy* disclosed application-specific virtual circuits through an MPLS network, or the "Application Wires" of the preferred embodiments of the '320 Patent. EX-1001 1:33-37, 3:17-23. Further, *Murphy* recognized and achieved the same benefits sought by the '320 Patent. Because the encapsulated packets traversed the MPLS network 6 as MPLS packets, the MPLS core routers were not required to monitor resource allocation or maintain state information; in other words, no deep packet inspection was required for the end-to-end application flows that were forwarded according to the label of the encapsulated MPLS packets. *Cf.* EX-1005 4:50-58 with EX-1001 1:64-2:3.

81. It is my opinion that *Murphy* (1) in the same field of endeavor of application-specific forwarding of traffic through an MPLS network as the '320 Patent; and (2) reasonably pertinent to the problem of providing application specific QoS faced by the inventors of the '320 Patent. EX-1001 2:22-26, 4:8-50.

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82. While *Murphy* disclosed various schemes for mapping an application flow to pseudowires, *Murphy* did not expressly disclose distributing the same flow across multiple pseudowires at the same time in the context of the preferred embodiments of the ’320 Patent.

2. Taguchi (EX-1006)

83. Japanese Patent Application Publication No. JP 2003-258857 to Taguchi (“*Taguchi*,” EX-1006) is titled “Network Policy Control System and Policy Server Used Therein.” EX-1006 (11), (72), (54). I have been informed that *Taguchi* qualifies as prior art.

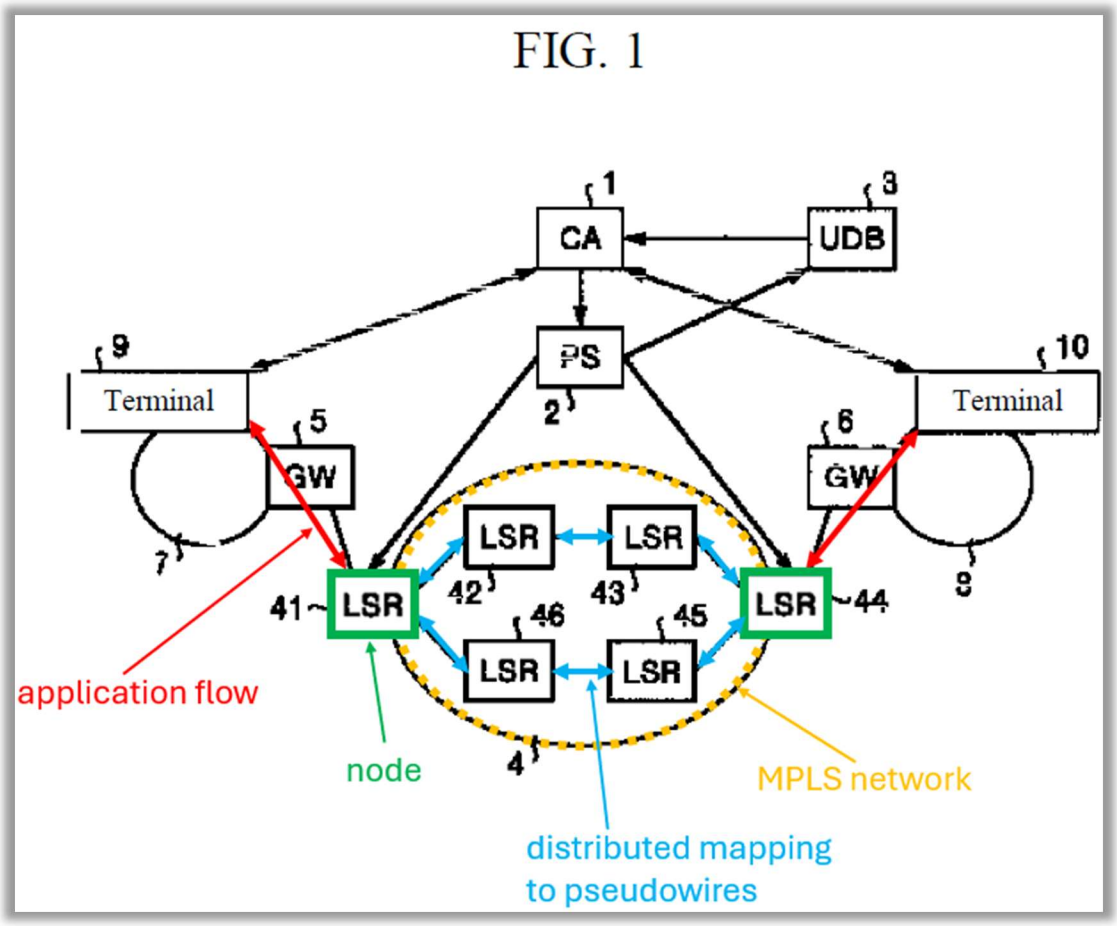
84. *Taguchi* disclosed a system that mapped a stream (*application flow*), such as a voice stream, to a plurality of LSPs (*pseudowires*) through a MPLS network between two edge routers (*nodes*).

85. *Taguchi* was directed to “autonomously determining a transfer path when an edge label switch router in an IP core network receives a stream.” EX-1006, 1. *Taguchi* explained that a “conventional technique” for VoIP communication in an MPLS network was to request that a MPLS server reserve resources for the VoIP stream. EX-1006 ¶¶2, 5. If a QoS-guaranteed LSP capable of transferring the VoIP stream was already set in the network, the MPLS server would direct the edge label switching routers (LSR) to “pass the VoIP stream through the LSP.” EX-1006 ¶¶3, 5. If the resources of the LSP were insufficient

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or an LSP had not been set, a new LSP was set. EX-1006 ¶5. *Taguchi* was concerned about overloading the MPLS server in the event of a large number of calls. EX-1006 ¶¶6-7. Thus, like the '320 Patent, *Taguchi* also had QoS concerns.

86. *Taguchi's* solution used a policy server 2 in communication with the edge LSRs (green) that determined the number of LSPs (*pseudowires*) (blue) to be set in the MPLS network (orange) between the edge LSRs that routed voice streams (*application flows*) (red) in a distributed manner:



EX-1006 ¶52, 48, FIG. 1 (annotated).

87. Utilizing user information (*e.g.*, flow identification information, the class of service/service class indicating the service grade applied to the flow, and the line resource capacity requirements) and the virtual communication path information, the policy server 2 determined either a single LSP or a plurality of LSPs to be set in the network. EX-1006 ¶50, 52, 73. For example, in FIG. 1 (above) "LSPs of two routes, 'LSR41-LSR42-LSR43-LSR44' and 'LSR41-LSR46-LSR45-LSR44'" form the "structural element" of the "virtual communication path" between LSR41 and LSR44. EX-1006 ¶52.

88. Like *Murphy*, the first stage LSR set up LSPs forming the virtual communication path using a signaling protocol, such as RSVP-TE. EX-1006 ¶54. Once the LSPs are set up in the network and a session is established, the first stage LSR transfers the packets of the stream according to the virtual communication path. EX-1006 ¶73. If the virtual communication path has only one LSP, "the stream is transferred to that LSP." EX-1006 ¶73. When a virtual communication path has multiple LSPs (*i.e.*, a *distributed mapping* of a stream), "the stream is transferred while being scheduled for each LSP so as not to exceed the resource capacity of each LSP" in the virtual communication path. EX-1006 ¶73.

89. Thus, *Taguchi* already disclosed a "*distributed mapping*" of a stream (*application flow*) to a plurality of LSPs (*pseudowires*).

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90. It is my opinion that *Taguchi* is: (1) in the same field of endeavor of application-specific forwarding of traffic through an MPLS network; and (2) reasonably pertinent to the problem of providing application-specific QoS faced by the inventors of the '320 Patent. EX-1001 2:22-26, 4:8-50.

3. Motivation to Combine

91. *Murphy* taught a one-to-one mapping of one application flow to one pseudowire, an aggregated mapping of multiple application flows to one pseudowire, and mapping of a packet flow to a primary LSP and a backup LSP. Although *Murphy* does not explicitly disclose distributing one application flow to two or more pseudowires for transmission at the same time, *Taguchi* does. A POSITA would have found it obvious to combine *Murphy* and *Taguchi* as described below.

92. *Murphy* described a system that provided QoS to packet flows within an *MPLS* network. Specifically, *Murphy* disclosed systems and methods for mapping end-to-end packet flows to LSPs and forwarding a packet flow according to the mapping. EX-1005 Abstract, 4:39-58, 7:16-26. *Murphy* disclosed that individual end-to-end packet flows may be mapped to an LSP or that multiple end-to-end packet flows may be aggregated to one common LSP. EX-1005 5:19-27, 7:16-26. *Murphy* also disclosed identifying a primary LSP and at least one backup LSP suitable for forwarding the packet flows. EX-1005 8:41-46. *Murphy*

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recognized that a suitable LSP would already need to exist or a new LSP would have to be established to meet the requirements of a packet flow. EX-1005 7:58-8:5. Further, *Murphy* disclosed that the requirements of the packet flow, and the mapping of the "suitable" LSPs, considered the bandwidth of a single and/or aggregated packet flows. EX-1005 7:9-26.

93. *Taguchi* taught the distribution of an application flow to multiple pseudowires at the same time to meet the needs of the flow, an improvement readily applicable to *Murphy*. *Taguchi* disclosed a system for providing QoS for a session stream, such as VoIP. EX-1006 ¶¶1-2. *Taguchi's* system established a virtual communication path that could include a plurality of LSPs to provide sufficient bandwidth for the stream transmitted through the virtual communication path. EX-1006 ¶52, FIG. 4 (illustrating the combined resource capacity, or bandwidth capacity, of each LSP provided the total resource capacity required for the virtual communication path). Further, when a virtual communication path included a plurality of LSPs, the stream was transferred along each LSP according to a schedule to avoid exceeding the capacity of the LSPs. EX-1006 ¶73. A POSITA would have recognized that incorporating *Taguchi's* teachings using multiple LSPs (which *Taguchi* calls a "virtual communication path"), including the scheduling of traffic over multiple LSPs based on bandwidth, would be advantageous because it would allow the system in *Murphy* to continue providing

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QoS for larger packet flows by distributing the packet flows along two or more LSPs without having to establish a new LSP, which could require installing additional routing equipment, if no LSP could meet the QoS or other traffic flow requirements. Such benefits were well known to the POSITA in the context of MPLS. §V.3 (citing EX-1007, EX-1009, and EX-1020).

94. It is my opinion that a POSITA would have found it obvious to combine both *Murphy* and *Taguchi*.

95. First, a POSITA would have been motivated by the express teachings of the references themselves. For example, *Taguchi's* express teachings of transferring a stream along multiple LSPs based on bandwidth availability provided a motivation to combine *Taguchi* with *Murphy*. As illustrated below, the virtual communication path identifier (VID) 1 had an overall resource capacity of 50 Mbps, which included LSP 1 (*i.e.*, LSR41→LSR42→LSR43→LSR44) with a resource capacity of 40 Mbps and LSP 2 (*i.e.*, LSR41→LSR46→LSR45→LSR44) with a resource capacity of 10 Mbps. EX-1006 FIG. 4. When the virtual communication was made of multiple LSPs, the stream was "transferred while being scheduled for each LSP so as not to exceed the resource capacity of each LSP." EX-1006 ¶73.

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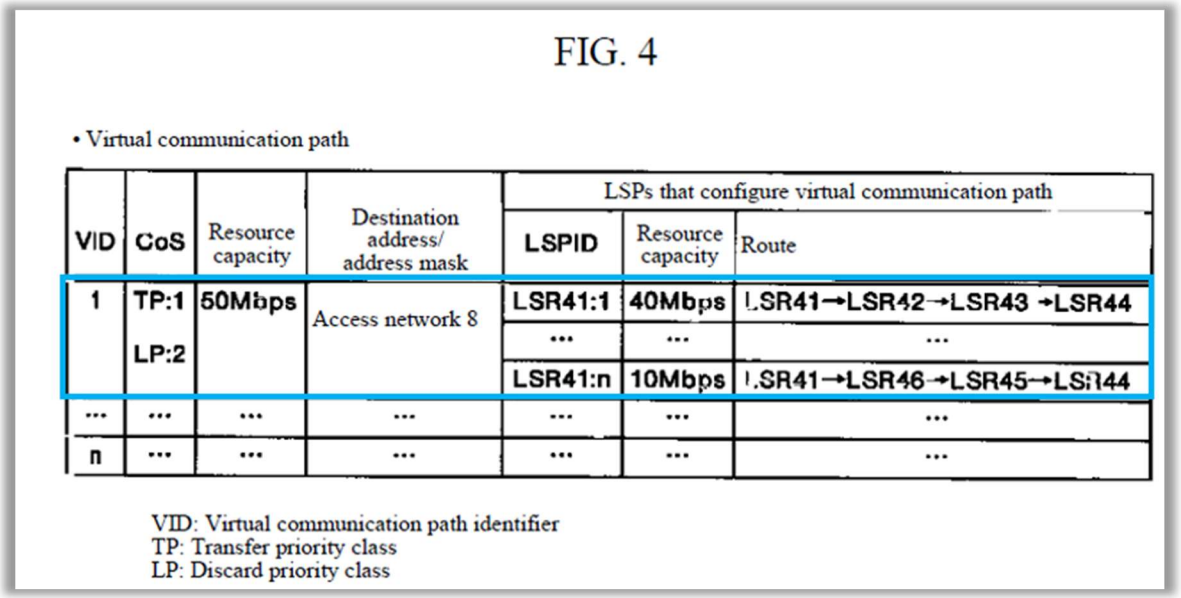


FIG. 4

• Virtual communication path

VID	CoS	Resource capacity	Destination address/ address mask	LSPs that configure virtual communication path		
				LSPID	Resource capacity	Route
1	TP:1 LP:2	50Mbps	Access network 8	LSR41:1	40Mbps	LSR41→LSR42→LSR43→LSR44
				...	...	...
				LSR41:n	10Mbps	LSR41→LSR46→LSR45→LSR44
...	...	...	...	...	...	...
n	...	...	...	...	...	...

VID: Virtual communication path identifier
TP: Transfer priority class
LP: Discard priority class

EX-1006 FIG. 4 (annotated). Thus, the bandwidth required for a virtual communication path could be shared across multiple LPSs.

96. A POSITA would have appreciated this bandwidth-sharing as a major benefit for providing quality of service for a packet flow, the goal of *Murphy's* invention, and would have been motivated to make this combination to provide the same benefits for *Murphy's* invention. Specifically, a POSITA would have recognized that bandwidth could be shared among existing LSPs in *Murphy's* network, without requiring the formation of a new LSP simply because the remaining bandwidth capacity of the existing LSPs was insufficient for a particular packet flow.

97. Second, a POSITA would have recognized additional benefits to *Murphy's* network using *Taguchi's* teachings. For example, a POSITA would have recognized that *Taguchi's* transferring of a stream along multiple LSPs would

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allow load balancing of *Murphy's* packet flows. EX-1006 FIG. 4, ¶73; *see also* EX-1007, EX-1009, and EX-1020. This load balancing would allow higher utilization of *Murphy's* LSPs while maintaining QoS at the application level. While *Murphy's* focus is on application-level QoS, effective network utilization was widely known in the art and an aim of network administration. *See* §§V.2-3; EX-1007, EX-1008, EX-1015, EX-1016, and EX-1017.

98. Third, a POSITA would have recognized that *Taguchi's* known technique of mapping a stream to multiple LSPs would have improved *Murphy's* mapping techniques in the same way. Both *Murphy* and *Taguchi* related to providing QoS for application-associated flows in an MPLS network, and both disclosed achieving this QoS through similar mapping methods. Given the overlap in MPLS technology, mapping of application flows to pseudowires, and goal of these references, a POSITA would have recognized that modifying *Murphy's* system according to the teachings of *Taguchi* would have improved *Murphy's* MPLS network to provide the same benefits and functionality of *Taguchi's* MPLS network.

99. Further, a POSITA would have recognized that the combination of *Murphy* and *Taguchi* required only basic hardware/software modifications and routine skill. Specifically, integrating *Taguchi's* teachings into *Murphy's* merely required minor software modifications to *Murphy's* edge routers, which was

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already performing mapping application flows to LSPs. For example, because their use of mapping software by *Murphy* and *Taguchi* was largely the same, a POSITA would realize that the edge routers in *Murphy* could be easily modified to incorporate *Taguchi's* known teachings to establish a mapping of multiple LSPs for a particular packet flow in *Murphy* using basic software modifications to *Murphy's* mapping software.

100. Further, benefits and mechanisms of distributed mapping of traffic was already widely known in the art, both generally and specifically in the context of MPLS. *See* §V.3; EX-1007, 122 (partitioning traffic by the router along multiple parallel LSPs); *see also* EX-1009, 4 (implementation of load balancing such that packets were transmitted through multiple LSPs); EX-1010, 24-25 (fragmenting IP packets at the source and reassembling the packets at the destination when a path's capacity could not support the packet size). Thus, a POSITA would have recognized *Murphy* could be improved with the known technique of mapping traffic to multiple LSPs as taught in *Taguchi* and had a reasonable expectation of success for making this improvement.

101. Additionally, combining the teachings of *Murphy* and *Taguchi* would have involved nothing more than combining prior art elements according to known techniques to yield predictable results. For example, a POSITA combining *Taguchi's* teaching of a "virtual communication path" comprising multiple LSPs

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with *Murphy's* teaching of LSPs, would have resulted in multiple, bi-directional LSPs capable of receiving portions of a packet flow scheduled for transmission. This combination would require only basic software modifications to the data structures of *Murphy's* edge routers. These basic software modifications were well within the routine skill of POSITA. Thus, a POSITA had a reasonable expectation of successfully combining *Taguchi's* teachings with *Murphy's* system.

102. Further, improvement of *Murphy's* mapping of end-to-end packet flows to LSPs in a MPLS network with *Taguchi's* known methods of transmitting a stream along multiple LSPs would have yielded predictable results. As discussed above, *Taguchi* and *Murphy* both used MPLS edge devices for transmission of flows through an MPLS network. *Murphy* disclosed mapping of a single packet flow to a single LSP, multiple packet flows to a single LSP, and mapping of a packet flow to a primary LSP and one or more backup LSPs. A POSITA would have recognized that *Taguchi's* mapping of a stream to multiple LSPs would have yielded predictable results in the improvement of *Murphy's* system to also include mapping of a single packet flow to multiple LSPs in the same way as *Taguchi*.

103. Thus, a POSITA would have been motivated to combine *Taguchi's* teaching of transferring a stream along multiple LSPs to *Murphy's* forwarding of an end-to-end packet flow through a MPLS network for multiple reasons and with a reasonable expectation that the combination would work.

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4. Detailed Application of *Murphy* in Combination with *Taguchi* to the Challenged Claims

Claim 1

[1pre] A method comprising:

104. *Murphy* disclosed *"[a] method"* for "mapping requests for end-to-end packet flows through a network to LSPs within the network, and forwarding packets associated with the end-to-end packet flows along the LSPs based on the mapping." EX-1005 Abstract. *Murphy's* method in view of *Taguchi* further *compris[ed]* limitations [1a]-[1d] as demonstrated below.

[1a] at a node associated with a multiprotocol label switching system (MPLS) network, performing:

105. *Murphy* disclosed this limitation. *Murphy* disclosed edge routers (green) (each *a node*) of an MPLS network (orange) (*associated with a multiprotocol label switching system (MPLS) network*).

106. For example, *Murphy* disclosed that edge router 8A (*at a node*) (green) encapsulated data packets associated with requested end-to-end flows, such as audio or video streams, within "MPLS packets" that traversed a MPLS network 6 (*associated with a multiprotocol label switching system (MPLS) network*) (orange):

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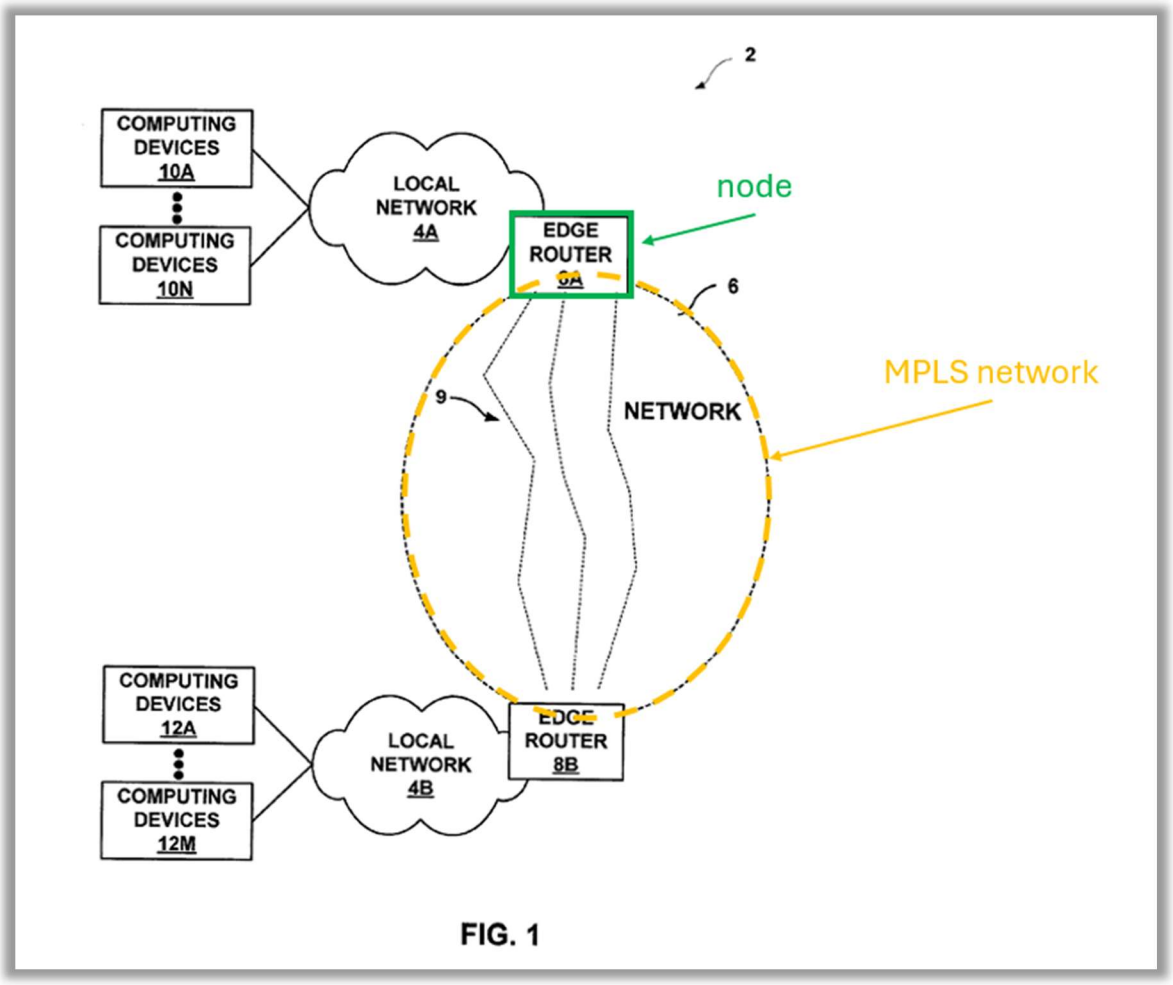


FIG. 1

EX 1005 4:14-15, 4:44-51, FIG. 1 (annotated); EX-1001 6:37-40 ("nodes" include "routers and switches").

107. *Murphy* further disclosed its edge routers (*node[s]*) "*performing*" limitations [1b]-[1d] as demonstrated below.

[1b] identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow;

108. *Murphy* disclosed this limitation. *Murphy* disclosed edge routers generating, maintaining, and referencing "attributes" of end-to-end packet flows (*identifying information associated with an application flow*), the "attributes" pulled from packet-header fields of the packet flows (*based on one or more unencapsulated packet headers of the application flow*) and, additionally, based on the same source and destination of the packet flows (*or based on an ingress data stream that includes the application flow*).

109. First, *Murphy* disclosed "*an application flow.*" For example, *Murphy* disclosed end-to-end packet flows including "real-time data, such as video or voice data." EX-1005 2:66-3:4, 4:8-13, 4:47-50 ("edge routers 8 encapsulate the **packet flows, such as the real-time audio or video streams**, produced by computing devices 10, 12"). These packet flows of *Murphy* are the same as the exemplary application flows disclosed by the '320 Patent. EX-1001 3:28-31 (VoIP and Video-on-Demand); *see also* EX-1001 3:23-28 ("an application flow" is "a set of packets exchanged between two or more devices for accomplishing a specific function"). *Murphy* further disclosed that "attributes" of the end-to-end packet flows included the source address, the destination address, the protocol, the

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protocol port numbers, the type-of-service (ToS) byte, the DiffServ Code Point (DSCP), or other applicable packet attributes. EX-1005 4:34-38, 6:62-7:8. As described below, these attributes were used to identify particular flows and map them to *Murphy's* LSPs (*pseudowires*). *Murphy's* packet-flow attributes are the same attributes of the application flows of the '320 Patent. EX-1005 4:34-38, 6:56-7:8; EX-1001 5:21-31 (header information of an application flow includes the source address, the destination address, protocol type, port numbers, etc.). A POSITA was well aware that such attributes, including, e.g., the "protocol" and "protocol port numbers", were associated with and used for handling application flows. *See* §V.1, (discussing EX-1012, EX-1013, EX-1014, EX-1019). Thus, *Murphy's* end-to-end packet flows were *application flows*.

110. Second, *Murphy* disclosed generating, maintaining, and referencing the "attributes" pulled from the packet-header fields of the packet flow (*identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow*). *Murphy* described that the edge router generated and maintained "reservation data" from reservation requests associated with packet flows. EX-1005 5:52-64, 6:56-7:8. Specifically, *Murphy's* edge router (green) included an access control module 52 that generated and maintained reservation data 53 (red):

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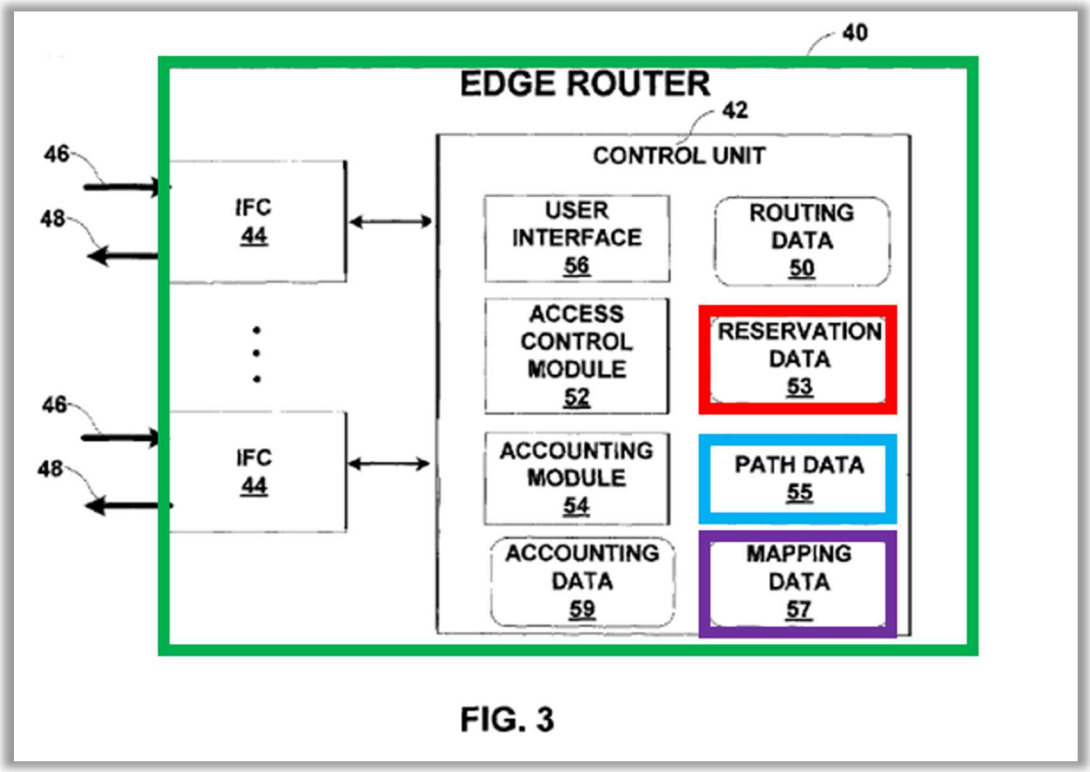
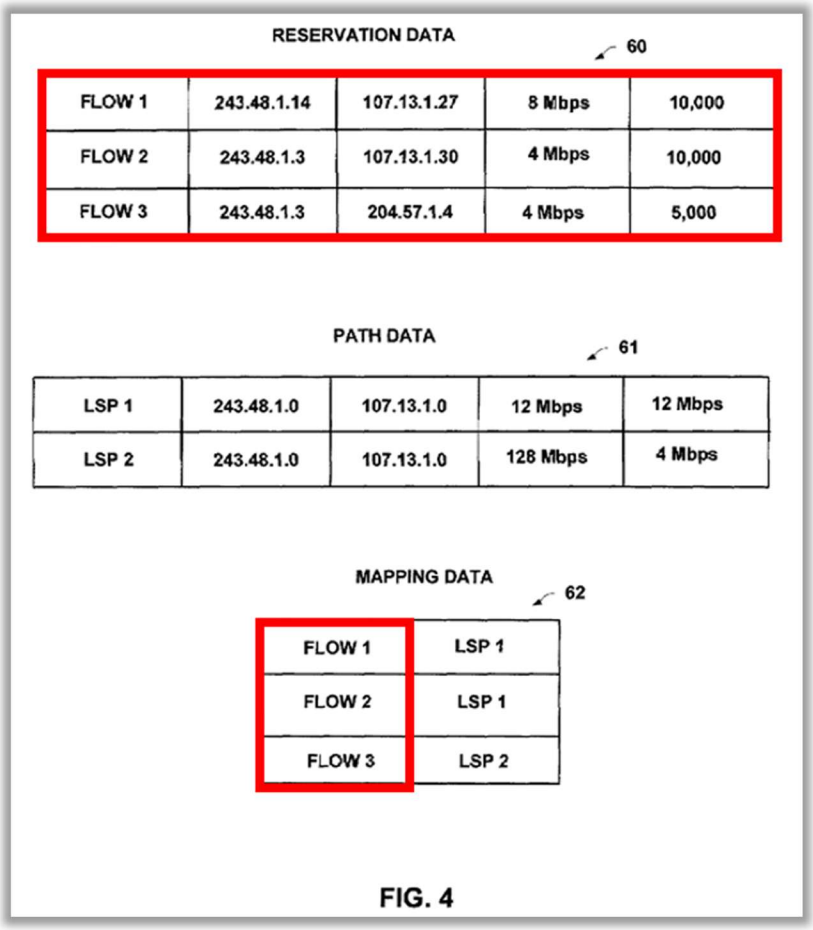


FIG. 3

EX-1005 5:52-54, FIG. 3 (annotated). Reservation data 53 specified, *e.g.*, "a source device, a destination device, and a QoS class, including required bandwidth and burst size, for each requested packet flow". EX-1005 5:54-57.

111. *Murphy* illustrated an example of reservation data in FIG. 4:



RESERVATION DATA 60

FLOW 1	243.48.1.14	107.13.1.27	8 Mbps	10,000
FLOW 2	243.48.1.3	107.13.1.30	4 Mbps	10,000
FLOW 3	243.48.1.3	204.57.1.4	4 Mbps	5,000

PATH DATA 61

LSP 1	243.48.1.0	107.13.1.0	12 Mbps	12 Mbps
LSP 2	243.48.1.0	107.13.1.0	128 Mbps	4 Mbps

MAPPING DATA 62

FLOW 1	LSP 1
FLOW 2	LSP 1
FLOW 3	LSP 2

FIG. 4

EX-1005 FIG. 4 (annotated). As seen above, the reservation data 60 (red) included attributes of a packet flow, such as the source address, the destination address, bandwidth, etc. EX-1005 FIG. 4. *Murphy* also disclosed that the reservation data could include "the **protocol**, the **protocol port numbers**, the type-of-service (ToS) byte, the DiffServe Code Point (DSCP), or other applicable packet attributes." EX-1005 4:34-38, 6:62-7:8. *Murphy's* "attributes" that specified packet flows included some of the same attributes identified by the '320 Patent. EX-1001 5:21-31. Thus, *Murphy* disclosed *identifying information associated with an application flow* at least because *Murphy's* reservation data described the attributes of each of

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the packet flows and, as described below, was used to map packets of a flow to particular LSPs. For example, the router identified and stored the reservation data 60 from the reservation requests which describe these common flow attributes for each of the flows and used this stored data to identify, map, and route subsequent packets from packet flows. EX-1005 6:62-7:26, 8:9-39, FIG. 6.

112. Some of the reservation data attributes described in *Murphy*, including at least the source and destination addresses, source and destination ports, and protocol type, were included in the packet header. EX-1005 1:48-56; EX-1018 ¶¶58-63 (packet header information includes source and destination addresses, the source and destination ports, and protocol type). *Murphy's* edge router received packets associated with an end-to-end packet flow and determined an LSP for the packet based on the mapping data, which included looking at the packet header information such that it could be mapped using the mapping data. EX-1005 8:9-39; 6:56-7:26.

113. Additionally, *Murphy* disclosed that the packet flow received at the router, from which the reservation data attributes were pulled, was unencapsulated and the router encapsulated the packet flow within MPLS packets before forwarding the MPLS packets through the MPLS network. EX-1005 4:39-59. Thus, *Murphy* disclosed *identifying* attributes for each packet flow based on the unencapsulated packet headers of the packet flows (*information associated with an*

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application flow based on one or more unencapsulated packet headers of the application flow).

114. Finally, *Murphy* also disclosed identifying attributes of a packet flow between a specific source and a specific destination (*information associated with an application flow…based on an ingress data stream that includes the application flow*). For example, *Murphy* disclosed that "specific packet flows, such as real-time audio and video streams" can be transferred from a computing device 10 to another computing device 12 on the other side of the network 6. EX-1005 4:8-10.

115. *Murphy* disclosed the claimed *data stream* in the same context as the '320 Patent. The '320 Patent states that a *data stream* may include the application flow. EX 1001 4:57-58. The '320 Patent further discloses that the "edge nodes 220 and 222 are configured to transfer the data streams between a core network…and the client devices." EX 1001 4:18-21; 4:27-28. Thus, when *Murphy's* "specific packet flow[]" of *Murphy* was transferred from the source computing device 10 to the destination computing device 12 through the MPLS network, it was part of the same "*data stream*" from which edge router 8 identified information (*e.g.*, the source address, the destination address, the QoS, etc.) for routing (*identifying information associated with an application flow based on…an ingress data stream that includes the application flow*). EX-1005 6:62-7:8.

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116. These "attributes" were used to map packet flows to the applicable LSP (*e.g.*, LSP 9) as discussed above and below.

[1ci] in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through the MPLS network,

117. *Murphy* disclosed this limitation. *Murphy* disclosed that in response to generating, maintaining, and referencing "attributes" of an end-to-end packet flow (*in response to identifying the information*) and "based on" mapping data stored associating packet flows with LSPs (*and based on stored data that maps application flows with pseudowires*) that *Murphy's* edge routers used path data to select from multiple LSPs through the MPLS network capable of servicing a packet flow (*determining a plurality of pseudowires corresponding to paths through the MPLS network*).

118. First, *Murphy's* MPLS LSPs were *pseudowires*. *Murphy* disclosed that its edge routers encapsulated reservation requests, and the requested, subsequent packet flows (*e.g.*, real-time audio and video) as MPLS packets over the LSPs. EX-1005 4:39-58. The edge routers also assigned a common MPLS label to each packet of the requested packet flow, forming MPLS packets. EX-1005 5:10-13. *Murphy* also disclosed that, because edge router "assigns…a common label, each packet flows down a common Label Switched Path, i.e.,

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LSP1." EX-1005 5:16-18. Further, because the encapsulated packets traversed the MPLS network 6 as MPLS packets, *Murphy's* MPLS core routers were not required to monitor resource allocation or maintain state information; in other words, no deep packet inspection was required for the end-to-end application flows that were forwarded according to the label of the encapsulated MPLS packets. EX-1005 4:50-58. When the encapsulated packet flows reach the egress side of the network, *Murphy* disclosed that an egress edge router removed the MPLS labels "to produce packets" "in their original form" and forwarded them toward end users. EX-1005 5:19-22.

119. Based on *Murphy's* description, a POSITA would have understood that *Murphy's* LSPs were *pseudowires*. Indeed, the prior art routinely called such uses of LSPs "pseudowires." For example, *Lee '600* called MPLS point-to-point connections, "known as Label Switched Paths" and "tunnels," "pseudowires." EX-1008 ¶¶15, 31, 67. Others also called MPLS LSPs pseudowires. EX-1015 ¶¶10 ("[T]he PW connection between the nodes can more generally be implemented using any available PW protocol, such as GRE or L2TPv3" in addition to "MPLS tunneling."), 11, 27, cls. 24 and 40; EX-1016 ¶21 ("Pseudowires" "connect a pair of provider edge PE routers for enabling transport across the core network," "using MPLS."); EX-1017 ¶24 (pseudowires connect edge devices and include tunnels such as MPLS tunnels).

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120. *Murphy's* LSPs also provided a "virtual circuit," emulating the IntServ/RSVP service over the MPLS core. Indeed, the art disclosed that LSPs provided virtual communication paths (aka, virtual circuits.). For example, *Taguchi* stated that LSPs constituted "virtual communication path[s]" and formed the "structural element" of such paths. EX 1006 ¶52, 73. *Murphy* also disclosed that edge routers may be coupled with a second LSP such that there is bidirectional communication. EX-1005 5:19-33.

121. *Murphy's* disclosure, and the prior art's reference to MPLS LSPs as pseudowires, is consistent with the preferred embodiments of the '320 Patent. The '320 Patent describes encapsulating packets from an application flow (*e.g.*, VoIP and VoD) with label information having the same format as an MPLS packet. EX-1001 3:26-31, 6:13-20. The encapsulated packet "is an MPLS formatted packet" that can be processed as a regular MPLS packet by an MPLS enabled device. EX-1001 6:37-42. The encapsulated MPLS packet is then sent to the MPLS network. EX-1001 6:13-16. At egress, the labeling is removed and the packet is forwarded to its destination. EX-1001 7:66-8:2. The '320 Patent also discloses that MPLS networks use prior art pseudowires to map flows into "virtual circuits," which emulates a native service over a network. EX-1001 1:33-37. The '320 Patent also discloses that deep packet inspection is not required at each of these internal routers because the intermediate nodes can be standard MPLS devices. EX-1001

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4:46-50. All of these disclosures are consistent with *Murphy's* LSPs and the prior art description of *pseudowires*. Thus, *Murphy's* LSPs are *pseudowires*.

122. Second, *Murphy* disclosed using path data to select from multiple LSPs through the MPLS network capable of servicing a packet flow (*determining a plurality of pseudowires corresponding to paths through the MPLS network*). With reference to FIG 3 (below), in addition to generating and maintaining reservation data 53 (red), the access control module 52 also generated and maintained path data 55 (blue):

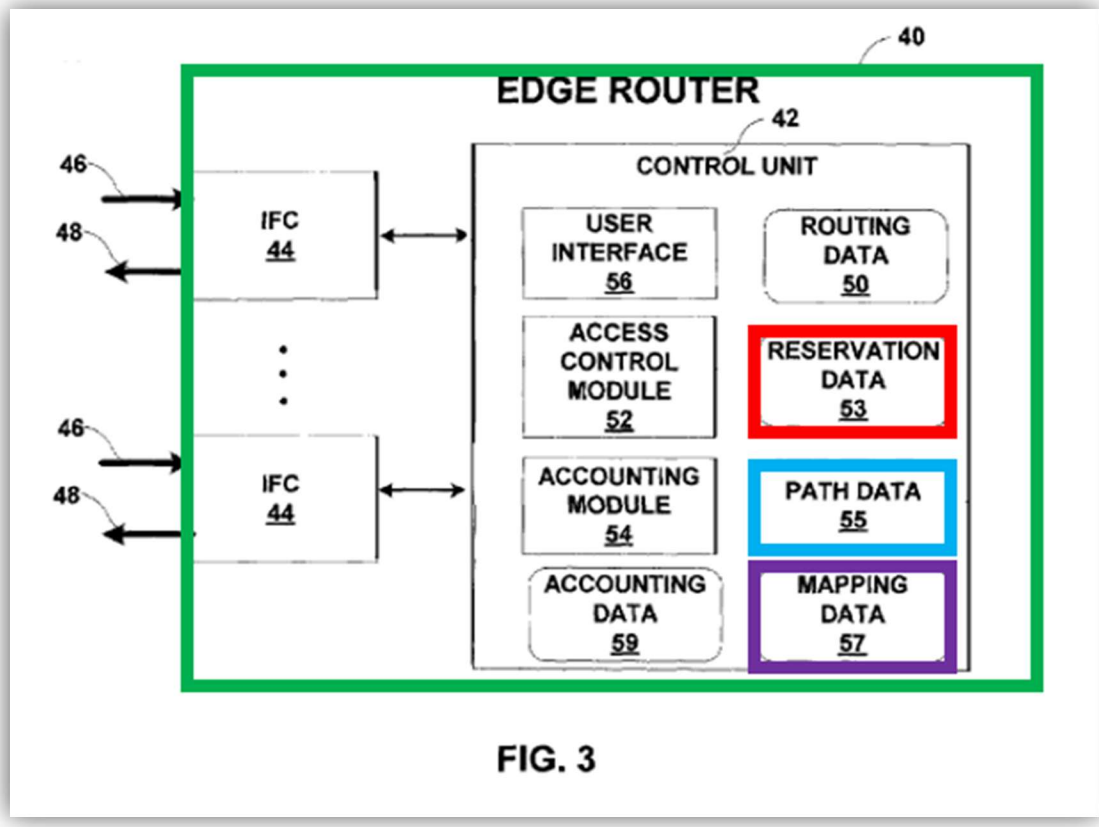


FIG. 3

EX 1005 FIG. 3 (annotated), 5:57-62. Path data 55 was representative of the label switch paths (LSPs) in a MPLS network, and included a source, destination, and

bandwidth for each LSP (*a plurality of pseudowires corresponding to paths through the MPLS network*). EX 1005 5:57-62. When the router received a packet flow or reservation requests for the same, the router would use the attributes of the packet flow (or request) (*see* [1b]), to determine the available LSPs capable of servicing the requested packet flow. EX-1005 4:39-58, 6:56-7:15. For example, each of LSP 1 and LSP 2 of FIG. 4 could individually service each of FLOWS 1-3 (from at least a bandwidth perspective):

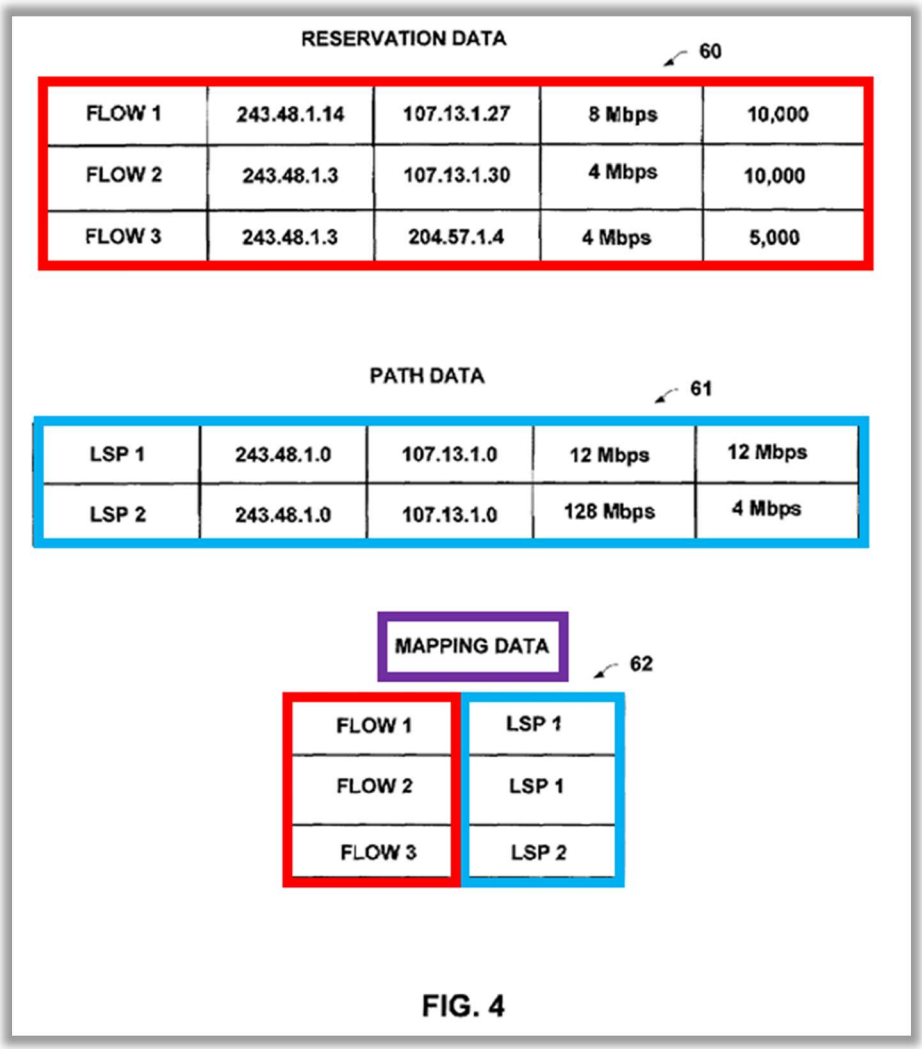


FIG. 4

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EX-1005 5:59-62, FIG. 4 (annotated). *Murphy* also disclosed that the router could also identify a primary LSP and one or more backup LSPs to service the given packet flow. EX-1005 8:41-45. *Murphy* further disclosed that the edge router could dynamically construct LSPs if needed to service requested packet flows. EX-1005 4:59-67, 7:58-67. If new LSPs were created, the path data was updated to include the new LSPs. EX-1005 4:66-67, 7:58-67.

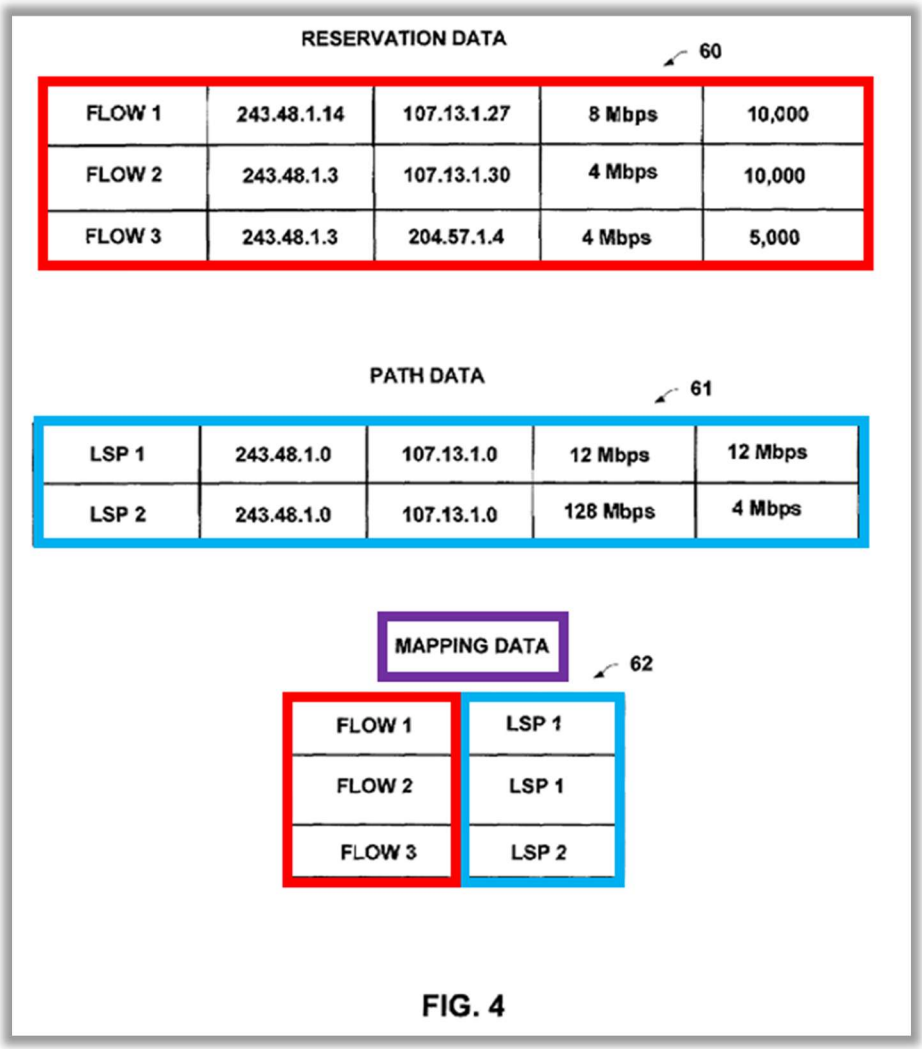
123. Murphy used the path data to select an appropriate LSP for a requested packet flow and assign that flow to that LSP in its mapping data 57. EX-1005 5:59-62, 6:14-17, FIGs. 3, 4. This assignment resulted in using that LSP for subsequent packets of the packet flow. EX-1005 6:14-17. Thus, Murphy used path data to select from multiple LSPs through the MPLS network capable of servicing a packet flow (*determining a plurality of pseudowires corresponding to paths through the MPLS network*).

124. As discussed above, the identification, selection, and routing of packet flows via the LSPs occurred after *Murphy's* routers referenced the "attributes" of end-to-end packet flows, thus occurring *in response to identifying the information*. *See* [1b].

125. Finally, *Murphy* also disclosed that the selection of LSPs through the MPLS network was "based on" mapping data stored in the edge routers that associates packet flows with LSPs (*and based on stored data that maps application*

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flows with pseudowires). As discussed above, the access control module 52 of *Murphy's* router stores mapping data 57 (purple) that associates the packet flows from the reservation data with one of the LSPs 9 from the path data 55. EX 1005 5:62-64. Specifically, *Murphy* described that the access control module of the router stored the reservation data 60 (red), path data 61 (blue), and mapping data 62 (purple) in a data structure:



EX-1005 3:34-36; 5:65-6:4; 6:56-58, FIG. 4 (annotated).

126. Thus, *Murphy* disclosed that the router, in response to receiving packets associated with a packet flow, and based on the mapping data stored in the data structure of FIG. 4, determined a plurality of LSPs corresponding to the paths through the MPLS network (*in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through the MPLS network*).

[1cii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and

127. *Murphy* in view of *Taguchi* rendered obvious this limitation. *Murphy* disclosed mapping data (*the stored data*) that mapped a packet flow from a computing device (*a sending device application*) to an LSP (*a…mapping of the application flow via at least one of the plurality of pseudowires*).

128. For example, as discussed in [1ci], *Murphy* disclosed that the router stored the reservation data 60 (red), path data 61 (blue), and mapping data 62 (purple) that mapped a packet flow (red) to an LSP (blue):

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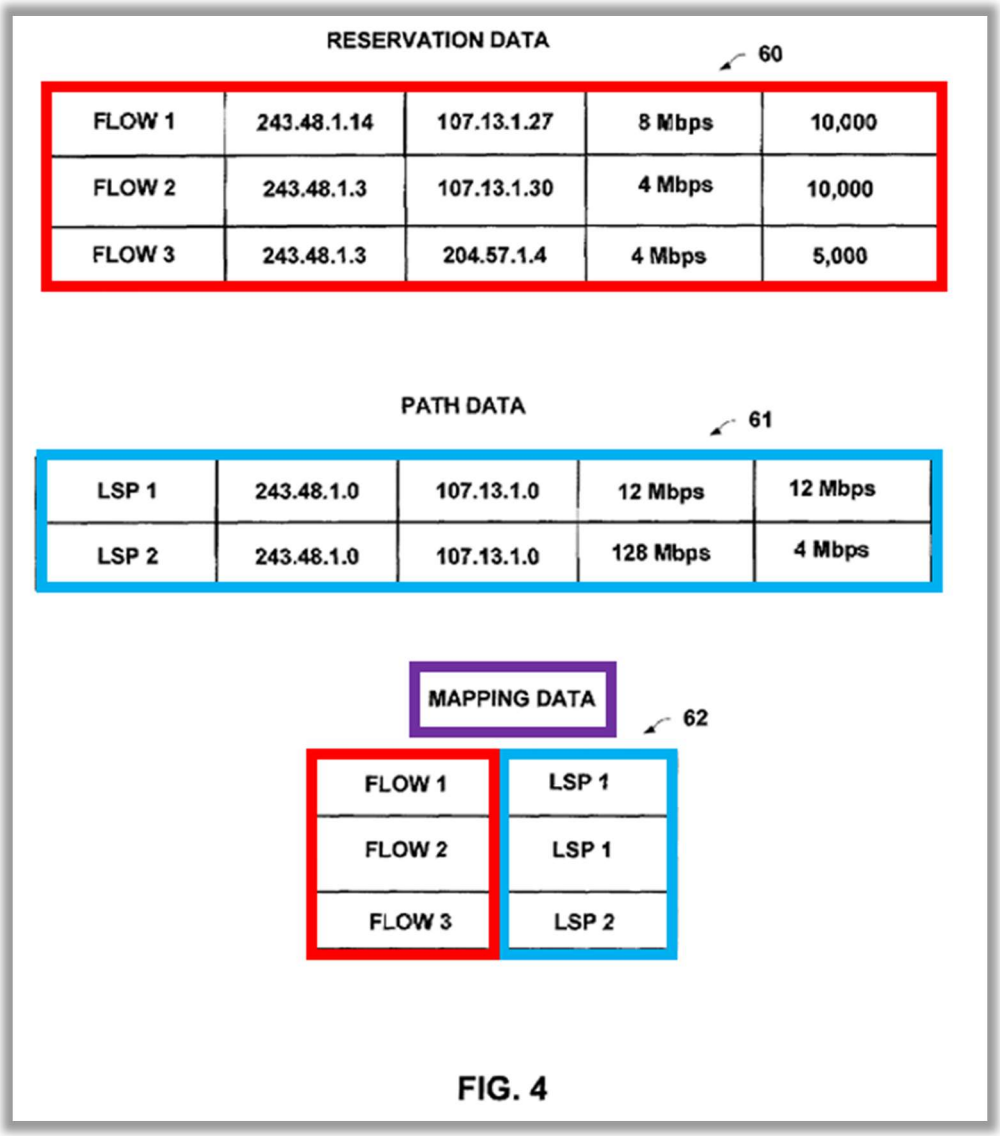


FIG. 4

EX-1005 3:34-36; 5:52-6:4; 6:56-58, FIG. 4 (annotated). As illustrated above, *Murphy* disclosed that the mapping data 62 associated a packet flow to one LSP (*e.g.*, FLOW 3 to LSP 2) and two packet flows to one LSP (*e.g.*, FLOW 1 and FLOW 2 to LSP 1). EX-1005 7:16-26. *Murphy* also disclosed mapping a packet flow to a primary LSP and a backup LSP. EX-1005 8:41-45. Thus, *Murphy* disclosed "*wherein the stored data indicates…a…mapping of the application flow via at least one of the plurality of pseudowires*."

129. Next, *Murphy* disclosed that its packet flows were "produced by computing devices," e.g., devices 10 and 12 (dark yellow):

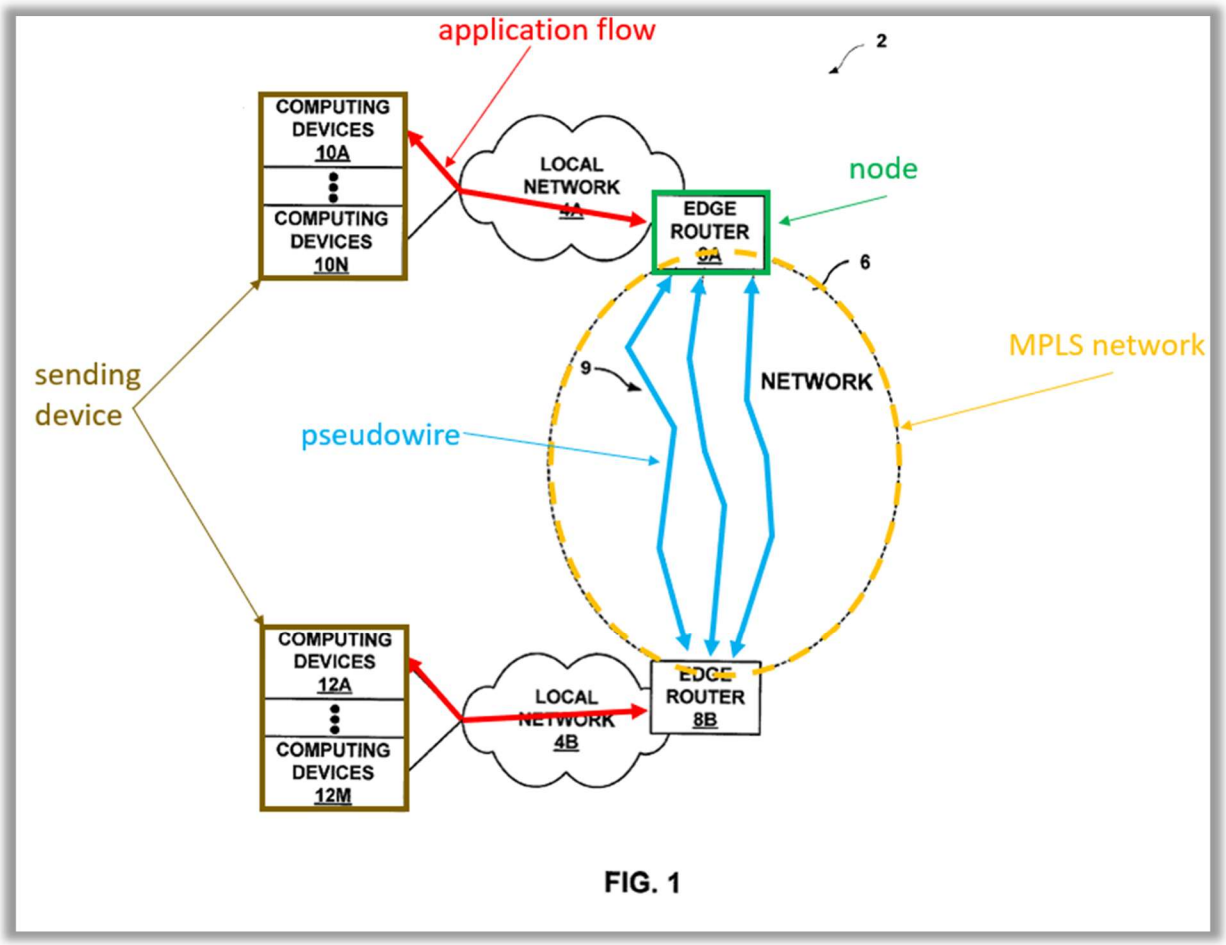


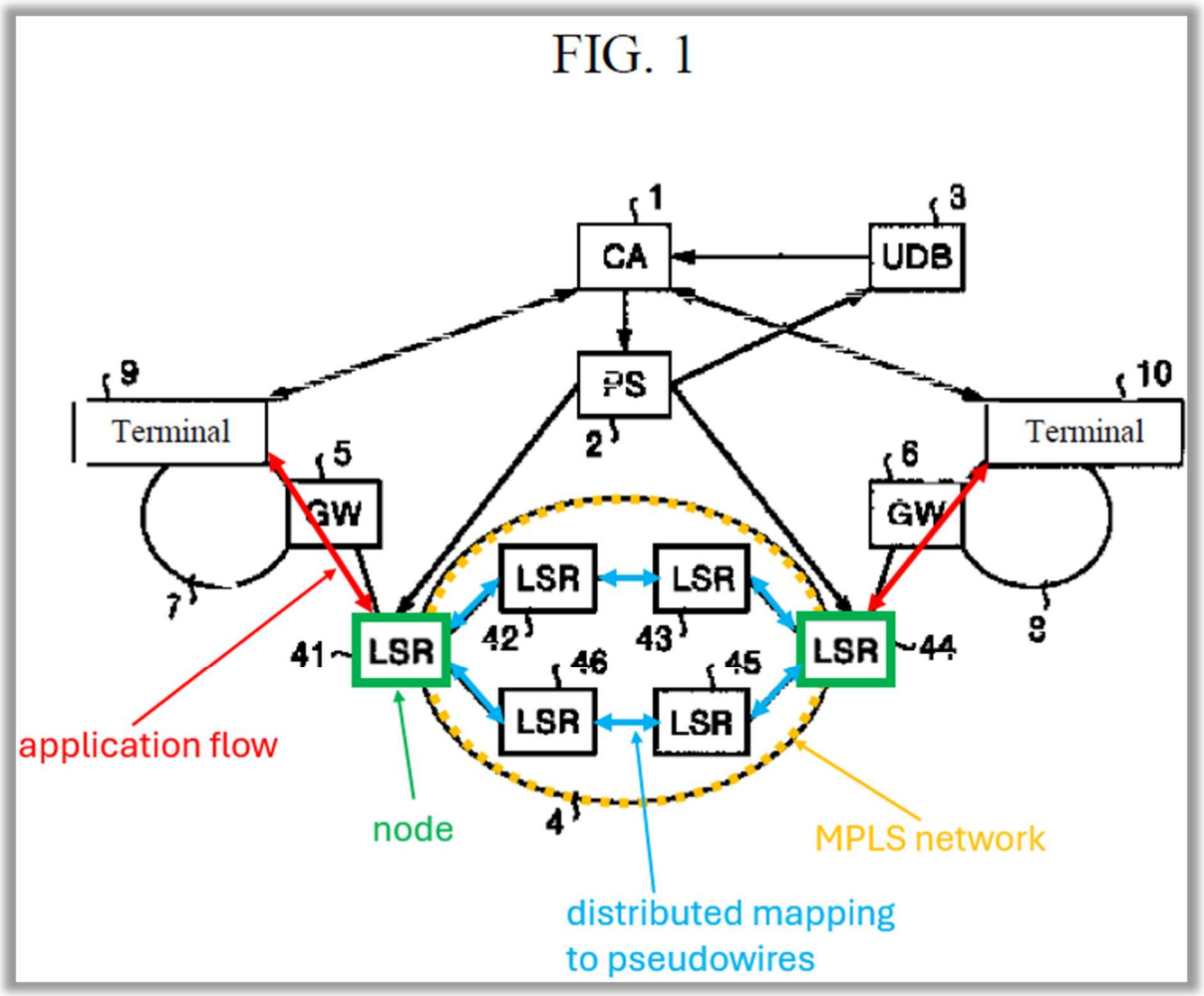
FIG. 1

EX-1005 2:66-3:4, 4:8-13, 4:47-50, FIG. 1 (annotated). Thus, the above discussed mapping of *Murphy's* packet flows to LSPs were "*for a sending device application*."

130. To the extent Patent Owner argues that *Murphy* does not disclose a "*distributed mapping*," *Taguchi* does. *Taguchi* disclosed using stored user information and virtual communication path information to associate a single

stream from a terminal with more than one LSP (*a distributed mapping of the application flow via at least one of the plurality of pseudowires*).

131. *Taguchi* disclosed that user information, including flow identification information (*e.g.*, information relating to VoIP, terminal address, protocol type, etc.) was stored on a policy server 2:



EX-1006 ¶¶ 5-6, 50-52, FIG. 1 (annotated). The user information defined requirements of *Taguchi's* flow and was used to determine which virtual

communication path, which was stored on the policy server 2, was suitable. EX-1006 ¶¶ 51-52.

132. Using the stored virtual communication path information, the number of LSPs (blue) required in the network (orange) for the flow was determined by the policy server 2. EX-1006 ¶52. The virtual communication path between the two edge LSRs 41, 44 (green) could take multiple paths, i.e., LSPs that were "considered as a structural element of the virtual communication path" EX-1006 ¶52. For example, a first LSP above included the path through LSRs 41, 42, 43, and 44, and a second LSP included the path through LSRs 41, 46, 45, 44. EX-1006 ¶52. Further, *Taguchi* disclosed that when its "virtual communication path" had multiple LSPs, such as that shown above, "the stream is transferred while being scheduled for each LSP so as not to exceed the resource capacity of each LSP." EX 1006 ¶73. Thus, *Taguchi* disclosed *a distributed mapping of the application flow via at least one of the plurality of pseudowires.*

133. A POSITA would be motivated to modify the teachings of *Murphy* to include *Taguchi's distributed mapping* for the reasons discussed in the motivation to combine section. §VI.A.3. For example, a POSITA would have been motivated to combine *Murphy's* teaching of mapping packet flows to LSPs with *Taguchi's* disclosure of *distributed mapping* to enable effective packet flow without establishing a new LSP while maintaining QoS requirements and ensuring

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effective utilization of *Murphy's* MPLS networks. §VI.A.3. As also demonstrated above, a POSITA would have had a reasonable expectation of successfully integrating *Taguchi's* teachings into *Murphy*. §VI.A.3.

134. In combination, *Taguchi's* teaching of *distributed mapping* with *Murphy's* mapping data would result in selecting multiple LSPs capable of servicing the packet flow (*determining a plurality of pseudowires*) which would be included in *Murphy's* mapping data. For example, as discussed in [1ci], *Murphy* disclosed that path data was used to select from multiple LSPs through the MPLS network capable of servicing a packet flow. EX-1005 4:39-58, 6:56-7:26. Using *Taguchi's* teachings of a virtual communication path for distributing a stream over multiple LSPs, *Murphy* would be modified such that the determined *plurality of pseudowires* would have been included in the *distributed mapping* taught by *Taguchi*, which would be mapped to a flow.

135. Thus, *Murphy* in view of *Taguchi* rendered obvious this limitation.

[1d] communicating data related to the sending device application via at least one of the plurality of pseudowires.

136. *Murphy* disclosed this limitation. As discussed above, *Murphy* disclosed the edge router encapsulated the packets of a packet flow (*e.g.*, real-time audio or video), and reservation requests for the same, with an MPLS label and forwarded the MPLS packet along the selected LSP in accordance with the label

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(*communicating data related to the sending device application via at least one of the plurality of pseudowires*). EX-1005 4:39-58, cl. 1, 1:57-65; *see also* [1b]-[1ci].

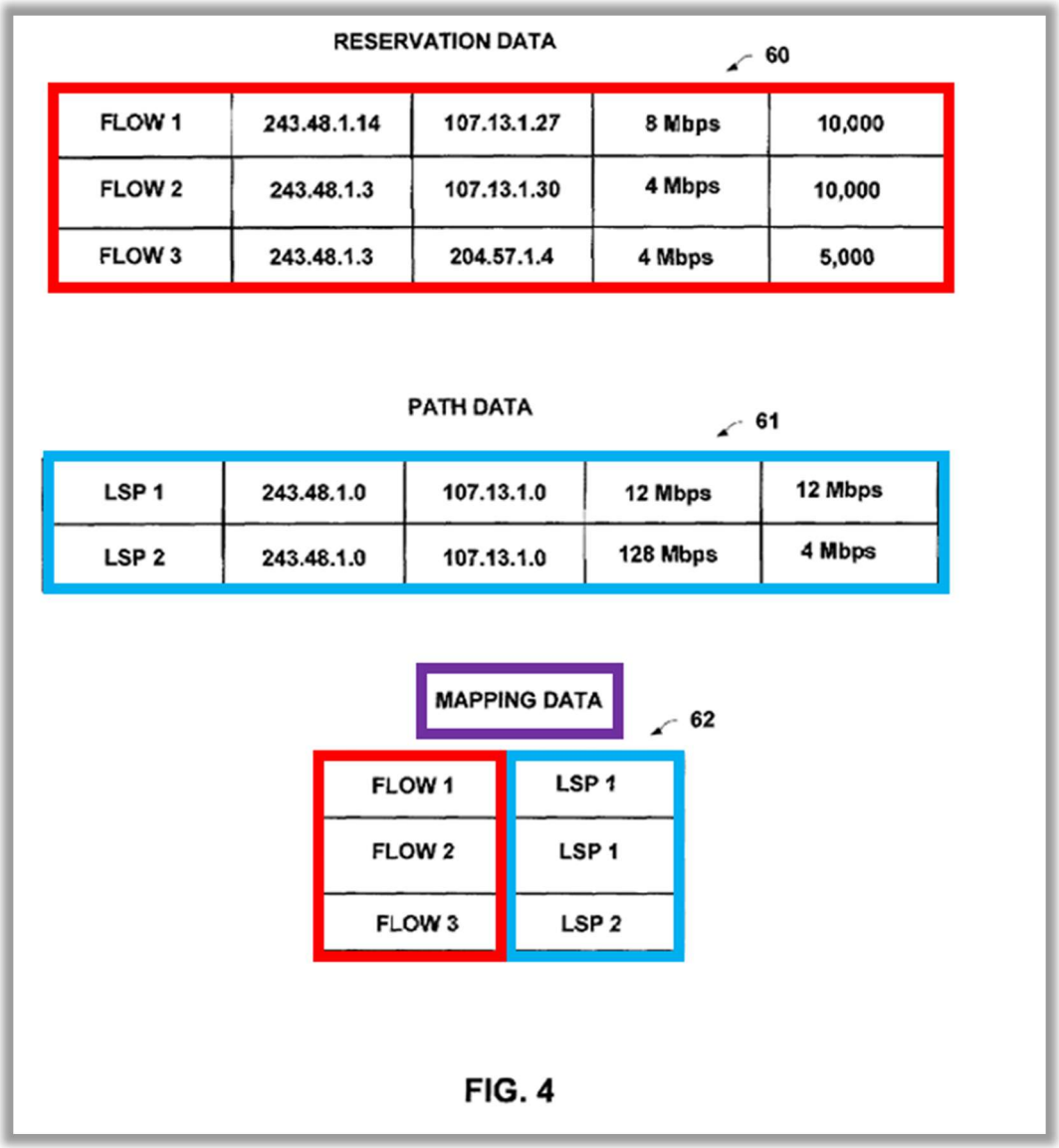
Claim 2

[2] The method of claim 1, wherein the stored data defines an application wire for use by the sending device application, the application wire configured to communicate particular data from a particular application flow of the sending device application to an edge node.

137. *Murphy* disclosed this limitation. *Murphy* disclosed mapping data (*the stored data*) was used to associate a packet flow from a computing device with an LSP (*an application wire for use by the sending device application*) and that the ingress edge router forwarded the packet flow along the LSP (*the application wire configured to communicate particular data from a particular application flow of the sending device application*) through the MPLS network to another edge router (*to an edge node*).

138. First, *Murphy* disclosed *stored data that maps application flows with pseudowires*. *See* [1ci]. Specifically, *Murphy* disclosed that access control module stored reservation data (red), path data (blue), and mapping data (purple) that associated the packet flows (*application flows*) from the reservation data with one of the LSPs (*pseudowires*) from the path data:

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EX 1005 5:62-64, 6:56-7:26, FIG. 4 (annotated); [1ci]. This mapping data associated packet flows to LSPs and was aware of the protocol and protocol port number, which were attributes of the packet flows and requests for the same found in the reservation data. EX-1005 6:62-7:26.

139. *Murphy's* disclosure is consistent with the '320 Patent, which states that application wires "map[] one or more application flows into Pseudowires, and

[are]…aware of the application protocol and the protocol requirements associated with the application flows." EX-1001 3:20-23. Thus, *Murphy* also disclosed an *application wire*.

140. Second, *Murphy* disclosed that *the application wire [was] configured to communicate particular data from a particular application flow of the sending device application to an edge node*. For example, *Murphy* described that the reservation data was arranged on a per flow basis, and included attributes such as the **bandwidth, the source address, the destination address, the protocol, the protocol port numbers, the type-of-service (ToS) byte, the DiffServe Code Point (DSCP), or other suitable attributes**. EX-1005 1:48-56, 6:56-7:8, FIG. 4. The mapping data 62 was used to associate the packet flows from the reservation data 60 with an LSP from the path data 61. EX-1005 7:16-18. In response to the mapping, the edge router 8A forwarded the packet flows, along with the data contained therein, including data from the reservation data, along the LSPs to edge router 8B (*to an edge node*). EX-1005 2:35-40; 4:39-51. The reservation data and subsequent packet flow from a client device are both independent examples of *particular data from a particular application flow of the sending device application* communicated between the edge routers.

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Claim 3

[3] The method of claim 1, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires.

141. *Murphy* in view of *Taguchi* rendered obvious this limitation.

142. As discussed in claim 2, *Murphy* disclosed that mapping data (*the stored data*) mapped packet flows and requests for the same from a computing device to LSPs (*an application wire for use by the sending device application*) and based on that mapping data, an edge router forwarded the packet flows, and data related to the reservation for the same, along the mapped LSP through the network (*the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires*). *See* [2].

143. To the extent *Murphy* does not explicitly disclose communicating data *via the plurality of pseudowires*, the combination of *Murphy* and *Taguchi* does. As discussed in [1cii], *Taguchi* modified *Murphy* such that the *plurality of pseudowires* would be included in the *mapping* of an application flow, and this mapping would be used to distribute an application flow along multiple mapped LSPs. *See* [1cii]. Thus, at least in in combination, *Murphy* and *Taguchi* disclosed that the *particular data* was *communicate[d] … via the plurality of pseudowires*.

144. Thus, *Murphy* in view of *Taguchi* rendered obvious this limitation.

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Claim 4

[4] The method of claim 1, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network.

145. *Murphy* in view of *Taguchi* rendered obvious this limitation. As discussed in claim 3, *Murphy* in view of *Taguchi* disclosed that the LSPs (*each of the plurality of pseudowires*) extended from the edge routers receiving the packet flows (*e.g.*, edge routers 8A, 8B) into the MPLS network in route to an edge router on the other side of the MPLS network (*e.g.*, edge routers 8B, 8A respectively) (*extends from the application flow in an ingress direction into the MPLS network*). *See* [3]. *Murphy* in view *Taguchi's* teaching of pseudowires transferring application flows into an MPLS network is consistent with the disclosure of the '320 Patent. *See* [3]; EX-1005 4:14-58; EX-1001 4:7-44.

146. Thus, *Murphy* in view of *Taguchi* rendered obvious this limitation.

Claim 5

[5] The method of claim 1, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device.

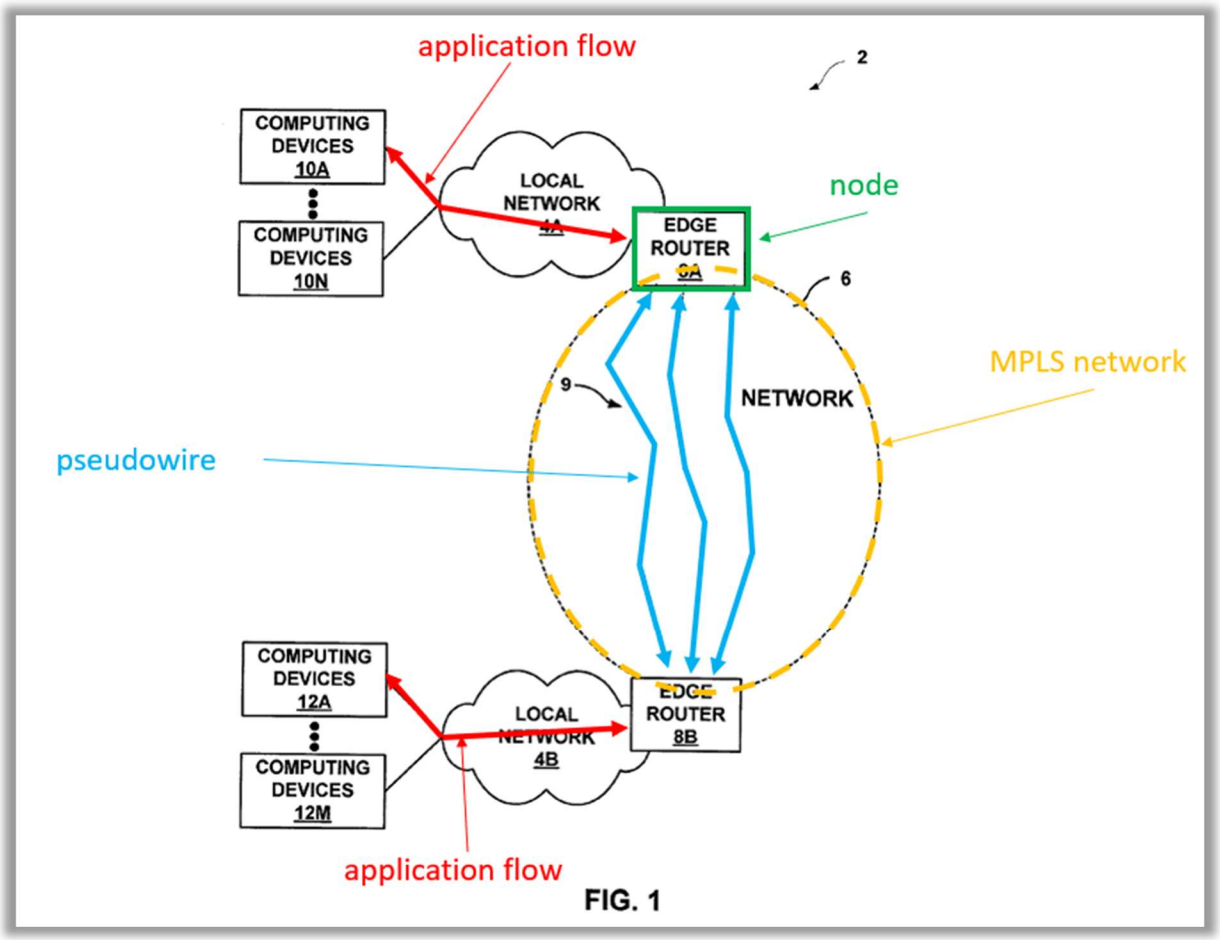
147. *Murphy* in view of *Taguchi* rendered obvious this limitation. *Murphy* in view of *Taguchi* taught that multiple LSPs were set (*each of the plurality of pseudowires is virtually coupled*) for specific packet flows from client devices between edge routers to another client device for packet flows (*e.g.*, real time audio streams, video streams, or voice data) and reservation requests for the same from

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computing devices (*a particular application being executed at a particular client device*), assigned an MPLS label to the received packets, and forwarded the MPLS packets along LSPs to an edge router where they were forwarded to another computing device (*a particular device*).

148. *Murphy* disclosed that the LSPs were set between edge routers on either side of a MPLS network (*each of the plurality of pseudowires is virtually coupled*). For example, *Murphy* disclosed that the LSPs 9 (blue) coupled first network 4A and second network 4B together through the edge routers 8A and 8B (green) of intermediate network 6 (orange):

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EX-1005 2:52-57; 4:14-58, FIG. 1 (annotated).

149. *Murphy* in view of *Taguchi* taught that edge routers forwarded packet flows between computing devices (*between a particular device and a particular application being executed at a particular client device*). For example, the edge router 8A received packets associated with the packet flow (*e.g.*, real-time audio streams, video streams, or voice data) and reservation requests for the same (red) produced by a computing device 10A-10N and assigned a MPLS label to the packets. EX-1005 4:39-51, 5:10-18. These MPLS packets were forwarded to edge router 8B along the LSPs 9 where the MPLS labels were removed. EX-1005 4:39-

51, 5:19-20. Packets in their original form were then forwarded to a computing device 12A-12M. EX-1005 5:19-23. In combination with *Taguchi*, this would occur *via the plurality of pseudowires*. *See* [1cii], [3].

150. *Murphy's* teaching, as modified by *Taguchi*, of *virtually coupl[ing]* and the location required by this claim is consistent with the '320 Patent. For example, the '320 Patent discloses that client devices are configured to communicate with other client devices on the other side of an MPLS network. EX-1001 4:9-14, FIG. 2. More specifically, application flows are produced by client devices on one side of a network, transferred between edge nodes of a core network along pseudowires, and then forwarded to other client devices. EX-1001 4:14-31.

151. Thus, *Murphy* in view of *Taguchi* rendered obvious this limitation.

Claim 7

[7] The method of claim 1, wherein the stored data maps the application flow to the plurality of pseudowires to create an application wire.

152. *Murphy* in view of *Taguchi* rendered obvious this limitation. As discussed in [1cii] and claim 2 above, *Murphy* and *Taguchi* disclosed that the mapping data mapped a packet flow, and reservation requests for the same, to multiple LSPs through a network (*the stored data maps the application flow to the plurality of pseudowires to create an application wire*). *See* [1cii], [2].

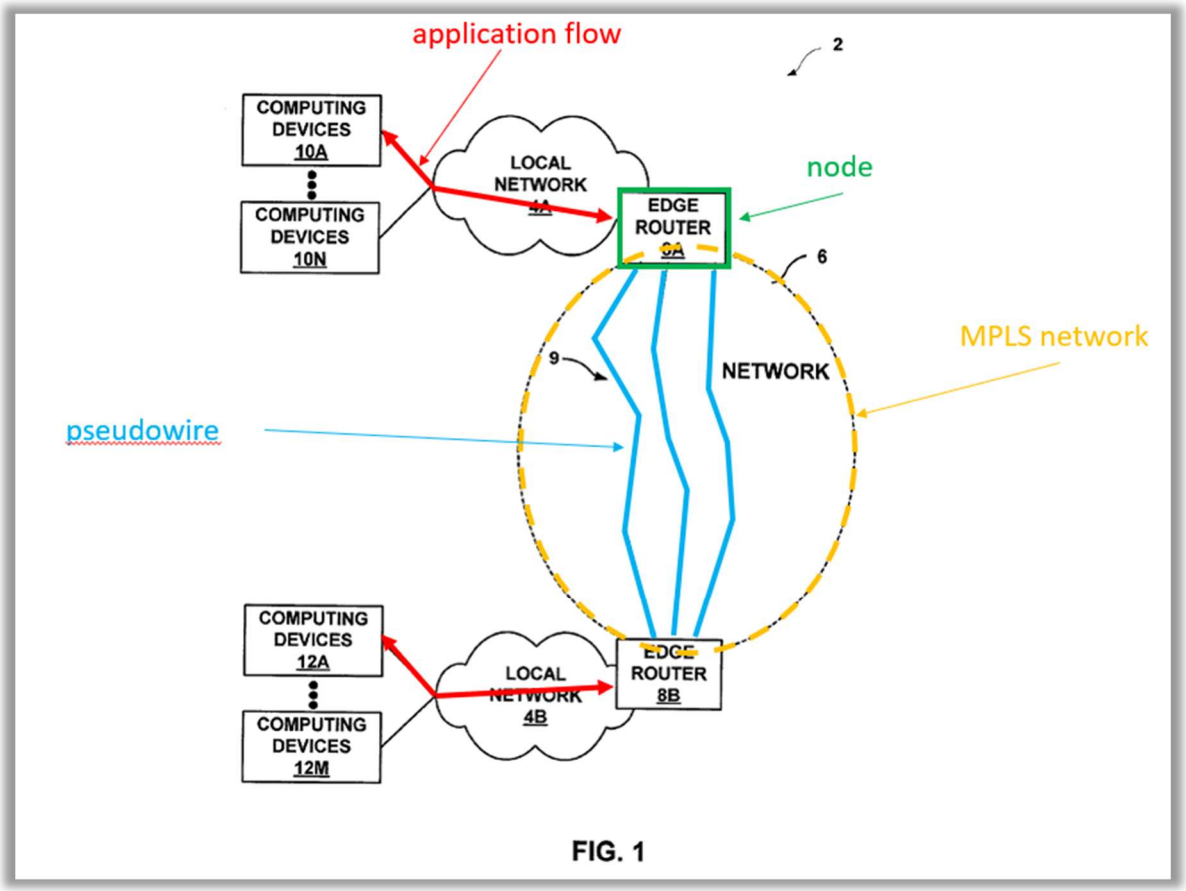
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153. Thus, *Murphy* in view of *Taguchi* rendered obvious this limitation.

Claim 8

[8pre] A device comprising:

154. *Murphy* disclosed an edge router (*a device*) that received and encapsulated packet flows and reservation requests of the same (red) from a computing device 10A-10N and mapped the packet flows to one or more LSPs (blue) through a MPLS network (orange):



EX-1005 4:39-51, FIG. 1 (annotated).

155. Further, *Murphy's* edge router (*device*) in view of *Taguchi* "*compris[ed]*" the limitations [8a]-[8d] as demonstrated below.

[8a] a processor; and a memory that stores instructions executable by the processor to:

156. *Murphy* disclosed this limitation. *Murphy* disclosed an edge router (*device*) that stored instructions for a processor to perform the functions of the edge router (*a processor; and a memory that stores instructions executable by the processor to*).

157. *Murphy* disclosed a "computer-readable medium comprising *instructions* to cause a *processor* to" perform the same functions performed by *Murphy's* edge router. EX-1005 2:27-34, cl. 22 and 25, 4:39-58. Further, as a router, *Murphy's* edge router contained a processor and memory that stores instructions for that processor. Therefore, *Murphy* disclosed this limitation.

158. Finally, *Murphy's* edge router, in view of *Taguchi*, performed the functions of [8b]-[8d] as demonstrated below.

[8b] identify information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow;

159. *Murphy* disclosed its edge router, using its processor and instructions ([8a]), performing this limitation as discussed in [1b]. *See* [1b].

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[8ci] in response to identifying the information, and based on stored data mapping application flows to pseudowires, determine a plurality of pseudowires as paths through a multiprotocol label switching (MPLS) network for the application flow,

160. *Murphy* disclosed its edge router, using its processor and instructions ([8a]), performing this limitation as discussed in [1ci]. *See* [1ci]. For clarity, *Murphy's* LSPs (*plurality of pseudowires*) are "*paths through a*" *MPLS* "*network*" ([8ci]) for the same reason they "*correspond[] to*" *paths through the MPLS network* as discussed in [1ci].

[8cii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and

161. *Murphy* in view of *Taguchi* rendered obvious an edge router, using its processor and instructions ([8a]), performing this limitation for the same reasons as discussed with respect to limitation [1cii].

[8d] communicate data associated with the sending device application via at least one of the plurality of pseudowires.

162. *Murphy* disclosed its edge router, using its processor and instructions ([8a]), performing this limitation as discussed in [1d]. *See* [1d]. For clarity, *Murphy's* forwarding of packet flows and reservation requests (*communicat[ing] data*) was "*associated with*" *the sending device application* ([8d]) for the same reason it was "*related to*" *the sending device application* as discussed in [1d]. *See* [1d].

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Claim 9

[9] The device of claim 8, wherein the stored data defines an application wire for use by the sending device application, the application wire configured to communicate particular data from a particular application flow of the sending device application to an edge node.

163. *Murphy* disclosed this limitation for the same reasons as discussed with respect to claim 2. *See* [9].

Claim 10

[10] The device of claim 8, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires.

164. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 3.

Claim 11

[11] The device of claim 8, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network.

165. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 4.

Claim 12

[12] The device of claim 8, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device.

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166. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 5.

Claim 14

[14] The device of claim 8, wherein the stored data maps the application flow to the plurality of pseudowires to create an application wire.

167. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 7.

Claim 15

[15pre] A computer-readable non-transitory medium storing instructions that are executable by a processor to initiate or perform:

168. *Murphy* disclosed "a computer-readable medium comprises instructions to cause a processor to" perform the functions of the edge router (*computer-readable non-transitory medium storing instructions that are executable by a processor to initiate or perform*). EX-1005 2:27-34, 5:65-6:4, claims 22-24, claim 29. *Murphy* in view of *Taguchi* rendered obvious limitations [15a]-[15c] as demonstrated below.

[15a] identifying information associated with an application flow based on one or more unencapsulated packet headers of the application flow or based on an ingress data stream that includes the application flow;

169. *Murphy* disclosed this limitation for the same reasons as discussed with respect to limitation [1b].

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[15bi] in response to identifying the information, and based on stored data that maps application flows with pseudowires, determining a plurality of pseudowires corresponding to paths through a multiprotocol label switching system (MPLS) network,

170. *Murphy* disclosed this limitation for the same reasons as discussed with respect to limitation [1ci].

[15bii] wherein the stored data indicates, for a sending device application, a distributed mapping of the application flow via at least one of the plurality of pseudowires; and

171. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to limitation [1cii].

[15c] communicating data related to the sending device application via at least one of the plurality of pseudowires.

172. *Murphy* disclosed this limitation for the same reasons as discussed with respect to limitation [1d].

Claim 16

[16] The computer-readable non-transitory medium of claim 15, wherein the instructions are executable to perform the identifying, the determining, and the communicating at a node associated with the MPLS network.

173. *Murphy* disclosed this limitation. As described above, Murphy disclosed edge routers having "*instructions that are executable by a processor to... perform*" (*see* [15pre]) "*the identifying*," "*the determining*," *and* "*the communicating*" (*see* [15a], [15bi], [15c], [1b], [1ci], [1d]). *Murphy* disclosed that

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its edge router was "*a node associated with the MPLS network"* for the same reasons discussed above in [1a]. *See* [1a].

Claim 17

[17] The computer-readable non-transitory medium of claim 15, wherein the stored data defines an application wire for use by the sending device application, the application wire configured to communicate particular data from a particular application flow of the sending device application to an edge node.

174. *Murphy* disclosed this limitation for the same reasons as discussed with respect to claim 2.

Claim 18

[18] The computer-readable non-transitory medium of claim 15, wherein the stored data further defines an application wire for use by the sending device application, the application wire configured to communicate particular data from an edge node through the MPLS network via the plurality of pseudowires.

175. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 3.

Claim 19

[19] The computer-readable non-transitory medium of claim 15, wherein each of the plurality of pseudowires extends from the application flow in an ingress direction into the MPLS network.

176. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 4.

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Claim 20

[20] The computer-readable non-transitory medium of claim 15, wherein each of the plurality of pseudowires is virtually coupled between a particular device and a particular application being executed at a particular client device.

177. *Murphy* in view of *Taguchi* rendered obvious this limitation for the same reasons as discussed with respect to claim 5.

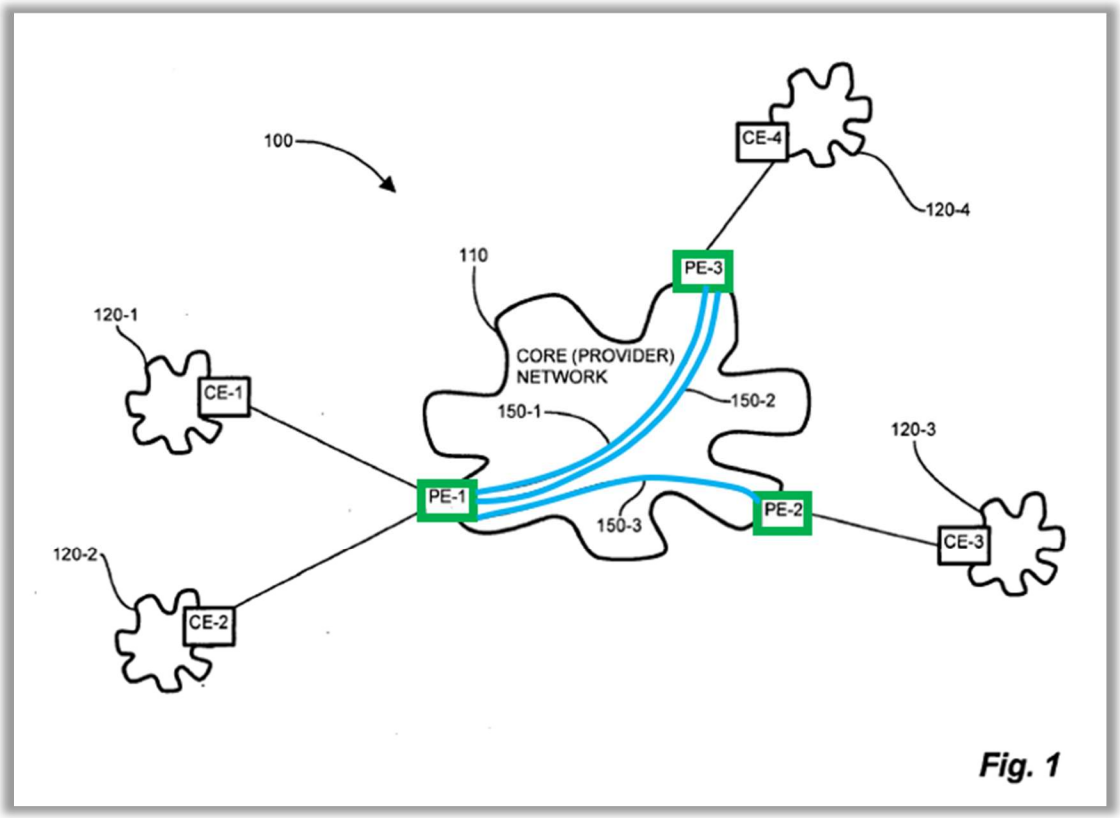
B. Ground 2: Claims 6 and 13 Are Obvious over *Murphy* in View of *Taguchi* and *Booth*

1. Booth (EX-1016)

178. U.S. 2006/0285500 to Booth, III et al. ("*Booth*," EX-1016) is directed to a "Method and Apparatus for Packet Loss Detection." EX-1016 (10), (76), (54). I have been informed that *Booth* qualifies as prior art

179. *Booth* provided packet loss and detection mechanisms used to maintain an accurate diagnosis of pseudowire health:

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EX-1016 Abstract, FIG. 1 (annotated). The pseudowire (blue) statistics provided a "complete view of pseudowire traffic" for an edge router (green), and was used for problem detection, diagnosis, and verification of QoS terms and/or service level agreements (SLAs). EX-1016 Abstract, ¶¶5, 21.

180. *Booth* stated that "[c]onventional sequence numbers on pseudowire frames exist[ed] in both MPLS-based… pseudowire tunneling technologies." EX-1016 ¶19. These sequence numbers were used "to ensure in-order delivery of packets across a pseudowire." EX-1016 ¶19.

181. *Booth's* system tracked packet loss and misordered packets. EX-1016 ¶7. *Booth's* system had the provider edge (PE) routers "perform the tracking by

writing a **sequence number** in a packet." EX-1016 ¶7. After the packets were transmitted along the pseudowire across an, e.g., MPLS network, the receiving PE router inspected "each packet to determine if the packet is in order." EX-1016 ¶¶7, 21, FIG. 1.

182. It is my opinion that *Booth* is (1) in the same field of endeavor of MPLS networking and (2) reasonably pertinent to the problem of ensuring the correct ordering of packets. EX-1001 4:7-50, 6:23-26; 6:55-67.

2. Detailed Application of *Murphy* in Combination with *Taguchi* and *Booth* to the Challenged Claims

Claim 6

[6pre] The method of claim 1,

183. *Murphy* in view of *Taguchi* disclosed the limitations of claim 1. *See* VI.A.4. *Murphy* in view of *Taguchi* and *Booth* disclosed limitations [6i]-[6ii] as discussed below.

[6i] wherein the application flow includes data packets transmitted and received by the sending device application, wherein the data is communicated via the at least one of the plurality of pseudowires,

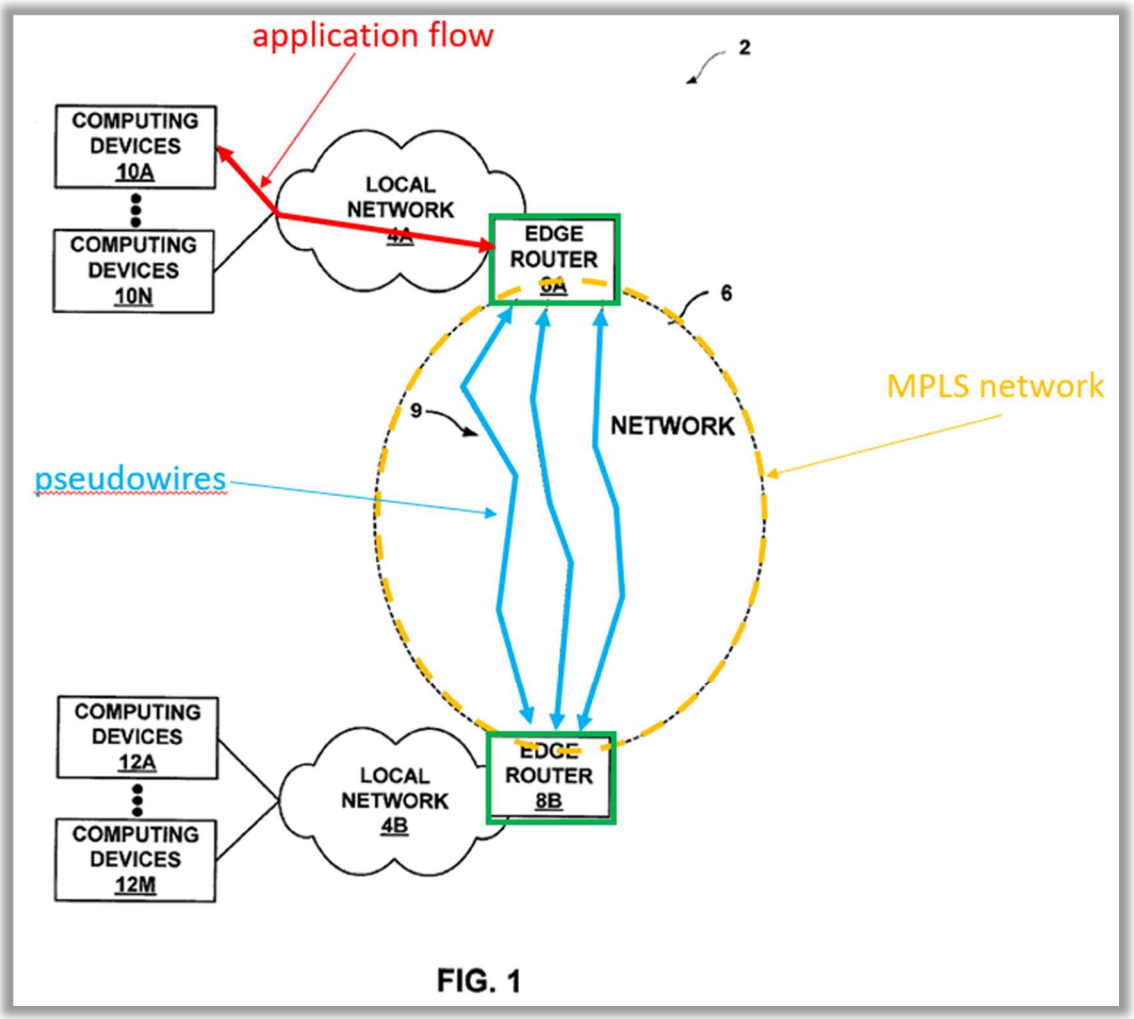
184. *Murphy* disclosed this limitation. *Murphy* disclosed that packets of an end-to-end packet flow, such as real-time audio and video streams, and reservation requests for the same were transmitted between computing devices 10A-10N and 12A-M (*wherein the application flow includes data packets transmitted and received by the sending device application*) and that the packet flows were

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forwarded along the LSPs in the network (*wherein the data is communicated via the at least one of the plurality of pseudowires*).

185. First, Murphy disclosed that the data is communicated via the at least one of the plurality of pseudowires for the same reason it disclosed communicating data … via at least one of the plurality of pseudowires as discussed above in [1d]. See [1d]. As described above, Murphy disclosed that the edge routers 8 (green) encapsulated the data packets associated with the end-to-end packet flow (red), such as real-time audio streams, video streams, or voice data, and reservation requests for the same "within MPLS packets, and forward[ed] the MPLS packets" along LSPs (blue) through the network (orange):

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EX-1005 2:66-3:4, 4:39-51, FIG. 1 (annotated); *see* [1d].

186. Second, *Murphy* disclosed that *the application flow includes data packets transmitted and received by the sending device application*. For example, *Murphy* disclosed that packets of an end-to-end packet flow, such as real-time audio streams, video streams, or voice data, and reservation requests for the same were transmitted "**between** computing devices" 10A-10N and 12A-M. EX-1005 2:66-3:4, 4:39-55, 6:5-7, 6:45-49. This transmission of data between computing devices 10A-10N and 12A-M included MPLS packets flowing through a second

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LSP coupling edge routers 8. EX-1005 5:28-33. Transmission of end-to-end packet flows, such as real-time audio streams, video streams, or voice data, between computing devices across a network included bidirectional (transmitting and receiving) data packets by the application associated with the packet flow. For example, voice data included voice communications like VoIP (EX-1006 ¶¶2, 5; EX-1022, 1496-97), which were bidirectional. Further, even more one-directional communications, e.g., video steaming, included bidirectional communications, e.g., to set up or disestablish the stream. Thus, *Murphy* taught that the forwarding of the end-to-end packet flows and reservation requests for the same between the edge routers 8 along the LSPs included transmitting and receiving the packets by the application (*the application flow includes data packets transmitted and received by the sending device application*).

[6ii] and further comprising assigning, at an edge node, sequence numbers to ingress data packets in an order in which they are received by the node.

187. *Murphy,* in view of *Taguchi* and *Booth* rendered obvious this limitation. *Murphy* in view of *Taguchi* taught an edge router that distributed an application flow across multiple pseudowires. *See* [1cii]. *Booth* taught that an edge router wrote sequence numbers in packets (*further comprising assigning, at an edge node, sequence numbers to ingress data packets in an order in which they are received by the node*).

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188. For example, *Booth* disclosed that "[c]onventional sequence numbers on pseudowire frames exist in both MPLS-based and L2TPv3 pseudowire tunneling technologies." EX-1016, ¶19. Sequence numbers were commonly used "to ensure in-order delivery of packets across a pseudowire." EX-1016, ¶19. *Booth's* system expanded this use of sequence numbers to also include tracking packet loss. EX-1016, ¶¶7, 27-32. The receiving router at the termination end of the pseudowire compared the sequence numbers to previously received sequence numbers to identify the order and potential omission of packets. EX-1016, ¶¶7, 27-32.

189. A POSITA would have found it obvious to combine *Booth's* teaching of sequence numbering with the distributed application flow of *Murphy* and *Taguchi*. A POSITA would have understood that this distribution of an application flow would need to be sequenced such that they could be tracked and reordered. §V.4. A POSITA would have been motivated to make this combination that the correct ordering of, and any loss of packets from the distributed application flow could be determined as expressly taught by *Booth*. EX-1016, ¶¶7, 27-32. Further, a POSITA would have been motivated to make such a combination to verify the "QoS" for the application flow with which the *Murphy-Taguchi* combination was also concerned. EX-1005 1:13-36, 4:21-25, 5:6-9, 6:12-20; EX-1006 ¶¶2, 5-6. A POSITA would have had a reasonable expectation of successfully integrating

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Booth's teachings into the *Murphy-Taguchi* teachings because it would have required simple modification of software in *Taguchi's* edge LSR to assign *sequence numbers* to the packets, and such numbers were widely used in computer networking. §V.4. Indeed, *Booth's* use of sequence numbers was but an alteration to the "[c]onventional sequence numbers on pseudowires" that existed in MPLS. EX-1016 ¶19. Further, *Booth* stated that its sequence-numbering teachings was "applicable to a variety of situations," and a POSITA would have recognized that the distributed application of *Murphy* and *Taguchi* was just one such situation. EX-1016 ¶5. Thus, when the packets of end-to-end packet flows were distributed to multiple LSPs, the edge router would have assigned a sequence number as taught in *Booth*. EX-1006 ¶73. Accordingly, *assigning, at an edge node, sequence numbers to ingress data packets in an order in which they are received by the node* is rendered obvious by *Murphy* in view of *Taguchi* and *Booth*.

Claim 13

[13pre] The device of claim 8,

190. *Murphy* in view of *Taguchi* disclosed the limitations of claim 8 as discussed in Ground 1 above. *See* §VI.A.4. *Murphy* in view of *Taguchi* and *Booth* disclosed limitations [13i]-[13ii] for the same reasons as discussed with respect to claim 6.

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[13i] wherein: the application flow includes data packets transmitted and received by the sending device application, the data is communicated via the at least one of the plurality of pseudowires,

191. *Murphy* disclosed this limitation for the same reasons as discussed with respect to limitation [6i].

[13ii] and the instructions are executable by the processor to cause assigning, at an edge node, of sequence numbers to ingress data packets in an order in which they are received by the node.

192. *Murphy* in view of *Taguchi* and *Booth* rendered obvious this limitation for the same reasons as described above in [6ii] (*assigning, at an edge node, of sequence numbers to ingress data packets in an order in which they are received by the node*) and [8a] (*the instructions are executable by the processor to cause*). *See* [6ii], [8a].

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CONCLUSION AND DECLARATION

The findings and opinions set forth in this declaration are based on my research and analysis to date. I may continue my examinations in view of additional documents or other factual evidence over the course of this proceeding that may necessitate supplementing and/or refining my opinions. I reserve the right to add to, alter, or delete my opinions and my Declaration upon discovery of additional information. I reserve the right to make such changes as necessary.

In signing this declaration, I understand that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

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, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

[SIGNATURE ON FOLLOWING PAGE]

Dated: 8/28/2025 By:__ A. L. Narasimha Reddy

Dr. A.L. Narasimha Reddy

APPENDIX A – MATERIALS RELIED UPON

Exhibit	Brief Description
1001	U.S. Patent No. 10,735,320 ("the '320 Patent")
1002	Prosecution History for U.S. Patent No. 10,735,320
1003	Intentionally Left Blank
1004	Prosecution History for U.S. Patent No. 10,411,999 (parent to the '320 Patent)
1005	U.S. Patent No. 7,477,657 ("*Murphy*"), filed May 8, 2002.
1006	Certified Translation of Japanese Patent Application Publication No. JP 2003-258857 ("*Taguchi*"), with certification of translation.
1007	*Awduche et al.*, "Internet traffic engineering using multi-protocol label switching (MPLS)", Elsevier Science B.V., Computer Networks 40, 111-129 (2002) ("*Awduche*")
1008	U.S. Patent Application Publication No. 2004/0165600 ("*Lee '600*")
1009	Certified Translation of Korean Patent Application Publication No. KR 10-2005-0077938 ("*Lee '938*"), with certification of translation, published August 4, 2005.
1010	*Deering et al.*, "Internet Protocol, Version 6 (IPv6)", The Internet Society, Network Working Group, Request for Comments 2460 (December 1998) ("*Deering*")
1011	*Stewart et al.*, "Stream Control Transmission Protocol", The Internet Society, Network Working Group, Request for Comments 2960 (October 2000) ("*Stewart*")
1012	*Harry Newton*, "Newton's Telecom Dictionary", Miller Freeman, Inc., Fifteenth Edition (February 1999) ("*Newton*")
1013	*Claise, et al.*, "Cisco Systems NetFlow Services Export Version 9", The Internet Society, Network Working Group, Request for Comments 3954 (October 2004) ("*Claise*")
1014	*Basel et al.*, "Ports, Protocols, and Services Management Process for the Department of Defense", Software Engineering Technology, Systems & Software Technology Conference (April 15, 2005) ("*Basel*")

Exhibit	Brief Description
1015	U.S. Patent Application Publication No. 2004/0037279 ("*Zelig '279*"), published February 26, 2004
1016	U.S. Patent Application Publication No. 2006/0285500 ("*Booth*"), filed June 15, 2005.
1017	U.S. Patent Application Publication No. 2004/0133619 ("*Zelig '619*"), published July 8, 2004.
1018	U.S. Patent Application Publication No. 2005/0013300 ("*Akahane*"), published January 20, 2005
1019	*Tschofenig et al.*, "RSVP Security Properties, draft-ieft-nsis-rsvp-sec-properties-06.txt", The Internet Society, Internet-Draft (February 20, 2005)
1020	*Awduche et al.,* "Requirements for Traffic Engineering Over MPLS", The Internet Society, Network Working Group, Request for Comments: 2702 (September 1999) ("RFC 2702")
1021	Applications and Patents related to the '320 Patent. Pulled from Patent Center on August 24, 2025
1022	*Bur Goode*, "Voice Over Internet Protocol (VoIP)", Proceedings of the IEEE, Vol. 90, No. 9 (September 2002) ("*Goode*")

APPENDIX B – *CURRICULUM VITAE*

NARASIMHA REDDY
Dept. of Electrical and Computer Engineering
Texas A & M University
333J Wisenbaker, College Station, TX 77843-3259
https://cesg.tamu.edu/faculty/narasimha-reddy/
https://scholar.google.com/citations?user=en&user=NbHZDW4AAAAJ
reddy@tamu.edu, 979-845-7598 (O), 979-845-2630 (FAX)

Educational Record:

University of Illinois (Urbana) : Ph.D. in Electrical and Computer Engineering. Aug. 1990

University of Illinois (Urbana) : M.S. in Electrical and Computer Engineering. May 1987

Indian Institute of Technology (Kharagpur, India) : Bachelor of Technology (Honors) in Electronics and Electrical Communication Engineering. May 1985

Thesis Topic:

Ph.D Thesis : Issues in IO architectures for high-performance/ multiprocessor systems

M.S. Thesis : Algorithm based Fault Detection Techniques for Specific Applications

B.Tech Thesis (Project) : Studies on Residue Number System for Signal Processing

Honors and Awards:

Cited for one of the most influential papers of first ACM Multimedia Conference

College of Engineering Excellence Award for Service, Texas A & M University, 2022

Catedra de Excelencia, University of Carlos III, Madrid, Spain, Aug. 2009-Feb.2010

Distinguished Achievement Award for teaching (College level), AFS, TAMU, 2005

Ford Fellow, College of Engg., TAMU 2004, TEES Fellow, College of Engg., TAMU, 2001, Neely Faculty Fellow, College of Engg., TAMU, 1999

Outstanding Professor Award, Dept. of ECE, TAMU, 2003-04, 2014-15

Outstanding Professor Award, IEEE Student branch, TAMU, 1997-1998

NSF Career Award (1996-2000)

IBM Plateau Invention Achievement Award

IBM Graduate Fellowship (1988-90)

Presidential Silver Medal, Indian Institute of Technology, Kharagpur, India (May 86)

Research Interests:

Storage Systems, Cybersecurity, Computer Networks and Computer Architecture

Work Experience:

Truchard Foundation Chair Professor in ECE, Texas A&M Univ., Sept. 2023-Present.
Associate Dean for Research, College of Engineering, Texas A&M Univ., Apr. 2016 -Aug. 2021
Associate Agency Director for Strategic Initiatives and Centers, TEES, Aug. 2016 - Aug. 2021
Assistant Agency Director for National and Global Initiatives, TEES, June 2014 - Apr. 2016
J.W. Runyon Professor, Dept. of ECE., Texas A&M University, Oct. 2008-Aug. 2023

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Professor, Dept. of Elec. and Compu. Engg, Texas A & M University, Sep. 2004 -Sep. 2008
Associate Professor, Dept. of Elec. Engg, Texas A & M University, Aug. 1995 - Aug. 2004
Research Staff Member, IBM Almaden Research Center: Aug. 1990 - Aug. 1995

Professional Activities:

- **Fellow** of the IEEE Computer Society, member of ACM SIGARCH
- Associate Editor, IEEE/ACM Transactions on Networking, 2014-2016
- Member, Advisory Board of Center for Hyper Scale Micro Data Center, South Korea
- External Evaluator, Faculty Promotion Committee, University of Jordan, 2012
- Program Committee Member, INFLOW Workshop, 2016
- Program Committee Member, NVM Workshop, 2011, 2015, 2016
- Program Committee Member, IEEE ANTS Conf., 2014
- Program Committee Member, Parallel Data Storage Workshop, 2012-2014
- Member, Information Technology Research Academy Strategy Formulation, India, Oct. 2011
- Review Chair, Los Alamos National Lab Research Information Institute program, Apr. 2011
- Program Committee Member, USENIX HotStorage Conf., 2010-2012
- External Evaluator, Faculty Search Committee, ICS-FORTH, Crete, Greece, 2009
- Program Co-chair, IEEE Broadnets 2008
- Area Lead, IEEE Infocom 2008
- Program Committee Member, USENIX FAST Conf. 2009
- Panels Co-Chair, COMSWARE 2008
- Program Committee Member, ICDCS 2008, 2013
- Program Committee Member, IEEE ICNP 2008
- Program Committee Member, COMSNETS 2009-2013, 2015
- Program Committee Member, COMSWARE 2007-2008
- Program Committee Member, Int. Workshop Visualization for Computer Security, 2006
- Program Committee Member, CoNEXT Conference, 2006, 2007, 2009
- Program Committee Member, Int. Workshop on QOS, 2006-2011
- Program Committee Member, IEEE Infocom, 2005-2015
- External Reviewer, Faculty promotion Committee, KAIST, Korea, 2003
- Technical Consultant, EMC Corp., 2001-2003

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- Educational Content Expert on Computer Networking, Jones International University
- Member, Technical Advisory Board, Netgeo Inc., Mountain View
- Technical Adviser, TBD Networks
- Proposal Reviewer, Netherlands NSF
- Program Committee member, ACM Multimedia Conference, 2002
- Program Committee member, MCW-2001, Multimedia on Clusters of Workstations, 2001
- Program Committee member, IEEE Int. Conf. on Multimedia Comp. and Systems, 1999
- Panel Chair, IEEE Conf. High Performance Computer Architecture, 1999
- Program Committee member, High Performance Computing, 1999
- Program Committee member, Int. Conf. on Parallel Processing, 1998
- Tutorial Chair, IEEE Conf. on Multimedia Computing Systems, 1998
- Panel Chair, Int. Conf. on Parallel Processing, 1995
- Program Committee member, Int. Conf. on Parallel Processing, 1995
- Program track coordinator, Hawaii Int. Conf. on Systems and Sciences, 1994

Patents:

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- Tirumalasetty, Chandrahas.[1], Chou, Chih Chieh.[1], Reddy, Narasimha., Gratz, Paul., and Abouelwafa, Ayman., "Reducing Minor Page Fault Overheads through Enhanced Page Walker, in ACM Transactions on Architecture and Code Optimization, July 2022.
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- Tiwari, A., Reddy, A. L. Narasimha, and Bukkaparnam, S., "Cybersecurity assurance in the emerging Manufacturing-as-a-Service (MaaS) paradigm: A lesson from the video streaming industry, ASTM Journal on Smart and Sustainable Manufacturing Systems, SSMS-2020-0066.R1, October 2020.
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Publication of Books or Book Chapters:

- Bhandarkar, S.[1], and Reddy, A. L. N., "TCP in Wireless Networks", invited book chapter in Encyclopedia on wireless and mobile communications", CRC Press, Dec. 2007.
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- A. L. Narasimha Reddy and J. Wyllie, "Disk Scheduling in a Multimedia I/O System", reproduced as a book chapter in Readings in Multimedia Computing and Networking, Morgan Kaufmann Publishers, Editors: Kevin Jeffay and HongJiang Zhang, Summer 2001.
- Reddy, A. L. N. and Wijayaratne R., "Scheduling for integrated service in multimedia systems", invited book chapter in *Multimedia Handbook*, CRC Press, Dec. 1997.
- Reddy, A. L. N. and Haskin R., "Video Servers", invited book chapter in *Communications Handbook*, CRC Press, 1996.
- Reddy, A. L. N., "Improving the interactive responsiveness in a video server", invited book chapter in *Multimedia Information Storage and Management*, Kluwer Academic Publishers, Dec. 1996.
- Reddy, A. L. N., "Scheduling in Multimedia Systems", invited book chapter in *Design and Applications of Multimedia Systems*, Kluwer Academic Publishers, Aug. 1995.

Rigorously Refereed Conference Publications:

- Singla, R.[1], Raval, V., Ibrahim, H., Kim, J., Enjeti, P., Narasimha Reddy, "Comprehensive Evaluation of Cyber Attacks on Grid-Connected Smart Inverters, Applied Power Electronics Conference, March 2025.
- Tirumalasetty, C.[1], Reddy, Narasimha Contention Aware DRAM Cache Prefetching for CXL-Enabled Pooled Memory, MEMSYS Conference, Sept. 2024.
- Dimantopouls, D., Pletka, R., Srafijanovic. S., Reddy, A. L. Narasimha, Pozidis, H., "WannaLaugh: A configurable Ransomware Emulator", ACM SYSTOR, Sep. 2024.
- Shrestha, Susav[1], Reddy, A. L. Narasimha, Li, Zongweng, "ESPN: Memory-Efficient Multi-Vector Information Retrieval", ACM Symposium on Memory Management, June 2024.
- Singla, R[1]., Srinivasa, S., Reddy, A. L. Narasimha, Pedersen, J.M., Vaselomanolakis, E., Bettati, R., An analysis of war impact on Ukrainian critical infrastructure through network measurements, Proc. of IEEE/IFIP Network Traffic Measurement and Analysis (TMA) Conference, June 2023.
- Tiwari, A., , Villasenor, E. J., Gupta, N., Reddy, A. L. Narasimha, Karri, R,, and Bukkaptnam, Satish T. S. "Protection against Counterfeiting Attacks in 3D Printing by Streaming Signature-embedded Manufacturing Process Instructions", In Proceedings of the 2021 Workshop on Additive Manufacturing (3D Printing) Security (AMSec 21), 2021,
- Qin, M.1, Reddy, A. L. Narasimha, Gratz, P., Pitchumani, R,, Ki, Y-S., "KVRAID: High Performance,Write Efficient, Update Friendly Erasure Coding Scheme for KV-SSDs", accepted at ACM Systor Conference., June 2021.

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- Wen, F., Qin, M.1, Gratz. P., and Reddy, A. L. Narasimha, "OpenMem: Hardware/Software Cooperative Management for Mobile Memory System", accepted at ACM/IEEE Design Automation Conference, Dec. 2021.
- Wen, F., Qin, M.1, Gratz. P., and Reddy, A. L. Narasimha, "FPGA-based Hyrbid Memory Emulation System", Field Programmable Logic and applications Conference, Aug. 2021.
- Qin, M.1, Lee. J-H., Pitchumani, R,, Ki, Y-S., Reddy, A. L. Narasimha, Gratz, P., "A Generic FPGA Accelerator for Minimum Storage Regenerating Codes", Proceedings of the 25th Asia and South Pacific Design Automation Conference, January, 2020.
- Chou, C-C.,1, Chen, Y., Milojicic, D., Reddy, A. L. Narasimha, Gratz, P., "Optimizing Post-Copy Live Migration with System-Level Checkpoint Using Fabric-Attached Memory, 2019 IEEE/ACM Workshop on Memory Centric High Performance Computing (MCHPC), Denver, CO, USA, 2019, pp. 16-24.
- Chou, Chih Chieh[1], Jung, J[1], Reddy, A.L. Narasimha, Gratz, Paul V., and Voight, Doug, "vNVML: An Efficient User Space Library for Virtualizing and Sharing Non-Volatile Memories", IEEE 35th International Conference on Mass Storage Systems and Technology, 2019.
- Zheng, Z.[1], Webb, A.[1], Reddy, A. L. Narasimha, Bettati, Riccardo, "IoTAegis: A Scalable Framework to Secure the Internet of Things", Invited Paper at IEEE ICCCN, July 2018.
- Zheng, Z.1, Reddy, A. L. Narasimha, "Safeguarding Building Automation Networks: THE-Driven Anomaly Detector Based on Traffic Analysis", IEEE ICCCN (Invited Paper), July 2017.
- Fedorov, V[1]., Kim, J., Qin, M[1]., Reddy, A. L. Narasimha and Gratz, P., "Speculative Paging for future NVM and SSD", Proc. of MEMSYS Conference, Oct. 2017.
- Zhang, Z[1], Jin, S., Bettati, R., Reddy, A. L. Narasimha, "Securing Cyber-Physical Systems with Adaptive Commensurate Response", Proc. of IEEE CNS, Oct. 2017.
- Zhang, Z[1], and Reddy, A. L. Narasimha, "Safeguarding Building Automation Networks: THE-Driven Anomaly Detector Based on Traffic Analysis", Invited Paper at ICCCN 2017, July 2017.
- Zhang, Z[1], and Reddy, A. L. Narasimha, "Towards Improving Data Validity of Cyber-Physical Systems through Path-Redundancy", 3rd ACM Cyber-Physical Systems Security Workshop, April 2017.
- Kim, J., Pugsley, S., Gratz, P., Reddy, A. L. N., Wilkerson, C., and Chisti, Z., "Path Confidence based Lookahead Prefeteching", MICRO Conf., Oct. 2016. **Best Paper Nomination**.
- Webb, A.[1] and Reddy, A. L. Narasimha, "Finding proxy users at the service using anomaly detection", IEEE Conf. on Communications and Network Security, Oct. 2016.
- Moon, S[1]., and Reddy, A. L. Narasimha, "Adaptive policies for balancing performance and lifetime of mixed SSD arrays through workload sampling", IEEE Mass Storage Symposium, April 2016
- Fedorov, V.[1], Reddy, A. L. Narasimha and Gratz, P., "Shared Last-Level Caches and The Case for Longer Timeslices", MEMSYS Conference, Oct. 2015

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- Kim, J., Fedorov, V.[1], Gratz, P., and Reddy, A. L. Narasimha, "Dynamic Memory Pressure Aware Ballooning", MEMSYS Conference, Oct. 2015
- Fedorov, V.[1], Qiu, S.[1], Reddy, A. L. Narasimha and Gratz, P., "ARI: Adaptive LLC-memory traffic management", HiPEAC Conf., Jan. 2014.
- Moon, S[1] and Reddy, A. L. Narasimha, "Don't let RAID raid the lifetime of your SSD array", Proc. of USENIX HotStorage Conf., June 2013.
- Qiu, S[1], and Reddy, A. L. Narasimha, "NVMFS: A hybrid file system for improving random write in NAND-flash SSD", Proc. of Mass Storage Systems Symposium, May 2013.
- Lee, Y-O[1], and Reddy, A. L. Narasimha, "Multipath Routing for Reducing Network Energy", IEEE Greencom Conf., Sep. 2012.
- Qui, S[1]., Reddy, A. L. Narasimha, "Exploiting superpages in a nonvolatile memory file systems", IEEE Mass Storage Symposium, Apr. 2012.
- Moon, S[1]., Reddy, A. L. Narasimha, "Write amplification due to ECC on flash memory or leave those bit errors alone", IEEE Mass Storage Symposium, Apr. 2012.
- Wu, X[1]., Reddy, A. L. Narasimha, "SCMFS: A file system for storage class memory", ACM/IEEE Supercomputing Conf. SC11, Nov. 2011.
- Yadav S.[1], Reddy, A. L. Narasimha, "Winning with DNS Failures: Strategies for faster botnet detection", SecureComm Conf., Sep. 2011.
- Lee, Y-O[1], Rengarajan, B., and Reddy, A. L. Narasimha, "Reaching approximate Wardrop equilibrium at reduced cost of link state updates" , COMSNETS Conf., Jan 2011.
- Qian,B[1]., and Reddy, A. L. Narasimha, "Measurement and performance study of PERT for on-demand video streaming" , Pfldnet workshop, Nov. 2010.
- Yadav, S[1], Reddy, A. K.[1], Reddy, A. L. Narasimha and Ranjan, S., "Detecting algorithmically generated malicious domain names" , Proc. of Internet Measurement Conference, Nov. 2010.
- Wu, X[1]., Reddy, A. L. Narasimha, "Exploiting concurrency to improve latency and throughput in a hybrid storage system", **Best Paper Nomination**, IEEE MASCOTS Conf., Aug. 2010.
- Devakota, P[1]., Reddy, A. L. Narasimha, "Performance of Quantized Congestion Notification in TCP Incast Scenarios of Data centers", IEEE MASCOTS Conf., Aug. 2010.
- Lee, Y-Oh[1]., Reddy, A. L. Narasimha, "Disjoint Multi-Path Routing and Failure Recovery", Proc. of ICC, May 2010.
- Yadav, S[1]., Reddy, A. L. Narasimha, "DNS Anomaly detection with NS and AS information", IASTED Conf. on Network Security, Nov. 2010.
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- Kang, S[1]., Reddy, A. L. N., "User-centric data migration in networked storage systems", Proc. of IPDPS, April 2008.
- Bhandarkar, S[1]., Reddy, A. L. N., Zhang, Y., Loguinov, D.,"Emulation of AQM at end hosts", Proc. ACM Sigcomm, Aug. 2007.
- Bhandarkar, S[1]., Reddy, A. L. N., "Robustness to packet reordering in high-speed networks", Proc. of Pfldnet, Feb. 2007.
- Al-Najjar, C[1]., Reddy, A. L. N., "A service provider's approach to improving performance of aggregate voice-over-IP traffic", Proc. of IWQOS, June 2006.
- Kim, S[1]., Reddy, A. L. N., "Netviewer: A Network traffic visualization and analysis tool", Proc. of USENIX LISA Conference, Dec. 2005, 185-196.
- Liu, Y[1], and Reddy A. L. N., "Routing among a group of multi-homed stub networks", Proc. of Globecom, Dec. 2005.
- Bhandarkar, S[1]., Reddy, A. L. N., "LTCP: A layered approach to TCP for high-speed networks", PFLDNet, Feb. 2005.
- Kim, S[1]., Reddy, A. L. N., "Modeling network traffic as images", ICC, May 2005.
- Kim, S[1]., Reddy, A. L. N., "A study of analyzing network traffic as images in real-time", IEEE Infocom, March 2005.
- Kim, S[1]., Reddy, A. L. N., "Real-time detection and containment of network attacks using QOS regulation", Proc. of ICC, May 2005.
- Kang, S[1]., Reddy, A. L. N., "Virtual Allocation: A scheme for flexible storage allocation" OASIS workshop at ASPLOS, Oct. 2004.
- Liu, Y[1], and Reddy A. L. N., "A fast rerouting scheme for OSPF/IS-IS networks", Proc. of ICCCN, Oct. 2004.
- Achanta, P.[1], and Reddy A. L. N., "LRU-FQ: Design and Evaluation of a Partial State Router", Proc. of ICC 2004, June 2004.
- Zhao, Z[1]., Reddy, A. L. N., "Impact of bandwidth-delay product and non-responsive flows on quueue management schemes", Proc.of ICC 2004, June 2004.
- Bhandarkar, S[1]., Reddy, A. L. N., "TCP-DCR: Making TCP robust to non-congestion events", Proc. of Networking 2004, May 2004.
- Kim, S[1]., Reddy, A. L. N., and Vannucci, M., "Detecting traffic anomalies at source through aggregate analysis of packet header data", Proc. of Networking 2004, May 2004.
- Kim, S[1].,Reddy, A. L. N., and Vannucci, M., "Detecting traffic anomalies using discrete wavelet transform", Proc. of Int. Conf. on Information Networking, Feb. 2004.
- Ma, X[1]., and Reddy, A. L. N., "SPIRAL: A novel third party transfer scheme for network attached devices", IEEE Mass Storage Symposium, April 2003.

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- Zhao, Z[1]., Ametha. J., Swaroop. D. and Reddy A. L. N., "A method for estimating non-responsive traffic at a router", ACM Conf. on Sigmetrics, June 2002.
- Garg, A[1]., and Reddy, A. L. N., "Mitigating Denial of service attacks through QOS regulation", IwQoS workshop, May 2002.
- Wijayaratne, R[1]. and Reddy, A. L. N., "System support for providing integrated services from networked multimedia storage servers", ACM Conf. on Multimedia, October 2001, 270-279.
- Smitha[1] and Reddy, A. L. N., "LRU-RED: An active queue management scheme to contain high bandwidth flows at a congested router", in IEEE Globecomm Conference, Nov. 2001.
- Smitha[1], Kim, I[1]., and Reddy, A. L. N., "Identifying long term high rate flows at a router", in Proc. of High Performance Computing, Dec. 2001.
- Yeom, I[1]., and Reddy, A. L. N., "Adaptive marking for aggregated flows", in Proc. of IEEE Globecom, Nov. 2001.
- Gopalakrishnan, S[1]. and Reddy, A. L. N., "SACRIO: An active buffer management scheme for Differentiated Service Networks", Proc. of NOSSDAV, June 2001.
- Ma, X[1]. and Reddy, A. L. N., "MVSS: MultiView Storage Systems", Proc. of Int. Conf. on Distributed Computer Systems (ICDCS), Apr. 2001.
- Khaleel, A[1]. and Reddy, A. L. N., "Evaluation of Request and data distribution polices in a clustered server", Proc. of High Performance Computing, Dec. 1999.
- Yeom, I[1]. and Reddy, A. L. N., "Realizing throughput guarantees in a differentiated services network", Proc. of IEEE Int. Conf. on Multimedia Computing and Systems, June 1999.
- Wijayaratne, R[1]., Reddy, A. L. N., "Integraed QOS management for disk I/O", Proc. of IEEE Int. Conf. on Multimedia Computing and Systems, June 1999.
- Yeom, I[1]. and Reddy, A. L. N., "Impact of marking strategy on aggregated flows in a differentiated-services network", Proc. of IEEE International Workshop on QOS (IwQOS 99), June 1999.
- Tong, D[1]. and Reddy, A. L. N., "QOS Enhancement with Partial Sate", Proc. of IEEE International Workshop on QOS (IwQOS 99), June 1999.
- Gupta, S[1]. and Reddy, A. L. N., "IPRP: A Client-oriented IP Redirection mechanism", Proc. of IEEE Infocom Conf., March 1999.
- Wijayaratne, R[1]. and Reddy, A. L. N., "Techniques for improving the throughput of VBR streams", Proc. of ACM/SPIE Multimedia Computing and Networking, Jan. 1999.
- Ma, G[1]. and Reddy, A. L. N., "An evaluation of storage systems based on network-attached disks", Proc. of ICPP Conf., Aug. 1998.
- Reddy, A. L. N., "Effectiveness of caching policies for a web server", Proc. of High Performance Computing, Dec. 1997.
- Reddy, A.L.N., "Caching strategies for a multimedia server", Proc. of IEEE Int. conf. on Multimedia Computing and Systems, June 1997.

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- Reddy, A. L. N., "Improving Latency in an Interactive Video server", Proc. of SPIE conf. on Multimedia Computing and Networking, Feb. 1997.
- Reddy, A.L.N., "Movie and communication scheduling on a multiprocessor video server system", Proc. of *IEEE Int. Conf. on Multimedia Comput. and Systems*, May. 1995.
- Reddy, A.L.N., Wyllie, J., "Disk Scheduling in a Multimedia I/O System", Proc. of *1st ACM Conf. on Multimedia*, Aug. 1993. Included as a chapter in "A guided tour of multimedia systems and applications", IEEE Press, 1995. Translated into Japanese by *Nikkei Electronics*, a Japanese technical magazine. To be included as "*one of the most influential papers*" in ACM Transactions on Multimedia, Applications and Communications.
- Chandy, J., and Reddy, A.L.N., " Failure evaluation of disk array organizations", Proc. of *Int. Conf. on Distributed Computing Systems*, May 1993.
- Reddy, A.L.N. and Freitas, R., "Fault-tolerance of adaptive routing algorithms in multicomputers", Proc. of *4th IEEE Symp. on Parallel and Distributed Processing*, Dec. 1992.
- Reddy, A.L.N., "A Study of IO System Organizations", Proc. of *ACM Int. Symp. on Computer Architecture*, May 1992.
- Reddy, A.L.N., "Reads and Writes: When IOs aren't the same", Proc. of Hawaii Int. Symp. on Systems and Sciences, Jan. 1992.
- Reddy, A.L.N., Banerjee, P. and Chen, D.K., "Compiler Support for Parallel I/O Operations", Proc. of *Int. Conf. on Parallel Processing*, Aug. 1991.
- Reddy, A. L. N. and Banerjee, P., "Gracefully Degradable Disk Arrays", Proc. of *Int. Symp. on Fault Tolerant Computer Systems*, June 1991.
- Reddy, A. L. N. and Banerjee, P., "A Study of IO Behavior of Scientific Applications on A Multiprocessor", Proc. of *ACM Int. Symp. on Computer Architecture*, June 1990
- Reddy, A. L. N. and Banerjee, P., "Performance evaluation of multiple-disk IO systems", Proc. of *Int. Conf. on Parallel Processing*, Aug. 1989.
- Reddy, A. L. N. and Banerjee, P., "IO issues in hypercubes", Proc. of *ACM Int. Conf. on Supercomputing*, June 1989.
- Reddy, A. L. N., Banerjee, P. and Abrham, S.G., "IO embedding in Hypercubes", Proc. of *Int. Conf. on Parallel Processing*, August 1988.
- Reddy, A. L. N. and Banerjee, P., "A Fault-Secure Dictionary Machine", Proc. of *3rd International Conference on Data Engineering*, Feb. 1987.

Other Publications:

- Kim, J., Gratz, P., and Reddy, A. L. Narasimha, " Lookahead Prefetching with Signature Path", ACM ISCA Workshop on Data Prefetch Competition, June 2015
- Huang, B[1]., Wang. S1., and Reddy, A. L. Narasima, "Who is Hiring Whom: A New Method in Measuring Graduate Programs", ASEE conference, June 2015.

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- Singh, A.[1], and Reddy, A. L. Narasimha, "Multi path PERT", **Invited Paper** at Int. Conf. on Computer Communications and Networks, July 2013.
- Amaleswaram, A.[1], Reddy, A. L. N., Yadav, S.[1], Gu. G., Yang, C., "CATS: Characterizing Automation of Twitter Spammers", **Invited Paper** at Int. COMSNETS conf., Jan. 2013.
- Wu, X.[1], and Reddy, A. L. N., "Data organization in a hybrid storage system", **Invited Paper** at Int. Conf. on Computing, Networking and Communications, ICNC'12, Feb. 2012.
- Yin, Z.[1], Hasari, C., Al-Nuweiri, H., and Reddy, A. L.N., "'Improving the Performance of Delay Based Protocol in Delivering Real Time Media via Early Retransmission", IEEE ICT Conf., Apr. 2011.
- Yin, Z.[1], Al-Nuweiri, H., and Reddy, A. L.N., "Performance of Early retransmission scheme in streaming media", IEEE ICT Conf., Apr. 2010.
- Kim, S[1]., and Reddy, A. L. N., "An evaluation of the effectiveness of measurement-based anomaly detection techniques", ADSN workshop, held in conjunction with ICDCS, June 2006.
- Vellanki, S[1]., and Reddy, A. L. N., "Improving service availability during link failure transients through alternate routing", Tech. Report, Texas A & M University, Feb. 2003.
- Ma, X[1]., and Reddy, A. L. N., "Implementation and Evaluation of an active storage system prototype", Workshop on novel uses of System Area Networks, Feb. 2002.
- Reddy, A.L.N., " An evaluation of multiprocessor video server system", *IBM Confidential report*, June 1994.
- Menon, J., Reddy, A.L.N., Treiber, K. and Tzou, S.Y., "Daisy: A Novel Heirachical Storage Management System, Functional Specification", *IBM Confidential Report*, 77 pages, Jan 1994.

Presentations:

- Invited Talk at Reliable and Resilient Digital Manufacturing Workshop, NYU, April 2024
- Invited Talk at NYU on Manufacturing Security, April 2023
- Invited Talk at ENSAM, Aix-en-Provence, France on Digital Manufacturing Security, Jan 2023
- Several talks on A& M Engineering Research Program at many Government Agencies and Labs 2015-21.
- Tutorial on Network Security at Int. Conference on Information Security, Hyderabad, India, Dec. 2014
- Invited talk at IEEE Communications Soceity, Hyderabad, India, August 2014
- Invited talk at University of Texas at San Antonio, Nov. 2013
- Presentation at Flash Summit, Aug. 2013
- Invited talk at Georgia Tech., May 2013

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- Keynote talk at Int. Conf. on Information Technology: New Generations, Las Vegas, April 2013
- Invited talk at COMSNETS Conf., Bangalore, India, Jan. 2013
- Invited talk at Int. Conf. on Networking and Communications, Maui, Feb. 2012
- Invited talk at NVRAMOS 2011, Jeju island, South Korea, Nov. 2011
- Invited talks at Korea University, Ajou University, Samsung and ADD, Korea, Nov. 2011
- Keynote talk at IEEE Int. Symp. on Computers and Communications, Italy, June 2010
- Catedra Series talk at University of Carlos III, Dec. 2009, Madrid, Spain
- Invited talk at Thomson Research, Paris, France, October 2009
- Invited talk at Telefonica Research, Barcelona, Spain, September 2009
- Distinguished Seminar Series, IBM Austin Research Lab, May 1 2008
- Invited talk at University of Illinois, November 2006
- Invited talk at Cisco, January 2005
- Invited talk at University of Birmigham, UK, June 2004
- Invited talk at Cisco Systems, San Jose, June 2002
- Invited talk at Juniper Networks, Mountain View, June 2002
- Invited talk at Univ. of California at Riverside, June 2002
- Invited talk at Nortel Networks, Santa Clara, June 2000
- Invited talk at Juniper Networks, Mountain View, June 2000
- Talk at Internet Engineering Task Force, Washington D.C., Oct. 1999
- Invited talk at EMC Corp., Boston, Aug. 1999
- Tutorial on "Scheduling for Multimedia Applications", presented at IEEE Int. Conf. on Multimedia Computing and Systems, June 1999
- Tutorial on High-Performance I/O at IEEE/ACM Int. Conf on Computer Architecture,Atlanta, May 1999
- Invited talk at AT & T Research Center, Florham Park, March 1999
- Invited talk at Bell Labs Research Center, Murray Hill, March 1999
- Invited talk at EMC Corp., Boston, Nov. 1997

Funding:

- "Distributed Key Value Storage Manager", NSF, PI, 2023-25.

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- "Data Driven Cybersecurity Research Infrastructure for Smar Manufacturing", NSF, PI, 2023-25.
- "PETS: Programmable Extensible zero-Trust Security for working across 5G networks", NSF, co-PI, 2022-23.
- "Multi-layer Cybersecurity and Situational Awareness to Enhance Resiliency in Qatars Power Grid", Qatar National Research Fund, co-PI, 2022-27.
- "Storage systems for streaming applications, Samsung, PI, 2022-24.
- "High-performance storage systems", Los Alamos National Lab, PI, 2022-25.
- "Cooprative Research Agreement", Army Futures Command, Co-PI, 2019-24.
- "Protecting Building Automation Networks from insider threats", 2016, QNRF, lead PI.
- EMC, DELL, HPE and Samsung membership participation in NSF I/UCRC Center.
- "NSF I/UCRC Center on Intelligent Storage", 2014, NSF, lead PI.
- "Equipment Donation", Viking Technologies, 2013.
- "Emerging memory architectures for big memory applications", National Science Foundation, 2013-2016, co-PI.
- "Exploiting social communication channels against cyber criminals", National Science Foundation, 2012-2015.
- "Client interfaces to object storage systems", Argonne National Lab, 2012-2015.
- "Detecting malicious activities by analyzing social communication contexts", Qatar National Research Foundation, 2012-2015.
- "Network traffic analysis for botnet detection", Narus Inc., Research gift, 2009-2010.
- "Design and Analysis of new generation of protocols for triple-play networks", QNRF, Jan. 1. 2008 - Dec. 31 2010, Co-PI.
- "Dynamic allocation and data distribution in networked storage systems", National Science Foundation, Oct. 2007 - Sept. 2010, sole PI.
- "Active Data Systems", National Science Foundation, Sept. 2006 -Aug. 2009, sole PI.
- NSF REU grant, co-PI, 2004-2007.
- Network Elements based on partial state, Intel Corp., gift, Feb. 2003.
- Texas A & M University, "High Availability Infrastructure Laboratory", TITF Award, Sept. 2002 - Dec. 2003, PI with R. Bettati, M. Vannucci and D. Swaroop.
- "Secure Networked Storage Systems", National Science Foundation, Research Instrumentation grant, Sept. 2002- Sept. 2005.
- Texas Advanced Technology Program, "Network Architectures based on partial state", Jan. 2001 - Dec. 2002.

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- "Fellowships for Computer Engineering", Department of Education, Aug. 2001- Aug. 2004, PI with R. Mercer and K. Watson.
- "QOS Enhancement with Partial state", National Science Foundation, June 2001-June 2004, sole PI.
- "Multiview Storage Systems", National Science Foundation, May 2001 - May 2004, sole PI.
- Equipment Donation, 3Ware Inc., Nov. 2000.
- "Scalable request-specific file service", National Science Foundation, Aug. 1999 - Aug. 2002, sole PI.
- Research gift, EMC Corp., 1998.
- "Scalable Multimedia Storage Server", Texas Higher Education Board, January 1996 - Dec. 1997, sole PI.
- "Scalable Storage Server for Multimedia and Scientific Applications", National Science Foundation, 1996-2000, sole PI.
- "Development of Novel Systems Software for Multimedia and High-performance computing", National Science Foundation, 1997-2000, PI along with R. Mercer, P. Cantrell, G. Choi and M. Lu.
- Equipment grant, Tandem Corporation, March 1997.
- Software donation, Microsoft Corporation, April 1997.

Teaching:

Redesigned the course ECEN 449 "Microprocessor Systems Design", Fall 2007.

Developed a new course ELEN 627 "Multimedia Systems and Networks".

Developed a freshman undergraduate course ENGR111 "Introduction to Electrical and Computer Engineering".

Developing a new graduate course on "Network systems security". Taught in Spring 2004, 2006.

Courses Taught: Undergradute Introduction to Electrical and Computer Engineering, Undergraduate Computer Architecture, Graduate Network Systems security, Graduate Computer Architecture, Graduate Computer Networks, Graduate Multimedia Storage and Delivery, Graduate Parallel Computer Systems, Graduate I/O and Memory Systems.

Student Advising:

- Aayush Gautam, Ph.D. candidate, Aug. 2024-present, Storage Systems.
- Caleb Norton, Ph.D. candidate, Aug. 2023-present, Storage Systems
- Susav Shresta, Ph.D. candidate, Aug 2021-present, Systems support for Machine Learning.
- Chandrahas Tirumalasetty, Ph.D. candidate, Aug 2019-present, Memory Systems.
- Rishabh Singla, Ph.D. , Aug 2024, "Improving IoT security in critical infrastructure"..

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- Mian Qin, Ph.D., Aug 2016-Aug 2021, "Accelerating Storage Applications with Emerging Key Value Storage Devices", next at VmWare.
- Chih-Chieh Chou, Ph.D., Aug 2014-Jan. 2020, "Optimizing Emerging Memory Systems for Performance", next at Amazon.
- Zhiyuan Zheng, Ph.D., Aug. 2013 -Dec. 2017, "Protecting Cyber-Physical Systems With Special Emphasis On Building Automation Networks", next at Pinterest.
- Jaemin Jung, Postdoc, Oct. 2016-18, Storage systems, next at Samsung Research.
- Allen Webb, Ph.D. candidate, Jan. 2013-17, "Addressing Insider Threats From Smart Devices", next at Google.
- Viacheslav Fedorov, Ph.D., 2010 - 2016, "Memory Management for emerging memory technologies", later at NXP.
- Jongmin Gim, Postdoc, 2013-2015, Storage Systems Software, Later at Samsung Research Labs, California.
- Sangwhan Moon, Ph.D., 2010 - 2015, "Reliability of SSD Storage Systems", later at Riverbed Technology.
- Sheng Qui, Ph.D. 2013 "Integration of nonvolatile memory into storage hierarchy", later at Samsung Research Labs.
- Yong Oh Lee, Ph.D., May 2012, "Improving efficiency and effectiveness of multipath routing in computer networks", later at Samsung.
- Jagadeesh Dyaberi, Ph.D., Aug. 2011, "Networking and Storage support for on-demand video delivery", Purdue University, External thesis committee member.
- Sandeep Yadav, Ph.D., 2012, "Scalable techniques for anomaly detection", Dec. 2012, later at Dumballa.
- Xiaojin Wu, Ph.D., Flash and Disk Hybrid storage systems, Aug. 2011, later at Marvell Semiconductor.
- John Garrison, Ph.D. , "Umbrella File System: Managing heterogeneous storage devices File systems", Aug. 2009, later at DOD Labs, Tuscaloosa, Alabama.
- Sukwoo Kang, Ph.D., "Flexible space allocation and management in networked storage systems", May 2007, later at IBM Almaden Research Center.
- Sumitha Bhandarkar, Ph.D., "Congestion control algorithms for TCP in emerging networks", Aug. 2006, later at Motorola.
- Yong Liu, Ph.D., "Dynamic Routing protocols in multihomed networks", Dec. 2006, later at EMC Corp.
- Seong Soo Kim, Ph.D., "Real-time analysis of aggregate network traffic", May 2005, later at Samsung, Seoul, Korea.
- Zhili Zhao, Ph.D., May 2004, "Estimation and control of nonresponsive traffic", later at Intel.

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- Xiaonan Ma, Ph.D., Aug. 2003, "Augmenting functionality at storage systems", later at IBM Almaden Research Center, San Jose.
- Ravi Wijayaratne, Ph.D., Dec. 2000, "PRISM: A file server architecture for providing integrated services", later at Quantum, San Jose.
- Ikjun Yeom, Ph.D., Dec. 2000, "Bandwidth assurance in differentiated services networks", later a faculty member at KAIST, South Korea.
- Naga Sai Gouthami Bejjanki, M.S. Candidate 2023-24, "Fabric Attached Memory".
- Adithya Kannan, M.S. Candidate, 2023-25,"Prefetching across pages".
- Daksh Vasistha, M.S., 2015-17, " Detecting Anomalies in Controller Area Network for Automobiles", next at Facebook
- Ayush Ruia, M.S., 2015, "Virtualization of nonvolatile memory", later at Microsoft.
- Bolun Huang, M.S. 2014, "Sentiment based classification of tweeters and university programs", later at Microsoft.
- Shyam Sambasivan, M.S. "Enhancements to SQLite library to improve performance on mobile platforms", Aug. 2013, later at Cisco.
- Ankit Singh, M.S., "Multipath Probabilistic Early Response TCP", Aug. 2012, later at Amazon.
- Cindy Cao, M.S., "SCMFS Performance Enhancement and Implementation on Mobile Platform", Aug. 2012, later at Microsoft.
- Amit Anand, M.S., "Proactive spammer detection on Twitter", Aug. 2012, later at Amazon.
- Bin Qian, M.S.. Aug. 2011, "Evaluation of Probabilistic Early Response TCP (PERT) for video streaming and extension with ACK coalescing", later at Amazon Data Services.
- Ashwath Reddy, M.S., Aug. 2010, Detecting networks employing algorithmically generated names, later at Microsoft.
- Prajjwal Devakota, M.S. Aug. 2010, Performance of Quantized Congestion Notification in TCP Incast in Data Centers, later at Bloomberg.
- Chaitanya Tadi, M.S., May 2009, IP Prefix Hijack Prevention Service, later at Intel.
- Marcus Dunn, M.S., May 2009, A new I/O scheduler for Solid State Devices, later at Cisco.
- Kiran Kotla, M.S., "Adapting the delay-based protocol PERT to heterogeneous environments", Aug. 2008, later at Cisco.
- Camelia Al-Najjar, M.S., August 2005, thesis on "An approach for improving performance of aggregate voice over IP traffic", pursuing Ph.D. at Case Western University.
- Saurabh Jain, M.S., May 2005, thesis on "LTCP-RC: RTT compensation technique to scale highspeed protocols to high RTT links", later at Cisco.

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- Sridhar Vellanki, M.S., Feb. 2003, thesis on "Improving service availability through alternate routing", later at Microsoft.
- Sadry, Nauzad, M.S., Dec. 2002, thesis on "Evaluation of Delayed Congestion Response protocols for tolerating channel errors in wireless networks", later at Netezza.
- Achanta, Phani, M.S., Dec. 2002, thesis on "Design and Evaluation of Partial State Routers", later at IBM.
- Smitha, M.S. student, May 2001, thesis on "An active queue management scheme to contain high bandwidth flows at a congested router", later at Intel India.
- Sumitha Bhandarkar, M.S., August 2001, thesis on "Delayed Congestion Response Protocols", Ph.D. at TAMU.
- Aman Garg, M.S., August 2001, thesis on "Mitigating Denial of Service using QOS regulation", later at Tipping Point Technologies, Austin.
- Sai Gopalakrishnan, M.S., May 2000, later at Cisco, thesis on "TRIO: Active resource management in differentiated services networks".
- Qian Ren, M.S., May 2000, later at Lucent, thesis on "MPEG-aware disk storage system".
- Marcus Grande, M.S., Dec. 1999, later at IBM, thesis on "Multiported Storage Devices".
- Adnan Khaleel, M.S., Aug. 1999, later at Motorola, thesis on "Request and data distribution on a clustered server".
- Deying Tong, M.S., May 1999, later at Cisco, thesis on "Partial state based approaches to QOS enhancement".
- Sumit Gupta, M.S., Aug. 1998, later at Sun Labs, thesis on "IPRP: A client-oriented IP redirection mechanism and its applications".
- Ashwin Madhwaraj, M.S., May 1998, later at Cisco, thesis on "Adaptive video transport over networks".
- Gang Ma, M.S., May 1998, later at EMC Corp., thesis on "Evaluation of storage systems based on network attached storage".
- Mike Nichols, M.S., May 1998, later at UT Law School, thesis on "Personal informal retrieval agent".
- Ikjun Yeom, M.S., May 1998, later a faculty member at KAIST, Korea, thesis on "ENDE: An End-to-end Network Delay Emulator".

Service:

- Member of several committees in the ECE department, 2023-24.
- Chair, MKO Process Safety Center Director Search Committee, 2020
- Member, University IT Research Committee, 2018
- Chair, Turbo Lab Director Search Committee, 2017

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- Chair, College Cybersecurity Search Committee, 2016-23
- Member, University Chief Communications Officer Hiring Committee, 2015-16
- Member, University level Assoc. Former Students Awards Committee, 2016
- Member, TAMUQ FASC Committee, 2013
- Chair, Department Growth Committee, 2013
- Chair, College Taskforce on National Security, 2013
- Member, College Research Strategy Subcommittee, 2012
- Member, Computer Science and Engineering Head Search Committee, 2010-11, 2013-14
- Member College Awards Committee 2006-2008. 2010-2012
- Member, Computer Engineering Curriculum Committee, 2003-2012. Led the restructuring of Undergraduate curriculum in Computer Engineering
- Member, Department Tenure & Promotion Committee, 2004-2006, 2010-2012
- Member, Electrical and Computer Engineering Department Head Search Committee, 2004
- Member, Department Advisory committee 2003-2004
- Chair and Member, department Awards committee 2004-2006
- Member, Department Awards committee, 1997-2003, 2008-2009
- Member, Department Distinguished Speakers committee, 1996-1999, 2006-2008
- Chair and Member, Department Distinguished Speakers committee, 2010-present
- Member, Department undergraduate studies committee, 1997-2000
- Member, Department web site design committee, 2000-2004
- Group leader, Computer Engineering, 2005-2014

Administrative Experience:

Group Leader, Computer Engineering, 2005-2014:

- Led evaluation, development and rearchitecting the Computer Engineering program, a joint program across two departments of Electrical and Computer Engineering and Computer Science Engineering.
- Led the hiring of about 10 Computer Engineering faculty.
- Led the development of ENGR 111 Freshman Introduction of Electrical and Computer Engineering, primarily to improve retention in Electrical and Computer Engineering programs. Increased retention rates from 45% to about 80%.
- Led the development of several other courses ECEN 449 Microprocessor Systems Design, ECEN 627 Multimedia Systems and Networks, ECEN689 Computer Networks Security.

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- Rebuilt several existing courses including ECEN 350 Computer Architecture and ECEN 676 Advanced Computer Architecture, ECEN 602 Computer Networks.
- Contributed to the national ranking of both undergraduate and graduate Computer Engineering programs to top 20 programs in the country.

TEES Assistant Agency Director for National and Global Initiatives, 2014- 2016:

- Developed and Established a TEES office in Yukatan, Mexico.
- Nurtured relationships in Brazil, France and India. The France relationship resulted in a collaborative center with ENSAM.
- Established realtionships with Kuwait Oil Company that led to a discussion on a $15 million research contract, which ultimately could not be closed for contractual difficulties.
- Developed a strategy to engage with National Labs and Federal Agencies.

Associate Dean for Research, College of Engineering and TEES Associate Agency Director for Centers and Strategic Initiatives, 2016-2021:

- Established strategic focus on several emerging areas of research including Autonomy, Synthetic Biology, Soft Matter, Cyber Security and Quantum Computing.
- Developed a strategy for supporting large multi-PI proposals and increased large proposal funding from 5-6 per year to about 25 per year.
- Increased TEES Research funding from about $110 million/year to $210 million/year from 2016-20.
- Increased Federal funding percentage from 38% to 68% of total TEES funding.
- Nurtured relationships with Army Research Lab (ARL) and facilitated the establishment of ARL-south relationship with A & M. Direct impact: ARL Cooperative Agreements in Synthetic Biology, Electric Power, Materials and Manufacturing, Autonomy and Cybersecurity with about 15 ARL people stationed at Texas A& M.
- Supported establishment of $65 million ARL/Army Futures Command (AFC) Cooperative agreement on Hypersonics, Autonomous vehicles and Networks.
- Contributed to $26 million Distributed Autonomy related project funded by Army Research Lab.
- Nurtured and furthered collaborations with Air Force Research Lab, resulting in the establishment of AFRL fellowships at A & M. Direct Impact: AFRL $4 million Minority Leaders Scholarships in Material Discovery and several projects with sensors, human performance and information directorates.
- Established relationships with Army Engineering and Research Development Center (ERDC). Resulted in $3 million contract. Exploring further options for joint projects.
- Establishing close collaborative ties with DOE/DOD National Labs. Resulted in Master Research Agreements and joint projects with several labs including Idaho National Lab(INL), Lawrence Livermore National Lab(LLNL), Pacific Northwest National Lab (PNNL) and others.

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- Contributed to successful $40 million proposal for "Offshore Energy Safety Center 2.0" proposal to Department of Interior and Department of Energy.
- Started and organized "TEES Tech. Talk" series to facilitate hosting Labs and Agency researchers and program managers.
- Organized National Labs Day to facilitate interactions of graduate students with National Labs.
- Championed "Remote Ph.D. program for national labs".
- Established "Research Impact Awards" to facilitate a discussion and recognition of impactful research within the College.
- Established External Awards Support office to promote faculty for external professional awards.
- Supported young faculty applications to NSF, DOD/DOE/DARPA CAREER and Young Investigator awards. Increased NSF CAREER awards from 2/year to 8/year.
- Established NSA Masters Program.
- Expanded a weekly "Research Opportunities" bulletin to cover broader research opportunities.
- Interacted with the Research Deans of other colleges and supported inter-college collaborations.
- Established procedures and metrics for evaluating centers within college and reorganized centers after a thorough review of the existing centers. Managed about 30 Centers and Institutes.
- Established support to help graduate student applications for NSF and NDSEG Fellowships.

[1]Reddy's Students.

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