IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Casimir M. Kaczmarczyk, et al.	
U.S. Patent No.:	6,950,441	Attorney Docket No.: 42360-0004IP3
Issue Date:	September 27, 2005	
Appl. Serial No.:	09/538,040	
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Title:	METHOD AND SYSTEM TO INTERNETWORK	
	TELECOMMUNICATION NETWORKS OF DIFFERENT	
	PROTOCOLS	

DECLARATION OF DR. VISHAL SHARMA

I, Vishal Sharma, of Union City, CA, declare that:

QUALIFICATIONS AND BACKGROUND INFORMATION

- 1. My qualifications for forming the opinions given in this expert report are summarized here and are addressed more fully in my curriculum vitae, which is attached as Exhibit A. That exhibit also includes a list of my publications.
- 2. I hold a Bachelor of Technology Degree in Electrical Engineering from the Indian Institute of Technology, Kanpur, and an M.S. Degree in Signals & Systems, an M.S. Degree in Computer Engineering, and a Ph.D. in Electrical and Computer Engineering from the University of California, Santa Barbara.

3. I have over twenty years of telecommunications and networking experience, spanning areas such as protocol design, system architecture, system analysis and optimization, and software prototyping.

4. I am a Senior Member (2001) of the IEEE and a Fellow (2005) of the IETE. I have been a Subject Matter Expert (SME) at the Broadband Forum. I

have been on the Scientific Committees of the World Telecommunications Conference, V6 World, MPLS World Congress (Paris), Wi-MAX Summit (Paris), FutureCon (New York), iPOP (Japan), and several academic conferences, such as IEEE's ICC, Globecom, and LAN/MAN Workshop. I have been a Guest Editor of six Feature Topic issues of the IEEE Communications Magazine, one of IEEE's most widely read and cited publications. I have been active in standards bodies, such as the IETF and OIF, having contributed to Working Groups focused on diffserv, traffic engineering, MPLS, virtual private networks, and optical networking technologies, during a period (1998-2004) when some of the foundational technologies widely used in the modern Internet were debated and standardized. I have over 10 RFC's published, and was a key contributor to the generalized MPLS standards.

5. I am a named inventor on 12 U.S. patents issued in the areas of MPLS recovery, high-speed switch architectures and scheduling, optical routing, and the IP control of SONET/SDH networks.

6. I am currently Principal at Metanoia, Inc., where I focus on telecommunications and networking technologies. From 2004 to 2007, I was also an Associate Professor (Contract) in the Department of Electrical Engineering at the Indian Institute of Technology Bombay (Mumbai, India & Silicon Valley, CA). In 2001, I was Principal Architect at Jasmine Networks, working on MPLS-based

control plane design for packet and TDM (SONET/SDH) data for Jasmine's CNS (Converged Network System) platform. From 1998-2000, I was a Research Engineer at the Tellabs Research Center (TRC) in Cambridge MA, where I analyzed and designed high-speed switch router architectures, and also worked on the evolution of SS7 and telephony networks using packet-switched technologies. From 1997-1998 I was a Post-Doctoral Researcher at the Multi-disciplinary Optical Switching Technology (MOST) Center in Santa Barbara, CA.

7. I have worked in, taught courses and industry workshops on, conducted research in, and consulted to industry in several of the technical areas that are material to the patents at issue in this matter, such as switch architectures, Ethernet technology, signaling and control protocol design and analysis, and the operation and analysis of circuit-switched and packet-switched networks and classic telephony networks.

8. Specifically, in the late 1990s, I worked on the problem of interfacing an ATM gateway product, which used an ATM backbone, with the PSTN network in a seamless manner. This involved, among other technical issues, the interworking of SS7 signaling with ATM signaling, and, later, with signaling in IP networks. I also investigated the problem of carrying PSTN control- and datatraffic over a packet-based network, so as to make a PSTN with such a packet-

switched backbone functionally indistinguishable from the then existing TDM and SS7-based PSTN network.

9. In writing this Declaration, I have considered the following: my own knowledge and experience, including my work experience in the fields of telecommunications, including switching systems, my experience in teaching those subjects, and my experience in working with others involved in those fields. In addition, I have analyzed the following publications and materials:

- U.S. Patent No. 6,950,441 (EX1001), and its accompanying prosecution history (EX1002);
- U.S. Patent No. 6,570,869 to Shankar et al. ("Shankar")(EX1004)
- U.S. Patent No. 7,336,649 to Huang ("Huang")(EX1005)
- U.S. Patent No. 6,614,781 to Elliott et al. ("Elliott")(EX1006)
- U.S. Patent No. 6,111,893 to Volftsun et al. ("Volftsun")(EX1007)
- Christian Huitema, An Architecture For Residential Internet Telephony Service, IEEE Internet Computing, June 1999("Huitema")(EX1008)
- Ramnath A. Lakshmi-Ratan, The Lucent Technologies Softswitch— Realizing the Promise of Convergence, Bell Labs Technical Journal, June 1999 ("Lakshmi")(EX1009)
- U.S. Patent No. 6,418,205 to Capers et al. ("Capers")(EX1010)
- U.S. Patent No. 6,052,448 to Janning ("Janning")(EX1011)

- U.S. Provisional Application 60/127,169 ("'169 Provisional")(EX1012)
- U.S. Patent No. 6,249,572 ("Brockman")(EX1016)
- M. Sestak et al., Traffic Monitoring in a Network of PBXs,
 GLOBECOM '90: IEEE Global Telecommunications Conference and Exhibition ("Sestak")(EX1017)
- Media Gateway Control Protocol (MGCP), V1.0, The Internet Society (October, 1999) ("MGCP Specification")(EX1018)
- U.S. Patent No. 6,311,072 ("Barclay")(EX1019)
- Newton's Telecom Dictionary, 11th Ed., 1996 ("Newton's")(EX1020)

10. Although this Declaration refers to selected portions of the cited references for the sake of brevity, it should be understood that these are examples, and that one of ordinary skill in the art would have viewed the references cited herein in their entirety and in combination with other references cited herein or cited within the references themselves. The references used in this Declaration, therefore, should be viewed as being incorporated herein in their entirety.

11. I am not, and never was, an employee of the Petitioner in this proceeding, Metaswitch Networks Ltd. and Metaswitch Networks Corporation. I have been engaged in the present matter to provide my independent analysis of the issues raised in the petition for *inter partes* review of the '441 patent. I received no compensation for this Declaration beyond my normal hourly compensation based on my time actually spent studying the matter, and I will not receive any added compensation based on the outcome of this *inter partes* review of the '441 patent.

OVERVIEW OF CONCLUSIONS FORMED

12. This expert Declaration explains the conclusions that I have formed based on my analysis. To summarize those conclusions:

- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 1, 3, 5-9, and 12-17 of the '441 patent are obvious over Shankar and Huang.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claim 2 of the '441 patent is obvious over Shankar, Huang, and Capers.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 18-25 and 28-32 of the '441 patent are obvious over Shankar, Huang, Capers, and Janning.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 4 and 10 of the '441 patent are obvious over Shankar, Huang, and Huitema.

- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claim 26 of the '441 patent is obvious over Shankar, Huang, Capers, Janning, and Huitema.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 1, 3, 13, and 14 of the '441 patent are obvious over Lakshmi.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 1-4 and 16 of the '441 patent are obvious over Lakshmi and Elliott.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 5-7 and 9-11 of the '441 patent are obvious over Lakshmi, Elliott, Volftsun, and Barclay.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claim 17 of the '441 patent is obvious over Lakshmi, Elliott, Capers, and Sestak.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 21-23, and 25-27 of the '441 patent are obvious over Lakshmi, Elliott, Capers, Sestak, Volftsun, and Barclay.

PERSON OF ORDINARY SKILL IN THE ART

13. Based upon my experience in this area and taking into account the above references, a person of ordinary skill in the art in this field at the relevant time frame ("POSITA") would have a Bachelor's degree or Master's degree in computer science, computer engineering, electrical engineering, or the industry equivalent thereof, would have an understanding of software, and three to five years' experience with telecommunications systems, including circuit-switched and packet-switched networks, or equivalent qualifications through some combination of education, training, and experience. Additional education or work experience in a relevant field may compensate for a deficit in one of the other aspects of the requirements stated above. I base this on my own practical and educational experiences, including my knowledge of colleagues and others at the time of the invention of the '441 Patent on or shortly before the March 29, 2000 filing date, and the March 30, 1999 filing date of Provisional Application No. 60/127,169 that the '441 Patent claims priority to. I am familiar with the knowledge of persons of ordinary skill in the art as of the filing date and the claimed priority date.

14. Based on my experience, I have a good understanding of the capabilities of a POSITA. Indeed, I have participated in organizations and worked closely with many such persons over the course of my career.

OVERVIEW OF THE '441 PATENT

15. The technology in the '441 Patent at issue generally relates to "softswitch" systems that interconnect multiple networks, typically of different types. Prior to the filing date of the '441 Patent, products, publications, and patents existed that implemented and described the functionality claimed by the '441 Patent. In other words, the features of the '441 Patent were known in the prior art. To the extent there were any problems to be solved by these features, the problems had already been solved in prior art systems before the filing date of the '441 Patent.

16. There are many different type of communication networks, such as the "Public Switched Telephone Network (PSTN), the Internet, and wireless networks. Like "softswitches" known at the time, the '441 patent describes a softswitch that provides interoperability between the "Internet central office and residential service gateway" using "any broadband internet technology," and thus allows a user's telephone service to be "geographically and service portable to any location." '441 Patent, 5:28-44.

17. The '441 patent describes that its softswitch includes six main "functional components." '441 Patent, 6:11-14. These "functional components" include a "call agent" and a "signaling agent" that communicates with the "call agent" and a network. *Id*. The '441 patent describes that the "role of the signaling agent 138 is to receive any type of access protocol, communicate with call agent

140, and to terminate the call to the appropriate network using the applicable protocol as instructed by call agent 140." Id., 6:18-20. The "[c]all agent 140 is responsible for managing the end-to-end control of the sessions or calls between packet-switched elements." *Id.* The softswitch may also include a "network directory server" for "managing user profiles, such as access authorization, call barring, dial plan, etc., and providing routing instruction for local and external (local number portability, 1-800) calls," a "network gateway" for "interconnecting the softswitch network to an external network," and a "resource manager" to "validate the incoming circuit, and to provide resource availability information for the outgoing call from the media switch." Id., 7:26-8:14. The '441 patent describes both distributed and co-located configurations of its softswitch. For example, the '441 patent describes that the network directory server "may reside on the same platform as call agent 140 or may be distributed." Id., 7:48-50. The '441 patent also describes that "[n]etwork directory service 200 accesses inmemory tables 202, which store user profiles, routing instructions, addresses, and subscriber services. Network directory service 200 further accesses external data servers 203." Id., 8:48-51.

I note that the '441 patent issued from U.S. Application No.
 09/538,040, filed March 29, 2000. The independent claims of the '441 patent all recite features related to a "signaling agent" and "call agent." Some claims also

recite features related to a "network directory server," "network gateway," "network gateway agent," or "resource manager," and particular configurations of functional components such as the "signaling agent" or "network gateway." These features are not described in provisional application no. 60/127,169 ("169 provisional"). The '169 provisional does not refer to these terms, or describe the same functionality as set forth in the description of the '441 patent.

Prosecution history of the '441 patent

19. I understand that the Examiner relied on Elliott in two office actions during prosecution of the '441 patent. I note, however, that the examiner's application of Elliott and stated reasons for allowance over Elliott are inconsistent with how a POSITA would have understood Elliott and inconsistent with the specification of the '441 patent. For example, the reasons for allowance concluded that "although Elliott teaches an external network directory server operable to receive request[s] for routing information (fig. 62 box 212) in communication with the soft switch, nothing in the prior art of record teaches or fairly suggests the soft switch comprises a network directory server operable to receive requests for routing information to establish data sessions from the call agent, and provide routing information to the call agent." Prosecution History, p.192; id., p.195 ("the prior art does not teach a soft switch comprising a server."). With respect to the "network gateway," the examiner indicated that "although Elliott teaches an

external network gateway operable to receive requests for address locations of called parties in external networks to establish data sessions and provide address locations (fig. 2B box 232, 234), nothing in the prior art of the record teaches or fairly suggests the soft switch comprises a network gateway operable to receive requests for address locations of called parties in external networks to establish data sessions from the call agent, and provide address locations to the call agent." The examiner's conclusions thus rely on a claim interpretation that excluded a distributed arrangement of these features. In contrast to the examiner's interpretation, the '441 specification describes that the network directory server, for example, "may reside on the same platform as call agent 140 or may be distributed." '441 Patent, 7:48-50; 8:48-51 (describing both "in-memory tables 202" and "external data servers 203.").

20. I also note that the examiner's conclusions overlook Elliott's description of configurations in which functional components of its system, particularly the "route server" and "configuration server," can be distributed or co-located. Elliott explains that "[i]n an additional embodiment of the invention, the functions of either or both of CS [configuration server] 206 and RS [route server] 212 can be performed by application logic residing on soft switch 204." Elliott, 49:12-18; 31:54-58; 58:41-47; 62:60-64:67.

INTERPRETATIONS OF THE '441 PATENT CLAIMS AT ISSUE

21. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their ordinary and customary meaning in view of the specification. I also understand that the words of the claims should be interpreted as they would have been interpreted by a POSITA at the time the invention was made (not today). For purposes of my analysis here, I have used the March 29, 2000 filing date. Without exception, however, my analysis of the plain meaning of the recited claim elements in this Declaration would be correct if the date of invention was anywhere in the late 1990s or early 2000s.

22. "Logic control" appears in claims 5, 9, 16, 21, 25, and 32. "Logic control" refers to the "data configurable generic state machine processor that execute logic control programs." '441 Patent, 10:34-36. This interpretation is consistent with the '441 patent's usage of "logic control," and consistent with how the term would have been understood by a POSITA in view of the '441 patent's specification. *Id*.

23. "[Logic control] program" appears in claims 5, 9, 16, 21, 25, 32.
"Logic control program" refers to actions, transitions, and data as a series of data items or independent building blocks that define what a logic engine application is to perform. '441 Patent, 10:42-45. This interpretation is consistent with the '441

patent's usage of "logic control program," and consistent with how the term would have been understood by a POSITA in view of the '441 patent's specification. *Id*.

LEGAL PRINCIPLES

<u>Obviousness</u>

24. I am not an attorney, but I have been informed by retaining counsel of the following with regard to the obviousness of a patent claim. I have been informed by retaining counsel that a patent claim is invalid as "obvious" under 35 U.S.C. § 103 in light of one or more prior art references if it would have been obvious to a POSITA, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called "secondary considerations" of nonobviousness, which include: (i) "long felt need" for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) "copying" of the claimed invention by others. For purposes of my analysis above and because I know of no indication from the patent owner or others to the contrary, I have applied a date of March 29, 2000, as the date of invention in my obviousness analyses, although the same analysis would hold true even at an earlier time than March 29, 2000 (e.g., late 1990s).

25. I have been informed by retaining counsel that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be

obvious in light of a single prior art reference or multiple prior art references, there must be a reason to modify the single prior art reference, or combine two or more references, in order to achieve the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference or references themselves, the knowledge or "common sense" of one skilled in the art, or from the nature of the problem to be solved, and may be explicit or implicit from the prior art as a whole. I have also been informed by retaining counsel that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand from retaining counsel that it is improper to rely on hindsight in making the obviousness determination.

SHANKAR AND HUANG

26. Shankar relates to a telecommunications system for communicating voice from a traditional telephone, such as a PSTN telephone or other communication device, over a packet-switched network. Shankar, Abstract. Shankar describes a system that includes one or more "signaling units" and one or more "coding units." Shankar, 2:44-55; 5:14-32; *see also* Abstract; 1:44-48; 2:44-55. The signaling units "implement a 'virtual switch' and are responsible for processing and routing the signaling messages that are exchanged to set up and tear down a voice connection." *Id.* The coding units "convert bearer voice traffic

between legacy and packet formats." *Id.* The signaling and coding units interconnect public branch exchanges, telephone switches, telephones, wireless public branch exchanges, or legacy telecommunications systems, for example, over the packet-switched network. Shankar, 3:65-4:3.

27. Shankar describes a configuration that include multiple signaling units or a single signaling unit. For example, the system may be configured to include two "signaling units" and/or two "coding units," servicing the originating side and terminating sides of a call, respectively. *See, e.g.* FIG. 1. In other examples, the system may include a single "signaling unit" and/or single "coding unit." *See, e.g.* FIGS. 5A-5C.



FIG. 1

Shankar, FIG. 1.

28. With reference to FIG. 1, for example, Shankar illustrates an example system including an "originating signaling unit 120" and "terminating signaling

unit 140." The "originating signaling unit 120" receives call signaling data, obtains the network address of the originating coding unit 110 that received the call, determines which "terminating signaling unit 140" should receive the call, and transmits a signaling message "including information for establishing the voice and the network address of the originating coding unit 110" to the "terminating signaling unit 140." Shankar, 5:31-52; 12:65-14:18. The terminating signaling unit 140 "determines which bearer should receive the call, and controls the terminating coding unit 150 to establish a bearer channel through the packet-switching network. *Id.*, 5:53-63; 14:18-15:49. "In this manner, a voice call that is originated from a legacy system 100 or terminated by a legacy system 160 is seamlessly established over the packet-switching network 130 without having to upgrade or replace the legacy systems." *Id.*

29. With reference to FIG. 5, for example, Shankar describes examples "a single signaling unit 500 handles the voice call signaling processing." Shankar, 4:55-65. "In this configuration, the OCC 502 is responsible for communicating the signaling data with the originating coding unit 110 over link 112, and the TCC 506 is responsible for communicating the signaling data with the terminating coding unit 150 over link 152. The UCM 504 is responsible for controlling and querying the originating coding unit 110 over link 114 and the terminating coding unit 150 over link 154." Shankar, 15:50-16:13.



Shankar, FIG. 5(a).

30. Shankar describes the function and components of its "signaling unit" that function to interconnect various network components. The "signaling units" include an "originating call control (OCC)," "universal call model (UCM)," and "terminating call control (TCC)." Shankar, 6:17-67; 8:57-12:64; 12:65-16:13. The OCC "models a call from the perspective of the originating protocol." Shankar, 11:16-22. For example, "the OCC 322 receives messages in the originating protocol from originating protocol adapter 312, and, in response, transitions from one state to another state, resulting in outputting a non-protocol specific (i.e., universal protocol specific) message to UCM 324." *Id.* The "TCC 326 receives non-protocol specific messages from UCM 324 and, by responsively transitioning from one state to another, outputs terminating protocol specific messages to terminating protocol adapter 312," which are in turn routed to the "corresponding

I/O channel controller 306, to a network node, and ultimately to the destination telephone." Shankar, 10:6-30; 11:27-36.





Shankar, FIG. 3.

31. The UCM is the software component that "manages the call." Shankar, 11:38-52. Shankar describes that the UCM "handles calls in the converted universal protocol, arranges for messages to be routed ultimately to the other protocol converter, and controls the originating coding unit 110 over a control link 114." Shankar, 6:29-33.

32. I note that Shankar incorporates the "entire contents" of Volftsun by reference. Shankar, 6:53-67. Volftsun describes an example of a protocol converter, including its internal workings. *Id.* Specifically, while some aspects of Shankar's protocol converter are described at a more general level, Volftsun describes additional details regarding the structure and operation of its I/O subsystem, protocol adapters, OCC, UCM, and TCC, including communication between these respective components. *See, e.g.* Volftsun, FIGS. 1-8b.

33. Huang describes a telecommunications system that connects networks of different types, including packet-switched (e.g., IP) and circuit-switched (e.g., PSTN) networks, like Shankar's system. Huang accomplishes interconnection using a "gateway computer (GC) or equivalent [that] interconnects the packet-switched network to each of the circuit-switched networks, and converts voice signals into data packets and vice versa, and resolves the call destinations while routing the packets." Huang, 2:24-34. Huang describes advantages of such interconnection, including that a user can benefit from the advantages of a packet-switched network while placing and receiving calls using traditional telephone equipment. Huang, 1:11-2:20; 2:53-67.

34. Each of Huang's gateway computers have several "functional components" that are involved in executing various functions. These "functional components" include "media conversion modules 31," "speech processing modules 48," "routing resolution modules 39," and "special services modules 38." Huang, 3:49-4:36; FIGS. 3a-3b. "Routing modules 39 include an address resolution logic 45 implemented with CPU 21, and a network routing database also implemented with CPU 21 and possibly shared with other GC's in a distributed manner." *Id.*, 4:5-9. The "routing resolution modules 39," including "address resolution logic 45," and "network routing database 46" are illustrated in FIG. 3b of Huang.



Huang, FIG. 3b (annotated). This feature is also described in Huang's claims. "6. A telecommunications system according to claim 1, wherein at least one of said routing components comprises an address resolution logic and a network routing database implemented with a central processing unit." *Id.*, claim 6.

35. Huang describes various system configurations in which the gateway computers interconnect packet-switched and circuit-switched networks. For example, FIG. 1 illustrates a system in which two gateway computers 3, 6, are used to interconnect a telephone set 1 of a circuit switched network 2 with a telephone

set 8 of a circuit switched network 7 via packet-switched network 6. Huang, 3:36-45; FIG. 1.



Fig. 1

Huang, FIG. 1.

36. In another example, a gateway computer 6 is used to interconnect a telephone set 8 of a circuit-switched network 7 with a caller's multimedia computer 4 via packet switched network 5. Huang, 4:42-67; FIG. 4.





Huang, FIG. 4.

37. Shankar and Huang are analogous art, both describing systems for interconnecting circuit-switched and packet-switched networks. Shankar describes that the UCM of its signaling unit "manages the call," and, more specifically, "resolves the call routing through the network 132" and selects bearer channels to

be used. Shankar, 11:38-52; 14:33-45. In other words, the UCM receives routing information to make routing determinations. Based on my knowledge and experience in the field and my review of Shankar and Huang, a POSITA would have been motivated to combine the relevant teachings in these references by integrating features of a routing resolution module in order to effectively resolve routing to execute a call. In view of Shankar's and Huang's teachings, it would have been obvious to a POSITA that Shankar's UCM would have effectively requested routing information from the routing resolution module such that the route could be resolved through the IP network, to an appropriate network node, and/or destination telephone. *Id.* Dialed digits, for example, must be correlated to the address of the network node/destination telephone in order to establish the call.

38. Based on my knowledge and experience in the field and my review of Shankar and Huang, a POSITA would have found it obvious that Huang's routing resolution module would have enhanced Shankar's system. For example, Huang's routing resolution module would have provided address resolution logic to facilitate resolution of an address, such as when processing a call between networks (e.g., between a circuit-switched PSTN network and a packet-switched IP network). A POSITA would have recognized that integrating Huang's address resolution modules would have facilitated efficient and effective call routing, and

that doing so would have amplified advantages obtained by interconnecting traditional telephone equipment with packet-switched networks.

39. I additionally note that a POSITA would have been further prompted to implement a routing resolution module, such as Huang's routing resolution module, because doing so would have been merely the application of a known technique to a known system ready for improvement to yield predictable results. As I discussed previously, both Shankar and Huang describe functional modules that request information to resolve a route to process a call between different networks. Based on my knowledge and experience and my review of Shankar and Huang, applying Huang's routing resolution module would have been obvious to a POSITA in order to effectively provide Shankar's UCM with routing information needed to resolve the route. Any additional modifications required to implement Huang's suggestions in Shankar's system would have been carried out by a POSITA with a reasonable expectation of success.

40. Shankar describes a system that interconnects networks of different transport protocols. For example, Shankar describes a "protocol converter" that implements a "signaling unit," that may be described as a "softswitch." As I discussed previously, the "signaling units" in Shankar's system function as a "virtual switch." Shankar, 5:14-6:67. They "are responsible for processing and routing the signaling messages that are exchanged to set up and tear down a voice

connection." *Id.* Shankar additionally describes that "the signaling units perform such functions as call resolution, call routing, bearer selection, and generation of call detail records (CDRs) for billing management." *Id.*; *see also* Abstract; 1:44-48; 2:44-55. The same is true in configurations in which a "single signaling unit 500 handles the voice call signaling processing for both the originating coding unit 110 and the terminating coding unit 150." *Id.*, 15:64-16:7.

41. I note that Shankar specifically describes its "signaling apparatus implements signaling interworking and protocol conversion, if necessary, between the legacy systems and the packet-switching network." Shankar, 2:44-55; 14:4-18. The "coding units convert bearer voice traffic between legacy and packet formats." This is like the "softswitch" system of the '441 patent, which describes that its softswitch "allows service providers to interconnect intelligent control and signaling systems between networks." '441 Patent, 2:4-9.

42. Components of Shankar's OCC and TCC describe a signaling agent.
Shankar, 6:17-67; 8:57-12:64; 12:65-16:13; FIGS. 1, 5a-c; Volftsun, 9:22-39; FIG.
4. I note that the '441 patent describes "[t]he role of signaling agent 138 is to receive any type of access protocol, communicate with call agent 140, and to terminate the call to the appropriate network using the applicable protocol as instructed by call agent 140." '441 Patent, 6:16-20. Shankar's "originating call control (OCC)" and "terminating call control (TCC)" handle these functions. The

OCC is operable to receive incoming signaling messages and translate the incoming signaling messages to a call model event. For example, Shankar explains that the "OCC 322 models a call from the perspective of the originating protocol." Shankar, 11:16-22. The "OCC 322 receives messages in the originating protocol from originating protocol adapter 312 and, in response, transitions from one state to another state, resulting in outputting a non-protocol specific (i.e., universal protocol specific) message to UCM 324." Shankar, 11:16-22. Volftsun's OCC does the same. See, e.g. Volftsun, FIG. 7. The information in the nonprotocol specific message can be described as corresponding to an event, and is output in connection with the modeling of the call by the OCC. The information thus corresponds to a call model event. Moreover, the information is used by the UCM, which also models the call; this additionally indicates that the OCC routes the call model event.

43. In addition, the TCC is also operable to route the information, corresponding to a call model event, in a second manner by routing to a terminating destination. For example, Shankar describes that the "terminating protocol adapter 316 can route messages from associated call instances to the corresponding I/O channel controller 306, to a network node, and ultimately to the destination telephone." Shankar, 10:6-25. This routing by the TCC is an

independent example that the signaling unit is "operable to route a call model event."



Portions of Shankar's originating call control and terminating call control that are operable to receive incoming signaling messages, translate the incoming signaling messages to a call model event, and route the call model event provide a signaling agent

Shankar, FIG. 3 (annotated); 8:58-61.

44. Shankar also describes that its "signaling units" include "protocol adapters" and "I/O channel controllers" in the "I/O subsystem" that are involved in receiving and outputting signaling. *See, e.g.* Shankar, 13:12-14:3; Volftsun, FIG.

4. Shankar's signaling agent may also be considered to include the signaling unit's "protocol adapters" and corresponding "I/O channel controllers" in the "I/O subsystem." *See, e.g.* Shankar, 13:12-14:3; Volftsun, FIG. 4.

45. The '441 patent describes the "signaling agent" is itself made up of multiple subcomponents. The '441 patent indicates the "signaling agent 138 includes a number of signaling agents 162-164 operable to interface with SS7 interface, SIP devices or interface, H.323 devices or interface, Q.931 interfaces and devices, and others." '441 Patent, 8:19-26. In other words, the subcomponents provide multiple different interfaces with entities external to the softswitch. Id. Each of these subcomponents is described to have a "respective logic control" and "logic control program," "filter," and "codec." '441 patent, 13:29-31. I note that Shankar describes a configuration that is likewise made up of multiple components-including the OCC and TCC-each of which provide different interfaces with external entities. Shankar's configuration is analogous to the '441 Patent's embodiment of signaling agent 138 made up of multiple subcomponents 162-164. Moreover, I note that a POSITA would have found it obvious to group the functionalities of the OCC and TCC (e.g., as a single module) because they both relate to translating the signaling between a protocol specific format (e.g., used by an external network entity) and a protocol independent format (e.g., used by the UCM).

46. Shankar describes a call agent provided by the universal call model ("UCM"), (e.g., alone or together with other components of the "OCC," "TCC," and/or other components of the "signaling unit."). As I discussed previously, the UCM "manages the call." Shankar, 11:38-52. Shankar describes that the UCM "handles calls in the converted universal protocol, arranges for messages to be routed ultimately to the other protocol converter, and controls the originating coding unit 110 over a control link 114." Shankar, 6:29-33; FIGS. 1, 5a-c; Volftsun, 13:25-34.



The Universal Call Model, alone or together with components of the signaling unit that are operable to receive the call model event, request outgoing resources for establishing data sessions, generate outgoing signaling messages, and send the outgoing signaling messages to the signaling agent, provides a call agent.

Shankar, FIG. 3 (annotated). The universal call model is the state machine that handles call set-up and teardown. Volftsun provides further details regarding its UCM, and highlights the call states associated with call set-up and call teardown. The UCM moves through these states as it manages the call during call processing. See, e.g., Volftsun, 20:31-60; FIG. 10; FIGS. 11-22; Shankar, 6:53-67.

47. Shankar describes that the UCM is operable to receive call model events from the OCC. For example, Shankar explains that the OCC "output[s] a non-protocol specific (i.e., universal protocol specific) message to UCM 324." *Id.*, 11:16-22 and that the "UCM 124 of originating signaling unit 120 receive[s] the universal protocol '[Call]' message." Shankar, 14:4-18.

48. Shankar describes that the UCM is operable to request outgoing resources for establishing data sessions. Shankar explains that the universal call model (UCM) "handles calls in the converted universal protocol" and "arranges for messages to be routed ultimately to the other protocol converter [e.g., the terminating protocol converter]." Shankar, 6:28-33; FIG. 1. The originating protocol converter and terminating protocol converter, and communication between these two entities and other network entities are shown in FIG. 1.





Shankar, FIG. 1 (annotated).

49. Shankar describes "the originating signaling unit 120," which operates the UCM, "determines which terminating signaling unit 140 should receive the call by accessing internal routing tables or querying external systems." Shankar, 5:44-52. Such requests result in a determination of at least a portion of the outgoing resources used to terminate requested data sessions, such as the "terminating signaling unit," and "terminating coding unit."

50. The UCM (and/or the UCM and some components of the OCC) is involved in such requests for outgoing resources. The UCM is the universal call model state machine that handles call set-up/teardown. This includes outgoing resource requests required to set-up the call. *See, e.g.* Volftsun, 20:31-60; FIG. 10; FIGS. 11-22. I note that Shankar illustrates only the UCM as connected via an

"external" adapter to external resources that would be used to query the "external systems." See, e.g. FIG. 3. Moreover, Shankar teaches that the TCC is "typically instantiated after routing analysis has determined the route," further indicating that the UCM is responsible for outgoing resource requests. Shankar, 6:40-45.

51. Shankar also describes that the UCM is operable to generate outgoing signaling messages, and send the outgoing signaling messages to the signaling agent, where they are converted into the appropriate signaling protocol. "The terminating call control (TCC) 126, typically instantiated after routing analysis has determined the route, converts signaling messages between the universal protocol and the protocol that provides connectivity to the terminating signaling unit 140." Shankar, 6:40-53. In other words, the UCM generates outgoing signaling messages and sends these messages to the TCC, which in turn converts the universal protocol messages to an appropriate protocol. Furthermore, "[a]fter the originating signaling unit 120 has performed this call routing capability, the originating signaling unit 120 transmits a signaling message, including information for establishing the voice and the network address of the originating coding unit 110, through network 132 to terminating signaling unit 140." Id., 5:44-52.

52. The TCC sends signaling that terminates the data sessions on the requested out-going resources. For example, "[o]nce the appropriate terminating signaling unit 140 is identified, TCC 126 of the originating signaling unit 120

generates and transmits an XISUP IAM message 410 to the terminating signaling unit 140 with the standard ISUP IAM information plus the Universal Call Reference and the network address of the bearer channel on the originating coding unit 110." Shankar, 14:33-45; 15:64-16:7 ("the TCC 506 is responsible for communicating the signaling data with the terminating coding unit 150 over link 152."); FIGS. 5a-c. The bearer channel is used for "carrying the voice data." Shankar, Abstract. The IAM message is based on the universal protocol message received from the UCM, and provides call set-up information that leads to termination of the call on the requested outgoing resources.

53. Shankar's system includes a network directory server that receives requests for routing information and in response provides routing information to the UCM. I note that the '441 patent describes that the "network directory server" is one of the "six main functional components" of its softswitch. '441 patent, 7:48-50. The "[n]etwork directory server 144 may reside on the same platform as call agent 140 or may be distributed." *Id.* The '441 patent describes that the "network directory server 144" includes a "network directory service 200" that "accesses inmemory tables 202, which store user profiles, routing instructions, addresses, and subscriber services," and "further accesses external data servers 203." '441 patent, 8:48-53. Here again, Shankar's features are analogous to the '441 patent. Shankar describes a network directory server provided by "lookup tables" and the

resource/medium that stores the "lookup tables." The "lookup tables" are analogous to the '441 patent's "in-memory tables," for example. Shankar's signaling unit "resolves the call routing through the network 132 to the terminating signaling unit 140, based on dynamic techniques, static techniques such as provisioned lookup tables, or a combination [thereof]," and, in turn, routes messages to a "network node," and "destination telephone." Shankar, 10:19-22. "The terminating protocol adapter 316 can route messages from associated call instances to the corresponding I/O channel controller 306, to a network node, and ultimately to the destination telephone." Id.; see also 14:32-45. In other words, the UCM handling call set-up queries the "lookup tables" to obtain routing information to resolve the call routing through the network 132. This is in turn used for route determination for user communications over network 130. Shankar's "lookup tables" are thus operable to receive requests for routing information to establish data sessions, and provide routing information to the UCM so that a route can be determined. I note that Shankar's "lookup tables," and the resource that stores them, effectively describe the configuration of "in-memory tables" recited by the '441 Patent.

54. Moreover, as I discussed previously, the UCM and related components of the signaling unit handle call routing, further indicating that the requests for routing information would have been received by the network
directory server from the UCM and related components, and the responsive information provided to the UCM and related components.

55. The combination of Shankar and Huang, as I discussed previously, likewise would have included such features. Huang describes that its "gateway computer" that interconnects different network types includes a network directory server provided by a "routing resolution module." Huang, 4:5-10. Its "routing resolution module" includes a "network routing database 46," which stores network routing information. *Id.* Based on my knowledge and experience in the field and my review of Shankar and Huang, a POSITA would have found it obvious that Shankar's UCM and related components would have requested routing information from the "routing resolution module," including information from the "routing resolution module," including information

56. The combination of Shankar and Huang, as I discussed previously, provides a network directory server that is operable to receive requests for address resolution to establish data sessions from the call agent, and provide address resolution responses to the call agent. Shankar explains that the signaling unit (e.g., the UCM responsible for call set-up/teardown) "resolves the call routing through the network 132 to the terminating signaling unit 140, based on dynamic techniques, static techniques such as provisioned lookup tables, or a combination of dynamic and static techniques." Shankar, 10:19-22. The messages are

subsequently routed to a "network node" and "destination telephone." *Id.* The "lookup tables" are thus operable to receive queries for address resolution, and provide address resolution responses, so that the UCM can "resolve the call routing." I note, as discussed previously, that Shankar's "lookup tables," and the resource that stores them describe the configuration of "in-memory tables" recited by the '441 Patent. I also note that the plain language of the claim is not limited to any particular type of address resolution. Likewise, nothing in the '441 patent's description provide specific implementations.

57. Shankar also describes a network directory server provided by a "domain name server (DNS)." The "domain name server" is queried for address resolution of the originating coding unit, for example, which is used to establish the call. Shankar, 5:32-43. Shankar further describes that "the originating signaling unit 120 obtains the network address of the originating coding unit 110 within the packet-switching network 130" by "inquiring another computer system (not shown) such as domain name server (DNS)." *Id.* In other words, the "domain name server" receives queries for the "network address"—which is an example of address resolution requests—and responds with the associated "network address"—which is an example of address resolution responses—so that the call can be set-up using the appropriate coding unit and associated resources. The '441 patent describes that "Network directory server 144 may reside on the same

platform as call agent 140 or may be distributed." '441 Patent, 7:48-50. Shankar's DNS is analogous to the '441 patent's "distributed" network directory server.

The combination of Shankar and Huang, as I discussed previously, 58. further includes a network directory server that is operable to receive requests for address resolution to establish data sessions from the call agent, and provide address resolution responses to the call agent, as explicitly described by Huang. Huang's "routing resolution module" includes an "address resolution logic 45." In the combined system, the UCM (e.g., and related components) would have made requests for address resolution when processing a call, and the "address resolution logic" would have in turn provided address resolution responses, in accordance with the call routing objectives described by Shankar and Huang. Based on my knowledge and experience in the field and my review of Shankar and Huang, a POSITA would have found it obvious that the responses would have provided address resolution to allow a data session to be established between an origination node and termination node.

59. Shankar's describes that its signaling agent includes a logic control executing a logic control program and operable to process signaling messages of a particular signaling protocol. For example, Shankar teaches that the "OCC" and "TCC" are implemented as "state machines" by "objects in an object-oriented

rogramming language or by other data structures," indicating that the "OCC" and "TCC" provide a logic control. Shankar; 11:4-15; 11:16-63.

Preferably, OCC 322, UCM 324, and TCC 326 are implemented as state machines by objects in an object oriented programming language such as C++ or by other data structures in other programming languages. A state machine is an automaton that transitions from one of a finite number of states to another of those states in response to particular inputs. The output of a state machine occurs upon a state transition and is based on the destination state and typically also on the input and/or source state. The OCC 322, UCM 324, and TCC 326 state machines model a call from the perspective of the originating protocol, a universal protocol, and the terminating protocol, respectively.

Id. These state machines execute a logic control program, transitioning between states to model a call from the perspective of the originating protocol, a universal protocol, and the terminating protocol, for example. *Id.*; *see also* 9:15-19 ("The protocol conversion engine 310 includes a plurality of protocol adapters, implemented to support respective protocols or protocol families."). Here again, Shankar's architecture is similar to the architecture illustrated in the '441 patent, which describes that "[1]ogic controls 315-321 are the data-configurable generic

state machine processors that execute logic control programs," and a "logic control program defines how the logic engine is to operate." '441 Patent, 10:34-37. "Logic controls 166-168 and 182 and call logic control 193 make up logic engine 195. Logic engine 195 is a protocol-independent, data-configurable, multi-threaded state machine processor." *Id.*, 8:38-41.

60. Shankar's logic control is operable to process signaling messages of a particular signaling protocol. "The OCC 322, UCM 324, and TCC 326 state machines model a call from the perspective of the originating protocol, a universal protocol, and the terminating protocol, respectively." Shankar, 11:12-15. Figure 3 further highlights this, and "schematically illustrates a software architecture relating to protocol conversion implemented on a computer system 200 of a protocol converter that implements originating signaling unit 120 and terminating signaling unit 140." *Id.* 8:58-61; *see also* 6:17-28; 9:15-24; 9:34-55; 11:16-25.

61. Shankar's "protocol adapter" is configured for parsing and formatting messages according to a particular signaling protocol. That is, the "protocol adapter" includes a codec that is *specialized* for the particular protocol of the access network. *See, e.g.* Shankar, 9:15-55. For example, Shankar describes that the "protocol adapter is a software module responsible for interfacing the protocol conversion engine 310 with the I/O subsystem 300," and "is capable of decoding an incoming message to determine the call with which the message is associated."

Id. The protocol adapter thus functions to decode incoming protocol-specific signaling messages by parsing and formatting signaling messages according to particular signaling protocols, which allows the protocol adapter to effectuate transmission and reception with the outside world. I note that the '441 patent describes its codecs merely as "coders/decoders" that are "specialized communication modules," and does not recite anything further in the plain language of the claim or in its description that requires more. '441 Patent, 8:25-26.

62. As I discussed previously, Volftsun provides further detail of an example protocol adapter, and its "entire contents" are incorporated into Shankar. In particular, Volftsun explains that the protocol adapter parses and formats signaling messages according to a particular signaling protocol. "Protocol Adaptors 404 and 408 respectively take the signaling messages coming from or going to the originating party and take the signaling messages coming from or going to the terminating party and parse and assemble the signaling messages." Volftsun, 9:45-49; 9:22-27("Call Control State Machines 410 and 412, working in conjunction with Protocol Adapters 404 and 408, respectively, convert signaling messages received from originating and terminating networks through I/O Subsystem 418 to non protocol-specific Internal Primitives."). This is further illustrated by FIG. 7. The protocol adapters execute a "Protocol Adapter

Receiving Message 712" process in which the protocol adapter receives incoming signaling Protocol Data Units ("PDU"), parses and formats the incoming signaling PDUs, and outputs "Internal Primitives" that are in turn routed to a "Call Control Receiving Message 714" process of the OCC. Volftsun, 14:2-8. Volftsun indicates that internal primitives are "vehicles for carrying signaling information data and/or signals," and "may contain State Signals and Information Elements," indicating the signaling is parsed and formatted. Volftsun, 10:20-27. "Protocol Adapter performs signaling message translation between external communication and/or application protocols and Internal Primitives specific to the Universal Protocol Converter." *Id.*, 5:40-45.



The "protocol adapter" includes a codec operable to parse and format incoming protocol data units (PDU) into "internal primitives"

Volftsun, FIG. 7(annotated). Figure 7 further illustrates that the Protocol Adapter carries out the translation to generate Internal Primitives in part using "message definitions." Volftsun explains that "message definitions" are "the collection of information about messages including format, content, and coding as would be required for a software process to receive, analyze, and reconstruct messages." Volftsun, 13:13-17. The protocol adapter includes a codec because it has modules, each specialized in a particular signaling protocol of an access network that generates "Internal Primitives" by parsing and formatting the incoming signaling it receives.

Based on my knowledge and experience in the field and my review of 63. Shankar, Volftsun, and Huang, a POSITA would have found it obvious to adapt internal communication in accordance with Volftsun's more specific description. Indeed, as discussed previously, Shankar's protocol converter likewise includes an I/O subsystem, protocol adapters, and OCC, UCM, and TCC call control state machines that communicate with each other to process a call. A POSITA would have found it obvious that incorporating specific implementation details in accordance with Volftsun's teachings would have facilitated communication between the components, such that incoming signaling messages could be processed, and a call completed. Indeed, Shankar itself describes communication between the components of the protocol converter. I further note that, based on my knowledge and experience in the field and my review of Shankar, Volftsun, and Huang, a POSITA would have had a reasonable expectation of success of implementing communication in accordance with Volftsun's description, especially in view of the common architecture, components, and functions described by Shankar and Volftsun. Id.

64. Shankar describes its protocol adapters are "implemented to support respective protocols or protocol families." Shankar, 9:15-17. Volftsun's description is consistent. "Protocol Adapters 510, 512, 514, 516, and 518, each

support a unique protocol or protocol family (comprised of a group of protocols which differ only by minor variance.)" Volftsun, 10:50-57; 11:16-19. The protocol adapters are specialized.

65. Based on my knowledge and experience in the field, "codecs" were widely known modules for parsing and formatting signaling messages used in a variety of applications so that signaling messages could be processed and generated. A POSITA would have found it obvious to use a codec in this conventional manner to implement translation between incoming signaling and Internal Primitives, because codecs are, by definition, communication modules that carry out translation.

66. Shankar's "protocol adapter" includes a filter that filters and routes signaling messages from the codec to the logic control. As I discussed previously, the protocol adapter includes a codec that generates "internal primitives." The protocol adapter in turn filters and routes the internal primitives to the associated OCC call instance, which is a logic control. Shankar describes that the "originating protocol adapter 312 is capable of decoding an incoming message to determine the call with which the message is associated." Shankar, 9:34-55. Shankar additionally describes that the "protocol adapter, when loaded and executed, is configured to connect with I/O subsystem 300 in order to route protocol-specific messages between an I/O channel and the appropriate call

instance." *Id.*, 9:21-24; *see also* 10:22-26 ("pass them to the appropriate call instance").

67. Volftsun provides further details of how the protocol adapter filters and routes the signaling messages from the codec to the logic control. A logic control (e.g., "OCC," "TCC") is instantiated for each call instance, and the "protocol adapter" routes "internal primitives" from its codec to the instance of the logic control associated with the call. An example of this is illustrated by Volftsun in FIG. 5.



The "protocol adapter" routes messages from its codec to the logic control (e.g., OCC) of the call instance associated with the message

Volftsun, FIG. 5(annotated).

68. Shankar describes use of various signaling protocols by its system, including SS7 signaling protocol, session initiation protocol ("SIP"), and H.323 signaling protocol. For example, Shankar describes that "the signaling units also convert the legacy protocols of the originating node 100 and the terminating node 160, such as DPNSS, ISDN_PRI, <u>SS7</u>/C7 (including ISUPs, TUPs, and NUPs), <u>H.323</u>, <u>SIP</u>, or CAS, into messages for communicating with one another and for controlling a coding unit over control links 114 and 154." Shankar, 5:20-26 (emphasis added). Shankar also describes specific examples in which the signaling protocol is SS7. "The set up message 420, in the case of SS7, is delivered directly to originating signaling unit 120 from the trunk via link 113." *Id.*, 13:12-32. "[T]he connection request message would be an Initial Address Message (IAM) in the Signaling System 7 (SS7) family of protocols." *Id.*

69. The '441 describes that the network gateway functions to provide an interface with a media gateway. For example, the '441 patent describes that "[n]etwork gateway 146 includes gateway agents 180 for interfacing with MGCP media gateway switch, IPDC media gateway switch, etc. Each gateway agent 180 each also includes a logic control 182 executing a logic control program, a filter processor 183, and a codec 184." '441 patent, 8:26-34. I note that the '441 patent imparts two discrete functionalities as provided by a "network gateway": 1) interfacing with a media gateway (*see, e.g.*, '441 patent, 8:26-33), and 2)

interconnecting the softswitch to an external network to determine user locations for routing to the external network (*see, e.g.*, '441 patent, 7:53-65, cl. 4). The plain language of claim 9 is directed only to the former functionality of interfacing with a media gateway, which a POSITA would have recognized as conventional in order to control handling of user communications (e.g., voice data).

Shankar's "signaling units" include functional units for interfacing 70. with its "coding units" that are analogous to the conventional network gateway recited in the '441 patent that interfaces with a media gateway. The UCM, for example, includes a network gateway operable to process messages of a particular transport protocol. "The UCM 124 generates and transmits a create connection message 406, specifying the bearer channel, through external protocol adapter 314, I/O channel controller 304, control link 114 to originating coding unit 110." Shankar, 14:10-13. "The create connection message 406 can be implemented according to an appropriate protocol such as a CRCX message in the Simple Gateway Control Protocol (SGCP), a proposed International Engineering Task Force (IETF) standard submitted by Bellcore and Soliant Internet Systems." Id; see also Shankar, 14:46-54 ("the terminating signaling unit 140 issues a CRCX" message 412 via SGCP and control link 154 to terminating coding unit 150 for setting up a connection from the endpoint for terminating node 160 to the bearer channel port of the originating coding unit 110." In other words, the UCM and

related components are operable to process messages with the coding unit (e.g., media gateway) of a particular transport protocol.

Shankar teaches that the UCM is implemented as a "state machine" by 71. "objects in an object-oriented programming language or by other data structures," like the OCC and TCC as I discussed above." Shankar, 11:4-15; 11:16-63. Based on my knowledge and experience in the field and my review of Shankar, a POSITA plainly would have recognized that the UCM provides logic control executing a logic control program. Id. The state machines execute a logic control program that models a call from the perspective of the universal protocol, and is able to interface with coding units using an appropriate transport protocol. *Id.*; 14:13-18 ("Simple Gateway Control Protocol (SGCP)"); 9:15-19; 14:19-32 ("The originating coding unit 110 thereupon responds back to the originating signaling unit 120 over the control link 114 with a message 408 that includes the network address of the originating coding unit 110. The create connection message 408 can also contain parameters that indicate the capabilities of the originating coding unit 110, for example, the encoding and compression types the originating coding unit 110 supports.").

72. Shankar's protocol adapter provides a codec that parses and formats messages according to the transport protocol of a media gateway. Shankar describes that "[f]or implementing voice over packet-switching networks, the

external protocol adapter 314 is used for real-time communication with a coding unit such as originating coding unit 110 and terminating coding unit 150." Shankar, 10:41-45. The "protocol adapter is a software module responsible for interfacing the protocol conversion engine 310 with the I/O subsystem 300," and is "responsible for connecting with the appropriate I/O channel controller 304 in the I/O subsystem 300 for sending and receiving messages with the coding unit and routing the messages to and from the proper call instance 320." Id., 10:45-50. Based on my knowledge and experience in the field and my review of Shankar, the protocol adapter thus functions to decode incoming protocol-specific signaling messages. Id.; 9:34-36. It is thus specialized to parse and format signaling messages according to specific signaling and/or transport protocols, and it effectuates transmission and reception of these messages with the outside world (e.g., with an external network entity). I note that the '441 patent describes its codecs as "coders/decoders" that are "specialized communication modules," without further explanation or details of implementation. '441 Patent, 8:25-26.

73. Volftsun's more specific description of the protocol converter provides further detail of an external protocol adapter that parses and formats messages according to the transport protocol of a media gateway. "Protocol Adaptors 404 and 408 respectively take the signaling messages coming from or going to the originating party and take the signaling messages coming from or

going to the terminating party and parse and assemble the signaling messages."

Volftsun, 9:45-49. Volftsun explains that "external" protocol adapter 406 operates "in a manner similar to Protocol Adapters 404 and 408," and "provides means for communicating to external systems and/or entities." Protocol adapter 406 thus receives incoming "protocol data messages," parses and formats these incoming messages, and outputs "internal primitives" that are in turn routed to the UCM of the appropriate call instance. *See, e.g.* FIG. 4.



Fig. 4

Volftsun, FIG. 4 (annotated).

74. The protocol adapters are specialized in a particular signaling protocol of the access network. Shankar describes its protocol adapters are "implemented to support respective protocols or protocol families." Shankar, 9:15-17; Volftsun, 10:50-57 ("Protocol Adapters 510, 512, 514, 516, and 518, each" support a unique protocol or protocol family (comprised of a group of protocols which differ only

by minor variance.); 11:16-19. The external protocol adapter thus likewise supports respective protocols or protocol families.

75. Based on my knowledge and experience in the field, codecs were widely known to a POSITA as modules for parsing and formatting messages so that messages could be processed by the system. Codecs are, by definition, communication modules that carry out such translation. A POSITA plainly would have been motivated to use a "codec" to implement translation according to the transport protocol of the coding unit, because doing so would have allowed translation and processing of the messages.

76. The combination of Shankar and Huang includes a filter provided by the "protocol adapter." The protocol adapter filters and routes messages from the codec to the logic control (e.g., each of which I discussed previously). The protocol adapter filters the "internal primitives" to the associated OCC call instance. Shankar describes that the "external protocol adapter 314 is responsible for connecting with the appropriate I/O channel controller 304 in the I/O subsystem 300 for sending and receiving messages with the coding unit and routing the messages to and from the proper call instance 320." Shankar, 10:45-50; 9:34-55; 9:21-24; 10:22-26 ("pass them to the appropriate call instance").

77. Volftsun's more specific description provides additional details of how the protocol adapter filters and routes the signaling messages from the codec

to the logic control. Each call instance has a logic control (e.g., "UCM,"). The "protocol adapter" routes "internal primitives" from its codec to the instance of the UCM associated with the call. This is shown in FIG. 5, such as between "call instance 402a" and "external systems interface protocol adapter 520" ("external systems interface protocol adapter 406" shown in communication with the UCM in FIG. 4).



The "protocol adapter" routes messages from its codec to the logic control (e.g., UCM) of the call instance associated with the message

Volftsun, FIG. 5(annotated).

78. Shankar describes the transport protocol used to communicate between the "signaling unit" and a "coding unit" may be "Simple Gateway Control

Protocol (SGCP)." For example, the "create connection message 406 can be implemented according to an appropriate protocol such as a CRCX message in the Simple Gateway Control Protocol (SGCP), a proposed International Engineering Task Force (IETF) standard submitted by Bellcore and Soliant Internet Systems." Shankar, 14:13-18; 9:39-47 (indicating that its system is "capable of supporting many different protocols.").

Shankar describes that its signaling unit connects to a public switched 79. telephone network. Shankar describes a need fulfilled by its system of connecting legacy PSTN systems and packet-switched networks. Shankar, 1:11-25 ("Public Switched Telephone Network (PSTN)"); 1:44-48("[T]here exists a need for establishing and carrying voice calls that are originated or terminated by legacy systems over a packet-switching network."); 1:49-65 ("[L]ocal telephone companies and other call access providers in certain countries are acutely interested in finding ways to integrate the PSTN with the Internet."). Additionally, Shankar specifically explains that the "originating" or "terminating node" can be a "telephone switch" or "legacy telecommunications system,"-e.g., the public switched telephone network. Shankar, 3:65-4:3; 4:4-20 ("In some implementations, the packet-switching network 130 may even be overlaid on the PSTN.").

80. Likewise, Shankar describes that it system includes a packet network. Shankar specifically describes use of a "packet-switching network" (e.g., packetswitching network 130) to carry voice calls from an originating node 100 to a terminating node 160. Shankar, 3:38-49; *see also* Shankar, Title ("Communicating Voice Over a Packet-Switching Network"); 1:5-2:67; FIGS. 1-5C.

81. Shankar describes that its system includes a wireless network. Shankar specifically explains that "originating node 100" can be implemented as a "wireless PBX" (private branch exchange). Shankar, 3:65-4:3.

82. Shankar describes that the UCM (e.g., and related components of the OCC and TCC that handle the universal protocol) manages the call using a "universal protocol" according to a "universal call model." Shankar, 11:38-52. Shankar describes that the UCM is "implemented as [a] state machine[] by objects in an object-oriented programming language," Shankar, 11:4-15. I note that this architecture is like the embodiment described by the '441 patent which describes the call agent logic engine as a "protocol-independent, data-configurable, multi-threaded state machine processor." '441 Patent, 8:34-56.

83. Shankar's UCM executes multiple logic control programs responsible for appropriate aspects of specific functions, including call resolution, call routing, bearer selection, generation of CDRs, communication with coding units, and other processing, and routing of incoming and outgoing signaling messages required to

establish a call. The UCM or portions therein provides the logic for call setup/teardown, and is involved in carrying out each of these specific tasks. Shankar, 5:14-32 ("the signaling units perform such functions as call resolution, call routing, bearer selection, and generation of call detail records (CDRs) for billing management.").

84. Volftsun provides further implementation details of its protocol converter that highlight the "protocol-independent" logic engine of the UCM. For example, Volftsun describes a "Call Context" that is "a collection of data elements that describe the contents of the messages passed through Protocol Conversion Engine 300. The description is in a physical representation independent, protocol-independent form." Volftsun, 9:51-55. Volftsun also describes that the "UCM 414 is comprised of states, primitives, alternatives, decisions, saves, and procedures that are invoked in response to Internal Primitives sent by OCC 410 and TCC 412 in such a way that a Call Instance 402 is processed in a protocol independent fashion."

85. Shankar describes that its "signaling units perform such functions as call resolution, call routing, bearer selection, and generation of call detail records (CDRs) for billing management." Shankar, 5:14-32. Based on my knowledge and experience and my review of Shankar, the billing sub-system involved in CDR generation is in communication, directly or indirectly, with the UCM involved in

routing and other call processing. *Id.* I note that Shankar explicitly teaches that "[s]ome call-related information that persists beyond the duration of the call may be stored in a database in main memory 206 or storage device 208 to implement billing records," which further indicates storage of information in a billing server. *Id.*, 10:56-11:3.

86. Based on my knowledge and experience in the field and my review of Shankar, even if Shankar were considered not to explicitly disclose that its billing subsystem is in communication with the call agent, a POSITA would have plainly recognized, in view of Shankar's description, that the UCM and billing subsystem are in communication (e.g., directly or indirectly) so that information related to billing management of the call can be collected and stored by the billing subsystem. A POSITA would have recognized that the call agent and billing subsystem are in communication as functional components of the signaling unit.

SHANKAR, HUANG, AND CAPERS

87. Capers describes a telecommunications network including a signaling gateway that translates between signaling protocols of interconnected networks. Capers, Abstract; 1:37-42; 2:36-3:7; 4:44-61; FIG. 1-8. The signaling gateway includes a transaction control layer (e.g., TCL 214) that performs call and resource state management functions. Capers describes that this includes "the capability of tracking different types of states for both calls and network resources (i.e., circuits)

while using industry standards for call processing." Id.



Capers, FIG. 1 (annotated). Capers illustrates a data path—labeled "voice" between the "bridging switch 104a" and the "NGSN 108a," for example, and a control path—labeled "SS7"/"MSP"—from the "bridging switch 104a" to the "STP 106a" to the "signaling gateway 110a" to the "NGSN 108a." In other words, control signaling from the "bridging switch 104a" to the "NGSN 108a" traverses a three-hop path via the "STP 106a" and the "signaling gateway 110a."

88. Capers describes "state tracking is performed by the TCL 214's statedependent processing 304 using a call/circuit state data store 306." Capers, 10:1040; Table 4; FIGS 2-3(illustrating call/circuit state data store 306 of TCL within

the signaling gateway). The "call/circuit state data store 306" is a "database" that includes information about the availability of a particular resource (e.g., circuit) to complete the call—in other words, resource availability information. The "signaling gateway 110 knows which circuits are available" and which are "unavailable" using information from the "call/circuit state data store 306." *Id.* A circuit may be unavailable due to an administrative block, processing of a current call, etc. *Id.* Capers describes that, using this information, an available circuit may be appropriately selected "so that the signaling gateway 110 may map calls to resources." *Id.*

89. Capers describes techniques to facilitate successful call execution, including confirming than an incoming circuit is valid such that the circuit can be used to handle an incoming call. For example, Capers describes checking that the incoming circuit is not in a blocked state. Circuits can be administratively blocked through a maintenance command, in which case the circuit is not valid to handle a call. Capers, 9:11-17 ("apply a block to a circuit"); 10:1-17. The "TCL 214 includes a single state machine process that tracks the states of both calls and resources," specifically including the "circuits between the bridging switch 104 and the NGSN 108," (i.e., an incoming circuit of an inbound call). Capers, 10:18-26. The "resource states are managed based on" SS7 ISUP messages "from the bridging switch 104." *Id.* Capers explains that the various states are tracked "so

that the signaling gateway 110 may map calls to resources." *Id.*, 10:27-41. In other words, calls are mapped to resources using the state information.

90. Additionally, Capers describes confirming that an incoming circuit is valid in a second manner by verifying the circuit is equipped on its platform. "Initial processing 302 for SS7 messages from bridging switch 104 includes general validation" that "ensures that the SS7 ISUP message sent to the signaling gateway 110 does not include a circuit identification code (CIC) of a circuit not equipped on the NGSN 108 platform." Capers, 9:18-25; Table 2 ("Unequipped Circuit Identification message"); Table 4.

91. I note that Capers was applied during original prosecution, including its teaching of "verifying an incoming circuit is in a valid state." Prosecution History, pp.190-191 (citing Capers, 9:21-24). I agree with the Examiner's analysis that Capers describes this feature.

Therefore it would have been obvious to one of ordinary skill in the art, having both Elliott and Capers before him/her and with the teachings [a] as shown by Elliott, a soft switch interconnecting networks of different transport protocols, and [b] as shown by Capers, general validation to ensure that the SS7 ISUP message does not include a CIC of a circuit not equipped for the platform, to be motivated to modify the system of Elliott by incorporating a software

routine to the soft switch to ensure that the SS7 ISUP message does not include a CIC of a circuit not equipped for the soft switch. This would improve the system by ensuring that the soft switch is capable of processing the SS7 ISUP messages sent to it.

Prosecution History, pp.190-191.

92. Shankar, Huang, and Capers, are analogous art, each describing systems that interconnect telecommunication networks. Based on my knowledge and experience in the field and my review of Shankar, Huang, and Capers, a POSITA would have been motivated to apply Capers' resource availability monitoring to enhance Shankar and Huang's system with additional resource availability information during call processing. Shankar already describes that its system selects bearer channels based on "channel availability." Shankar, 19:10-15 ("dynamic logic may be set up at run-time based on such factors as channel availability."); 14:4-18("the UCM 124 selects the bearer channel to be seized by the coding unit based upon . . . an available channel."). A POSITA would have understood, especially based on Capers teachings, how channel availability information can be monitored and made available to the entity handling the call.

93. Based on my knowledge and experience in the field and my review of Shankar, Huang, and Capers, a POSITA plainly would have been led to include a "call/circuit state data store," similar to that suggested by Capers. Capers, 10:10-4.

The data store would have stored information about the availability of a particular resource (e.g., circuit) to complete the call, in accordance with Capers' teachings. *Id.* The combined system would have included a database that receives resource requests, such as requests for outgoing circuit/bearer channels, and responds with circuit/bearer channel availability. The availability information in turn would be used by the UCM to map the call to particular resources so the call could be set up.

94. Resource management was a known feature of conventional call processing. Shankar itself indicates resource management is included in its system, and Shankar specifically describes use of "availability" information in selecting a bearer channel. Based on my knowledge and experience in the field, a POSITA would have had a reasonable expectation of success incorporating Capers' resource management features to perform bearer selection, based on the teachings of Shankar, Huang, and Capers.

95. Additionally, a POSITA would have been led to incorporate Capers' suggestions as I discussed above in order to improve the reliability and efficiency of Shankar's system. Based on Capers' teachings regarding resource management, a POSITA plainly would have found it obvious that call set-up would be enhanced by selecting a channel for a call using resource availability information because doing so would ensure that the selected resources were available to effectively handle the call. If instead unavailable resources were selected (e.g., inadvertently)

for a call, the call would not be effectively completed and the parties to the call would be unable to connect with one another.

96. Capers teaches yet another advantage of tracking resource availability. By tracking resource availability information, more information about an unavailable circuit can be known, such as the specific circuit and the reason the circuit is unavailable. Capers, 3:1-7 ("the reason a call or circuit is blocked or otherwise unavailable can be known."). The additional information would thus be available for addressing resource unavailability and would be useful for enhancing system reliability and performance, troubleshooting, and so on.

97. A POSITA would have been led by Capers to enhance the system of Shankar and Huang in another manner by confirming an incoming circuit could handle an inbound calls. For example, based on my knowledge and experience in the field and my review of Shankar, Huang, and Capers, a POSITA would have been led to confirm the incoming circuit is valid by verifying that the incoming circuit is not in an administratively "blocked" state. When a circuit is in a "blocked" state, the circuit is not in a state appropriate to handle transmission of the voice data to establish a call. Based on Capers teachings, the benefits of such validation would have been clear to a POSITA. Doing so would have enhanced reliability and efficiency of the Shankar/Huang system because the incoming circuit would have been checked to confirm usability for the inbound call before

proceeding further with call processing. Capers describes that "when requests may not be accomplished due to resource limitations" appropriate responses can be generated by TCL 214 and/or appropriate remedial action taken, such as generating an error message. Capers, 9:48-52. Moreover, a POSITA would have been motivated to incorporate advantages associated with identifying and knowing the circuit is not valid, as I discussed previously. Rather than the call simply failing or otherwise not being connected, an appropriate message could be generated, an alternative circuit could be used, or some other action could be taken, for example. Capers, 3:1-7 ("Yet another advantage of the present invention is that it closely monitors the state of calls and resources. Therefore, the reason a call or circuit is blocked or otherwise unavailable can be known").

98. Additionally, based on my knowledge and experience in the field and my review of Shankar, Huang, and Capers, in accordance with Capers' teachings a POSITA would have been led to confirm the incoming circuit is valid by using the circuit identification code to verify that the circuit is not "unequipped" to handle calls via the platform. Doing so would have similarly enhanced reliability by confirming usability of the circuit for the inbound call before proceeding further with call processing. If the circuit is not one that is equipped to be used with the signaling unit/coding unit, the invalidity is identified and known, which is one of the advantages described by Capers. Capers, 3:1-7.

99. I additionally note that a POSITA would have been prompted to implement Capers' resource management and circuit validation as I discussed in the preceding paragraphs, because doing so would be merely the application of a known technique to a known system ready for improvement to yield predictable results. Shankar and Capers both describe bearer channel/circuit selection based on the circuit's ability to handle transmission required for call execution. Based on my knowledge and experience in the field and my review of Shankar, Huang, and Capers, a POSITA would have found it obvious that applying the suggestions of Capers to Shankar/Huang's system would have led to predictable results without significantly altering or hindering the functions performed by Shankar/Huang's system. I note that any additional modifications to implement Caper's suggestions in Shankar/Huang's system would have been carried out by a POSITA with a predictable expectation of success.

100. The combination of Shankar, Huang, and Capers would have included a "call/circuit state data store" database in accordance with Capers' teachings. The data store would have been operable to receive outgoing resource requests from the UCM, and provide bearer channel/circuit availability responses (e.g., outgoing resource availability responses) to the UCM to use on call-setup. Capers, 10:27-40 ("map calls to resources.").

SHANKAR, HUANG, CAPERS, AND JANNING

101. Janning provides an example of the well-known function of generating a call detail record (CDR) in a telecommunications system. Janning, Abstract. In the system described by Janning, "raw call information for calls" is first collected, and then this information is used for "producing a CDR" based on an "optimal data structure" determined from the raw call information." Abstract. A "formatting agent" selects the "optimal data structure." Janning describes various advantages of its system, including that it provides flexibility and efficiency in creating CDRs because a format is selected based on the raw call information. Janning, Title ("Method For Flexible Formatting of Call Detail Records and Switching System Incorporating Same"); 1:43-61; 2:28-59.

102. It was common for the disconnection of a call to serve as a trigger for CDR generation, especially because information such as call duration is not available until the call is disconnected. Janning provides an example of this common technique.

When the call is disconnected, the unformatted raw information and the capture map contained in the RU 26 are transmitted to a formatter 28 where the unformatted raw information is formatted into a defined data structure. As will be more fully described below, the formatter 28 formats the raw information into a selected data structure commonly referred to as a call detail record (or "CDR")

Janning, 4:4-11. Accordingly, Janning teaches that the CDR is generated in response to disconnecting the call.

103. Shankar, Huang, Capers, and Janning are analogous art—Janning describing features of its telecommunications switching system directed to call detail records. Based in my knowledge and experience in the field and my review of Shankar, Huang, Capers, and Janning, a POSITA would have been motivated to have Shankar's UCM and related functional components generate a call detail record in response to disconnecting the call, in view of Janning's teachings to do so. Shankar already describes that its "signaling units perform such functions" as "generation of call detail records (CDRs) for billing management." Shankar, 5:14-32; 10:56-11:3. Janning describes additional details for generating CDRs, and explains advantages of its system that promote flexibility and efficiency. Janning specifically describes triggering generation of the CDR based on disconnecting the call. I further note that a POSITA would have combined Shankar, Huang, and Capers, with Janning such that the "formatter" was part of the UCM or within the "signaling unit" in communication with the UCM, such that it was operable to generate a CDR in response to disconnecting the call.

104. As an initial matter, I note that CDR generation was a widely known and practiced feature in order to track call information and prepare bills used to generate revenue from operation of a telecommunications system. Shankar itself

describes that its "signaling units" should include such features. Moreover, generation of a CDR in response to disconnecting a call was also commonplace. Janning, 4:4-11; Sestak, pp.1-6 ("generates a CDR at call termination); Brockman, 3:4 ("Typically, the CDR is generated when a call is completed."). A POSITA would have had a reasonable expectation of success incorporating these common features in the system of Shankar/Huang/Capers.

105. Janning teaches advantages of efficiency and flexibility provided by its techniques for generating CDRs. Janning, Title ("Method For Flexible Formatting of Call Detail Records and Switching System Incorporating Same"); 1:43-61(describing prior techniques as "inefficient"); 2:28-59. Janning explains that, rather than adhering strictly to a pre-specified format, the formatting of the CDR can be based at least in part on the raw information associated with the call. Notably, as I discussed above, information to populate the CDR and select an appropriate format, including call duration, is available upon disconnecting the call. Based on my knowledge and experience in the field and my review of Shankar, Huang, Capers, and Janning, a POSITA would have generated CDRs in accordance with Janning's teachings because doing so would facilitate efficient and flexible CDR generation.

106. I additionally note that a POSITA would have been prompted to implement Janning's CDR generation in response to disconnecting a call as I

discussed above, because doing so would be merely the application of a known technique to a known system ready for improvement to yield predictable results. Shankar and Janning both describe CDR generation, and Janning describes a specific manner of CDR generation in response to disconnecting the call that can promote efficiency and flexibility. Based on my knowledge and experience in the field and my review of Shankar, Huang, Capers, and Janning, a POSITA would have found it obvious that applying the suggestions of Janning to Shankar/Huang/Capers' system would have led to predictable results without significantly altering or hindering the functions performed by Shankar/Huang/Capers' system. I note that any additional modifications to implement Janning's suggestions in Shankar/Huang/Capers' system would have been carried out by a POSITA with a predictable expectation of success.

107. Shankar's UCM, alone or together with related components of the signaling agent, is operable to verify the validity of incoming circuits of inbound calls. Shankar's UCM selects an "available" bearer channel on the trunk associated with the incoming call setup message. "[T]he UCM 124 selects the bearer channel to be seized by the coding unit based upon a bearer channel specifically requested or merely 'preferred' in the Setup message, or upon an available channel on the associated trunk (for example, T1 or E1 line)." Shankar, 14:4-9. Additionally, Shankar describes that "logic for selecting a channel may be static or dynamic. For

example static logic may be implemented by a hard-coded table in a configuration file resident in storage device 208, and dynamic logic may be set up at run-time based on such factors as channel availability." Shankar, 10:10-14. The UCM is operable to verify the validity of incoming circuits by selecting an "available" bearer channel such that the call can be set up.

108. Shankar verifies that incoming circuits are valid to transmit voice data by carrying out the connection set-up process with the originating coding unit. Shankar explains that the UCM "generates and transmits a create connection message 406, specifying the bearer channel," to "originating coding unit 110." Shankar, 14:10-18. In response, the originating coding unit 110 "seizes an endpoint" for the specified bearer channel, "associates a network address for the selected bearer channel," and "responds back to the originating signaling unit 120 over the control link 114 with a message 408 that includes the network address of the originating coding unit 110." *Id.* 14:19-31. Based on my knowledge and experience in the field, these exchanges also serve to verify the incoming bearer channel such that a valid bearer channel is identified for use to complete the call.

109. Additionally, as I discussed previously (refer to ¶¶91-104), the combination of Shankar, Huang, Capers, and Janning includes a UCM operable to verify the validity of incoming circuits of inbound calls by verifying that the incoming circuit has not been "blocked." I note that such validation is analogous
to the preferred embodiment described by the '441 Patent, which "confirms the call is being processed from a circuit in a valid state" to "prevent processing a call from a circuit that has been administratively locked or through fault management has been disabled." '441 Patent, 9:9-13. Additionally, the combination includes a UCM operable to verify the validity of incoming circuits by ensuring inbound messages do not include a circuit identification code (CIC) of a circuit not equipped on Shankar's signaling unit/coding unit system. Capers, 9:18-25.

110. The "external protocol adapter 314" and "I/O channel control 304," alone or together with related components of the UCM, are operable to receive a request to establish a data session on a selected outgoing resource and set up an open session. Shankar's "signaling unit" controls the "coding unit" over a control link in order to "establish a bearer channel for the voice data." Shankar, 5:14-32. The UCM "controls the originating coding unit 110 over a control link 114." Shankar, 6:28-33. The "external protocol adapter 314" and "I/O channel control 304 in the I/O subsystem 300" handle control messages from the UCM requesting a data session. The "UCM 124 generates and transmits a create connection message 406, specifying the bearer channel, through external protocol adapter 314, I/O channel controller 304, control link 114 to originating coding unit 110." Shankar, 14:10-18; 10:31-55 ("the external protocol adapter 314 is responsible for connecting with the appropriate I/O channel controller 304 in the I/O subsystem

300 for sending and receiving messages with the coding unit and routing the messages to and from the proper call instance 320."). In other words, the "external protocol adapter 314," "I/O channel control 304," and/or related components of the UCM, are operable to receive a request to establish a data session (e.g., from portions of the UCM that handle call set-up), and set up an open session by communicating with the coding unit.

111. I note that the '441 patent describes that "[n]etwork gateway 146 includes gateway agents 180 for interfacing with MGCP media gateway switch, IPDC media gateway switch, etc." '441 patent, 8:26-29. Shankar's UCM, "external protocol adapter 314," and "I/O channel controller 304" operate similarly. The "external protocol adapter 314" and "I/O channel control 304," interface with the coding unit to set up data sessions using the bearer channels and other resources indicated by the UCM.

112. Shankar describes that the UCM of the originating soft switch resolves the route to a terminating signaling unit after communicating with the originating coding unit to establish an incoming bearer channel. "Once the appropriate terminating signaling unit 140 is identified, TCC 126 of the originating signaling unit 120 generates and transmits an XISUP IAM message 410 to the terminating signaling unit 140 with the standard ISUP IAM information plus the Universal Call Reference and the network address of the bearer channel on the

originating coding unit 110." Shankar, 14:33-45; Abstract ("establish a bearer channel . . . for carrying the voice data."); 15:64-16:7 ("the TCC 506 is responsible for communicating the signaling data with the terminating coding unit 150 over link 152."); FIGS. 5a-c. The IAM message transmitted by the TCC is based on the universal protocol message the TCC received from the UCM. This IAM message provides call set-up information that leads to termination of the call on the requested outgoing resources. Furthermore, the "create connection message" generated by the UCM specifies the bearer channel, which is also a resource requested to process the call. The message leads to a complete connection used to transmit voice in order to terminate the call.

113. The combination of Shankar, Huang, Capers, and Janning, as I discussed previously, is operable to generate a call detail record in response to disconnecting the data session (refer to ¶¶105-110).

SHANKAR, HUANG, AND HUITEMA

114. Huitema describes a telephony system that interconnects PSTN and Internet (IP) networks. Media gateways, including residential gateways (RGW), trunking gateways (TGW), SS7 gateways, etc., translate voice communication between "PSTN and Internet telephony voice formats." Huitema explains that "call agents" handle call signaling from trunks that interconnect the PSTN and the IP network. Media Gateway Control Protocol is a protocol used to control the

media gateways. "The call agent uses the MGCP for controlling the residential and trunking gateways." Huitema, pp.2-3. The architecture described by Huitema is illustrated in FIG. 1, including the use of MGCP between the call agent and media gateways.



Figure 1. Proposed network architecture. <u>Call agents use the Media Gateway Con-</u> trol Protocol to control residential and trunking gateways.

Huitema, Figure 1(annotated); Huitema, p.3 ("call agent controls both residential gateways and trunking gateways via the MGCP."). Huitema also explains the background of MGCP. "The Media Gateway Control Protocol is a new protocol that can be used by call agents for controlling gateways," and "resulted from the merger of the Simple Gateway Control Protocol and Internet Protocol Device Control." Huitema, p. 5.

115. The call agents of Huitema's system support a "distributed

architecture." A "large number of call agents" are able to control gateways over the internet. Huitema, p.4. Two are shown in FIG. 1, although many more could be used. Additionally, multiple call agents may be used to determine a route and complete a call when different call agents service the origination and termination of the call, for example. Huitema explains how call agents interact to establish a call in this scenario. "If the two RGWs participating in a two-party call are controlled by different call agents, the agents will need to coordinate to set up the call." Id. Huitema describes the call agents have an interface to communicate with one another using ISUP "so that information about the IP addresses, ports, and codecs" for the "originating and terminating party can be exchanged between the two call agents." Id. Huitema explains that "each gateway participating in an Internet telephony call must have" this information in order for a call to successfully be established. Moreover, Huitema specifically indicates that it is the "call agents" that "are responsible for ensuring that this is so." Id.

116. Shankar, Huang, and Huitema are analogous art, each describing telecommunications systems that interconnect different networks. Based on my knowledge and experience in the field and my review of Shankar, Huang, and Huitema, a POSITA would have been motivated to combine Huitema with Shankar/Huang in at least two ways. A POSITA would have been motivated to use MGCP to communicate between Shankar's signaling agent and coding agent.

As I discussed previously, Shankar already describes use of SGCP. For example, Shankar explains that the "create connection message 406 can be implemented according to an appropriate protocol such as a CRCX message in the Simple Gateway Control Protocol (SGCP), a proposed International Engineering Task Force (IETF) standard submitted by Bellcore and Soliant Internet Systems." Shankar, 14:13-18. SGCP was a precursor to MGCP, which was a combination of the IPDC protocol and the SGCP protocol. Huitema, p.5. The MGCP Specification itself explains that "MGCP version 0.1 results from the fusion of the SGCP and IPDC proposals." MPGC Specification, 126. A POSITA plainly would have found it obvious to use MGCP in its system in place of SGCP, for example, as a simple matter of using the newest protocol and to enhance its system by keeping current. Additionally, a POSITA would have been motivated to utilize the advantages provided by the current MGCP, as compared to the earlier developed SGCP, and to obtain the additional functionality and enhancements included in MGCP, such as the functionality of the IPDC protocol added to the existing SGCP protocol. See, e.g. MGCP Specification, 126-27.

117. Based on my knowledge and experience in the field and my review of Shankar, Huang, and Huitema, a POSITA would have been motivated to modify Shankar/Huang's system in a second manner by interfacing between signaling units in accordance with Huitema's suggestions. In particular, interfacing between

signaling units to exchange routing information for call set-up and execution. I note that Shankar already describes call establishment using "originating" and "terminating" signaling units 120, 140 that communicate with one another in order to determine a route to complete a call to a destination in a network external to that serviced by the "originating" signaling unit. For example, the "originating" signaling unit 120 selects the incoming bearer channel. Shankar, 14:4-45. However, the "originating" signaling unit 120 does not have access to routing information to select the terminating bearer channel, and thus looks externally. Id. Shankar explains that the "originating" signaling unit communicates with the "terminating" signaling unit, and the "terminating" signaling unit in turn resolves routing to the terminating node. Id. Shankar describes XISUP messages used to communicate between the signaling units via the TCC. "TCC 126 of the originating signaling unit 120 generates and transmits an XISUP IAM message 410 to the terminating signaling unit 140." Id., 14:38-45. After setup of the outgoing routing by the "terminating" signaling unit 140, the "terminating signaling unit 140" transmits an "XISUP ACM message 424 to the originating signaling unit 120" that contains "ISUP ACM information" and "the network address of the terminating coding unit 150." Communication between the signaling units is illustrated in Shankar's FIG. 4.





118. As I discussed previously, Huitema describes that its call agents communicate to facilitate call setup, and provides additional details of this communication. For example, Huitema explains that if "two RGWs participating in a two-party call are controlled by different call agents, the agents will need to coordinate to set up the call." Huitema, p.4. This coordination includes communication of "information about the IP addresses, ports, and codecs . . . for the originating and terminating party can be exchanged between the two call

agents." Id.

119. Based on my knowledge and experience in the field, and my review of Shankar, Huang, and Huitema, a POSITA plainly would have been led to have the UCM of an "originating" signaling unit request address locations needed to reach the called party, and receive the address locations in response so that the call could be set-up. Moreover, this request would have been made via the TCC that interfaces with a "terminating" signaling unit. A POSITA would have been motivated to incorporate Huitema's suggestions to promote effective communication between an "originating" signaling unit and a "terminating" signaling unit that supports an external network. Doing so would allow a call to the external network to be completed. Huitema, 4 ("each gateway participating in an Internet telephony call must have" IP addresses, ports, and codecs).

120. Based on Huitema's teachings, a POSITA would have recognized that Huitema's configuration allows users to call a large number of destination telephones. This is because using Huitema's teachings a particular call agent can communicate with another call agent to obtain address location information about destinations in external networks. Huitema, p.4. Based on my knowledge and experience and my review of Shankar, Huang, and Huitema, a POSITA would have been led to implement Huitema's suggestions based on its explicit teachings that its configuration promotes reliability and scalability. Huitema, p.2 ("scalability and availability"). A large number of call agents, with multiple call agents capable of controlling a particular gateway, means that failure of one signaling unit/call agent can be addressed by another signaling unit/call agent taking over. Huitema, p.2.

121. I additionally note that a POSITA would have been led to implement MGCP in Shankar/Huang's system, and would have been led to communicate between signaling units using an interface that can receive requests for address locations and respond with address location information, because doing so would have been merely the application of a known technique to a known system ready for improvement to yield predictable results. Moreover, based on my knowledge and experience in the field, and my review of Shankar, Huang, and Huitema, any additional modifications to implement Huitema's suggestions in Shankar/Huang's system would have been carried out by a POSITA with a predictable expectation of success.

122. In the combined system of Shankar, Huang, and Huitema, the signaling unit would have included an interface for communication with a terminating signaling unit, such that the interface receives, from the portions of the UCM handling call set-up, requests for address locations associated with a called party in an external network , communicates with a terminating signaling unit or other external network entity to obtain the address locations, and provides the

address locations to the UCM in response to the request from the UCM. As I discussed previously, Huitema explicitly teaches call agents exchange this information to complete a call to an external called party. Likewise, in the combined system, Shankar's TCC that interfaces with another signaling unit would carry out this function, in accordance with Huitema's teachings.

123. In the combined system of Shankar, Huang, and Huitema, the protocol used to communicate between the signaling unit and the coding unit is media gateway control protocol (refer to ¶¶118, 119, 124). For example, the control link 144, shown in FIG. 1 of Shankar, would have been implemented using MGCP..



Shankar, FIG. 1 (annotated).

SHANKAR, HUANG, CAPERS, JANNING, AND HUITEMA

124. Based on my knowledge and experience in the field and my review of Shankar, Huang, Capers, Janning, and Huitema, the reasons I discussed above illustrating that a POSITA would have been motivated to combine Shankar with Huang, Capers, Janning, and/or Huitema apply equally to the combination of all of these references.

LAKSHMI

125. Lakshmi describes a "softswitch" that interconnects packet-switched networks, such as the Internet, with legacy networks, such as the PSTN. Lakshmi, pp.1-22. Multiple networks are in communication via the "softswitch." For example, as shown in FIG. 6, the "softswitch" allows use of a packet-switch network to complete a call that originates and/or terminates at the PSTN, for example.



Lucent Softswitch-based VoIP network architecture.

Lakshmi, FIG. 6(annotated); p.11.

126. Lakshmi explains that packet-switched networks were viewed as

"flexible" and "cost-effective." Lakshmi, p. 1. To benefit from these advantages, service providers "need the ability to interconnect their customers with these" packet-switched networks "without losing the reliability, convenience, and functionality of the public switched telephone network." *Id.* Lakshmi's "softswitch" is described to address this need.

127. Lakshmi describes that the "softswitch" is a "programmable callprocessing system supporting a variety of PSTN, ATM, and IP protocols." Lakshmi, p.8. The "softswitch" provides "the same functionality as a circuit switch, but it does so in packet-based networks designed to be interconnected with PSTNs." *Id.* In other words, Lakshmi's "softswitch" controls the switching and routing of media packets between media gateways, and accomplishes this in a manner that is protocol- and device-independent such that network components that use different protocols can communicate via the "softswitch." Lakshmi, pp.7-8.

128. Lakshmi describes the configuration and structure of the components that make up the "softswitch." The "softswitch" system includes "a set of software components, including call coordinators, device servers, and directory coordinators." Lakshmi, p.13. The "call coordinator" is the "entity in charge of call processing." Lakshmi indicates that the "call coordinator manages individual calls or sessions, maintains call state, and is the entity that coordinates multiple

device servers for accomplishing communication." *Id.*, p.15. The "device servers" receive incoming telephony signaling protocols and "translate[] telephony protocols" to an internal form used by the call coordinator. *Id.*, pp.14-15. Call processing by the "call coordinator" is "initiated by call-request events sent by device servers." Lakshmi, p.15.



Lucent Softswitch system architecture.

Lakshmi, FIG. 11(annotated); p.21.

129. A "routing database" of the "softswitch" provides routing information used to determine the route for a call. Lakshmi describes that the "routing database" can be "provisioned in a high-performance relational database such as an Oracle database," and that the "routing database" is accessed by the call coordinator via a "directory coordinator." *Id.*, pp.18-19 ("directory coordinator that is a meta-directory providing uniform access to multiple types of directories

transparently.").



Figure 8.

Lucent Softswitch-based network architecture for managed modem services.

Lakshmi, FIG. 8 (annotated).

130. Lakshmi describes a system that interconnects networks of different transport protocols. As I discussed previously, Lakshmi indicates that the

"softswitch" provides the functionality of a circuit switch "in packet-based networks designed to be interconnected with PSTNs," and explicitly indicates its system supports "PSTN, ATM, and IP protocols," for example. Lakshmi, p.8. "Calls from any devices (using any protocol) can gain access to the current assets of the entire PSTN because of the seamless interworking made possible by the Lucent Softswitch." *Id.*, p.12. Figure 6 shows an example of the "softswitch" interconnecting an IP network that uses "SIP" with an SS7 network.



Lakshmi, FIG. 6 (annotated); p.11. Moreover, Lakshmi explains that the "softswitch" controls "media gateways that convert TDM flows to IP or ATM packet flows." Lakshmi, p. 7 ("controls the switching and routing of media

packets between media gateways").

131. Lakshmi's "softswitch" includes "device servers," such as an "SS7 device server" coupled to an SS7 network by an SS7 link and an "SIP device server" coupled to an IP network. Lakshmi, p. 11. These "device servers" are operable to receive incoming signaling messages, translate the incoming signaling messages to a call model event, and route the call model event.



Lucent Softswitch system architecture.

The "softswitch" includes "device servers" coupled to respective networks operable to receive incoming signaling messages, translate the incoming signaling messages to a call model event, and route the call model event.

Lakshmi, FIG. 11(annotated).

132. Lakshmi explicitly indicates that the "device server" is the entity that "translates telephony protocols to Mantra." Lakshmi, pp.13-14. Lakshmi explains that Mantra is a "proprietary canonical multi-party call model" used by the call

coordinator. The "device servers" thus receive incoming signaling messages in a protocol specific format, and translate these messages using "a canonical model that hides" implementation details of a particular signaling protocol. Lakshmi, p.9. Lakshmi provides a specific example in which the "device server" translation can provide a "call-request event." The "call-request event" is an example of a call model event. *Id.*, p.15; p.9 ("Existing call models, such as the Q.931 model, become a special case of this model.").

133. The "device servers" are operable to route the output, such as the "call-request event," to the call coordinator. Lakshmi specifically indicates that call processing in the call coordinator is initiated by "call-request events sent by device servers." *Id.*

134. Lakshmi's "softswitch" includes multiple "device servers" that handle particular protocols. I note that this configuration is analogous to the embodiment described by the '441 patent in which the "signaling agent" is itself made up of multiple subcomponents. The '441 patent recites that the "signaling agent 138 includes a number of signaling agents 162-164 operable to interface with SS7 interface, SIP devices or interface, H.323 devices or interface, Q.931 interfaces and devices, and others." '441 Patent, 8:19-26; 13:29-31. Moreover, I note that a POSITA would have found it obvious to group the functionalities of the "device servers" (e.g., as a single device server module) because they all relate to

translating signaling between a protocol specific format (e.g., used by an external network entity) and a protocol independent format (e.g., used by the call coordinator).





Like the embodiment of the '441 Patent, Lakshmi's signaling agent includes multiple subcomponent "device servers" '441, FIG. 6 (annotated); Lakshmi, FIG. 11 (partial, annotated).

135. Lakshmi's call coordinator/SPS is operable to receive a call model event, request outgoing resources for establishing data sessions, generate outgoing signaling messages, and send the outgoing signaling messages to the device servers. Lakshmi's "softswitch" includes a "call coordinator" that "manages individual calls or sessions, maintains call state, and is the entity that coordinates multiple device servers for accomplishing communication." Lakshmi, p.15. "This entity processes all signaling information and arranges media paths between device servers and gateways." *Id.* In other words, the "call coordinator" is the "entity in charge of call processing." *Id.*



Figure 11.

Lucent Softswitch system architecture.

The "call coordinator" is the "entity in charge of call processing," and provides a call agent

Lakshmi, FIG. 11 (annotated).

136. The "call coordinator" is operable to receive a "call-request event" from the device servers. Lakshmi explains that "[c]all processing is initiated by call-request events sent by device servers." Lakshmi, p.15. In other words, the "device server" generates the "call-request event" and sends to the "call coordinator," which receives the "call-request event" for processing.

137. In the course of call setup, the "call coordinator" requests outgoing resources for establishing data sessions. Lakshmi explains that the call coordinator

"arranges media paths between device servers and gateways" and "coordinates multiple device servers for accomplishing communication." Lakshmi, p.15. Lakshmi also describes that the softswitch "controls the switching and routing of media packets between media gateways." Lakshmi, p.7. The "call coordinator" would have been involved in handling this function as the entity "in charge of call processing." Lakshmi, p.15; see also p.8 ("controls external trunking gateways, access gateways, and remote access servers (RASs)"); p.15 ("in charge of call processing."). As another example, Lakshmi explains that the softswitch "identifies the best possible egress gateway to be used for terminating the call and uses this information to command the trunking gateways to perform specific functions." Lakshmi, p.10. Here again, the call coordinator would have been involved in handling this function as the entity "in charge of call processing." The softswitch "can choose to complete most of the calls through a least-cost routing logic that chooses the egress gateway closest to the destination phone." Id. Accordingly, the "call coordinator" makes requests for the device servers, gateways, and associated channels needed for transmitting and carrying voice and/or data in order to set up a call.

138. Lakshmi also describes a "service provider servlet" (SPS) that is part of the "call coordinator." The SPS is an "active piece of code that controls the basic call model (Mantra) that is embedded in the call coordinator." Lakshmi,

p.16.



Lucent Softswitch system architecture.

Lakshmi, FIG. 11 (annotated).

139. The "call coordinator" generates outgoing signaling messages, which it sends to "device servers," for example, for transmission to an external network element. The "device servers" in turn convert the internal protocol messages to an appropriate protocol-specific message so that it can be understood by the external network element. As I discussed previously, Lakshmi specifically attributes such functions to the call coordinator when it explains that the call coordinator "arranges media paths between device servers and gateways," and "coordinates multiple device servers for accomplishing communication." Lakshmi, p.15; p.14 ("Protocol translation" by the device servers "also involves translating the Mantra semantics" of the call coordinator "to protocol-specific behavior.").

140. Lakshmi's "device servers" are used to terminate data sessions on the outgoing resources requested by the call coordinator. As I discussed previously, Lakshmi explains that the softswitch "device servers" are used for "accomplishing communication." Lakshmi, p.15 (the call coordinator "is the entity that coordinates multiple device servers for accomplishing communication."). In other words, the device servers receive signaling from the call coordinator and translate to an appropriate protocol to be understood by the receiving network entity so that the call can be terminated. Lakshmi, p.14 ("Protocol translation" by the device servers "also involves translating the Mantra semantics" of the call coordinator "to protocol-specific behavior."); *id.* p.15 ("[d]evice servers are implemented for . . . SS7 signaling interfaces, and SIP devices.").

141. I note that Lakshmi illustrates the links, which show the path of signaling from the "device servers" of the "softswitch" to other network entities for "accomplishing communication." For example, FIG. 6 illustrates an ISUP link between the softswitch—particularly the "SS7 device server"—and the "SS7 network."



Lakshmi, FIG. 6.

142. Figure 8 illustrates an SIP link between the softswitch—particularly an SIP device server (which is not shown in FIG. 8) and the cable network. Lakshmi, FIGS. 6, 8 (partial, annotated).



Lakshmi, FIG. 8 (partial, annotated).

143. Lakshmi describes a "directory coordinator" and "routing database" that receive requests for routing information from the call coordinator to establish data sessions and that provide routing information to the call coordinator. Lakshmi explains that the "routing database" can be "provisioned in a high-performance relational database such as an Oracle database." Lakshmi, p.19 ("directory coordinator that is a meta-directory providing uniform access to multiple types of directories transparently."). It is accessed by the call coordinator via the "directory coordinator." *Id.* Calls are routed using routing information requested from the routing database, and Lakshmi describes that "[c]all coordinator instances cache the routing table during startup for high performance." Routing information from the "routing database"/"directory server" is requested by the call coordinator, and provided to the call coordinator, to establish data sessions.

144. Based on my knowledge and experience in the field and my review of Lakshmi, Lakshmi's "routing database" is analogous to the embodiment of the network directory server described by the '441 Patent. The '441 patent indicates that network directory server of its softswitch "may reside on the same platform as call agent 140 or may be distributed." '441 patent, 7:48-50. The '441 patent further describes that the "network directory server 144" includes a "network directory service 200" that "accesses in-memory tables 202, which store user profiles, routing instructions, addresses, and subscriber services," and "further accesses external data servers 203." '441 patent, 8:48-53.

145. The "directory coordinator" and "routing database" also receive requests for address resolution from the call coordinator to establish data sessions from the call coordinator, and provide address resolution responses to the call coordinator. Lakshmi describes that the call coordinator/SPS accesses information in its "routing database" in order to route a particular call. For example, Lakshmi indicates that [c]all coordinator instances cache the routing table during startup for high performance," and "new calls are routed using the new [routing] table." Lakshmi explicitly indicates that the SPS—the code which "controls the basic call model"—"performs basic address resolution." Lakshmi, pp.16, 18. Lakshmi describes that the "routing database" (e.g., accessed via the "directory coordinator") is where routing information is stored, and this routing information is needed to perform the "basic address resolution." Based on my knowledge and experience in the field and my review of Lakshmi, the "routing tables" from the "routing database" are queried for address resolution, and provide address resolution responses so that the call can be resolved between the PSTN and an IP network in order to complete the call.

146. I note here again, that Lakshmi's "directory coordinator"/"routing database" is like the embodiment of the network directory server described by the '441 Patent, which indicates that its network directory server "may reside on the

same platform as call agent 140 or may be distributed." '441 patent, 7:48-50. The '441 patent further describes that the "network directory server 144" includes a "network directory service 200" that "accesses in-memory tables 202, which store user profiles, routing instructions, addresses, and subscriber services," and "further accesses external data servers 203." '441 patent, 8:48-53.

147. The networks interconnected by Lakshmi's "softswitch" include a public switched telephone network. As I discussed previously, Lakshmi indicates that its softswitch provides "the same functionality as a circuit switch, but it does so in packet-based networks designed to be interconnected with PSTNs." Lakshmi, p.8 ("programmable call-processing system supporting a variety of PSTN, ATM, and IP protocols."); p.12 ("Calls from any devices (using any protocol) can gain access to the current assets of the entire PSTN because of the seamless interworking made possible by the Lucent Softswitch."); p.13 ("For enhanced PSTN service features, the Lucent Softswitch is shown connected to the SS7 network, as before.").

148. The networks interconnected by Lakshmi's "softswitch" include a packet network. The softswitch provides "the same functionality as a circuit switch, but it does so in packet-based networks designed to be interconnected with PSTNs," indicating the networks include a packet network. Lakshmi, p.8; p.7 ("controls the switching and routing of media packets between media gateways

across the packet backbone."); ("media gateways that convert TDM flows to IP or ATM packet flows.").

LAKSHMI AND ELLIOTT

149. Elliott describes a telecommunications system for communicating voice and data over a packet-switched network. Elliott, Abstract. Its system is "adapted to coexist and communicate with a legacy PSTN." *Id.* The system includes "soft switch sites" that provide "the core call processing for the voice network architecture," and that can "process multiple types of calls." *Id.* The system also includes "media gateways" that provide for the transmission of voice and data traffic through data network 112." Elliott, 19:32-39. The gateways are "controlled or managed by one or more soft switch sites." Elliott, 19:40-43. Elliott's Figure 1 shows a "high level view" of its telecommunications network, including "soft switch sites" that "provide the core call processing," and "gateway sites" controlled by the "soft switch sites" that facilitate calls between calling parties 102, 122. Elliott, 18:5-20:36.



Elliott, FIG. 1.

150. In more detail, Elliott describes the interaction of various components "to connect a call through the telecommunications network 200." For example, Elliottt describes that the softswitch can include a "route server" that includes "route logic" and "port status" components. Elliott, FIG. 2B; 49:12-18. "Route logic 294" of the "route server" serves to provide route information. For example, "route logic 294" can serve to "translate" a number or circuit group into an egress port, or identify a terminating soft switch that handles the identified termination. Elliott, 49:49-50:50; 51:32-52:62; 203:64-67; 206:61-64. The "port status 298" is a component of the route server that is queried to identify available ports in the trunking gateway, for example. Elliott, 28:36-45; 50:51-51:31; 208:35-42.



Elliott, FIG. 2B (annotated).

151. Elliott describes operation examples in which a destination of the call is external to a network serviced by an originating softswitch. The originating softswitch communicates with the terminating softswitch to obtain address location information of the destination in order to set-up the call.

"In situations where another route server 314 services the selected circuit group, the response for that route [from route server 212 of the originating soft switch 204] only contains the circuit group and the destination soft switch 304. Originating soft switch 204 can then make a request to terminating soft switch 304 to query the terminating route server 314 for a circuit within the identified circuit group. The terminating soft switch 304 can then control the termination of the call."

Elliott, 54:44-51. Additionally, Elliott describes that a terminating "[s]oft switch 304 can then communicate with [originating] soft switch 204 to establish connection 2312, between TG 234 and TG 232." The terminating "[s]oft switch 304 can provide the IP address for TG 234 to soft switch 204. Soft switch 204 provides this address to TG 232. TG 232 sets up a real-time transport protocol (RTP) connection 2312 with TG 234 to complete the call path." *Id.*, 204:10-15.

152. Elliott describes that its software code is organized according to "object-oriented programming" principles. For example, Elliott describes various classes/functions that provide function specific logic control programs and that communicate appropriate information to one another in order to carry out their respective functions. Elliott, 57:39-64:67. Elliott explains that the "software objects [that] interact and communicate with each other by sending one another messages." Elliott, 58:23-26. In other words, information is directed to the appropriate destination within the softswitch site and within components of the softswitch. "Computer programs (also called computer control logic), including object oriented computer programs, are stored in main memory . . . Such computer programs, when executed, enable computer system 7008 to perform the features of the present invention." *Id.*, 58:63-59:7; *see also* 59:19-52("Software object 7002 is comprised of methods and variables."); 59:53-64:67(describing classes/subclasses of its system). The organization of software code into modular software objects was widely known as an effective way to develop and organize software programs, particularly in systems that carry out a variety of functions.

153. Elliott describes numerous examples of software objects that perform specific functions and communicate with other objects. For example, with reference to FIG. 4B, Elliott describes a softswitch class that includes various methods/functions that communicate with various other methods/functions (e.g., getCallContextFromIPDCMsg() which communicates with IPDCMsg). Elliott, 4A-4E; 60:4-13 ("get call context information from an IPDC message", etc.). Relatedly, different software functions are associated with different types of signaling messages, such as call request messages (i.e. IAM), answer messages (i.e. ANM), release messages (i.e. REL), etc. Elliott, FIG. 4D.

154. Lakshmi and Elliott are analogous art. Both describe "softswitch" systems used to interconnect packet-switched and circuit-switched networks. Both Lakshmi and Elliott describe various components of their systems. For example, Lakshmi describes a "routing database" including "routing tables" to provide route information, a "merge device" that serves to provide communication between softswitches, and other related features. Elliott provides additional implementation

details regarding its "softswitch" system. Particularly, Elliott provides implementation details related to route information storage and retrieval, route selection, resource management, and communication between softswitches, specifically in scenarios in which the call destination is in a domain external to the originating softswitch. Based on my knowledge and experience and my review of Lakshmi and Elliott, a POSITA would have been motivated to incorporate Elliott's suggestions from its more detailed description into Lakshmi's system so as to improve its route information, storage, and call set-up processes, for example. Moreover, given the similar architecture and common features, a POSITA would have plainly expected success in implementing Elliott's suggestions.

155. As an initial matter, I note that route resolution during call set-up using information from a routing database was widely known, and a feature that Lakshmi itself describes. In the combined system, Lakshmi's call coordinator— "in charge of call processing"—would have effectively requested routing information from "route logic" of the "routing database," and received route information in response, in accordance with Elliott's explicit teachings. Indeed, a POSITA would have had a reasonable expectation of success in implementing this combination based on Elliott's teachings. Likewise, a POSITA would have been led to query the "route logic" for address resolution, in accordance with Elliott's teachings, in order to resolve a call through the network so that it could be completed.

156. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have found it obvious that routing in Lakshmi's system would have been effectively resolved by integrating "route logic" components of Elliott's "route server." For example, a route server that provided routing information and address resolution was a known feature that Lakshmi itself indicates should be included in its system, as indicated by Lakshmi's teachings related to its "routing database" used in call set-up. A POSITA would thus have had a reasonable expectation of success in incorporating Elliott's teachings of its "route server"/"route logic" features in Lakshmi's system.

157. An improved route selection process during call set-up also would have led a POSITA to incorporate Elliott's suggestions. For example, Elliott's "route logic" would have facilitated the call coordinator's access to routing information needed for call set-up, and provided address resolution needed to route a call through the network (e.g., between PSTN and IP networks). Based on my knowledge and experience in the field, and my review of Lakshmi and Elliott, a POSITA would have found it obvious based on Elliott's disclosure to integrate Elliott's suggestions of its "route server"/"route logic" in order to efficiently and effectively route calls. A POSITA plainly would have recognized that this

improvement in route determination/resolution would have enhanced the advantages already obtained by Lakshmi's system in interconnecting traditional telephone equipment with packet-switched networks.

158. A POSITA would have implemented Elliott's teachings in Lakshmi's system in a second manner by incorporating Elliott's suggestions of its "port status" component. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have recognized that Lakshmi's system would be improved by such integration. In the combined system, Lakshmi's call coordinator would have effectively requested resource availability information from a "port status" component of the "routing database," and provided resource availability information in response.

159. Here again, I note that resource management was a known feature of conventional call processing by a softswitch. *See, e.g.*, Elliott, FIG. 2B; 49:12-18. A POSITA plainly would have had a reasonable expectation of success in incorporating resource availability information in Lakshmi's "routing database," as suggested by Elliott's "port status" features. Moreover, a POSITA would have considered Elliott's suggestions in order to improve system reliability and efficiency. A POSITA would have recognized, based on Elliott's teachings, that selecting a circuit based on resource availability would have enhanced call set-up because doing so affirms that the selected resources are available to effectively
handle the call. The call is more likely to be successfully connected if available resources were assigned to the call.

160. A POSITA would have implemented Elliott's teachings in Lakshmi in a third manner. Lakshmi's "softswitch" includes a "merge device" that provides an interface for "inter-softswitch connectivity" between call coordinators. The "merge device" is "used for calls originating in one Softswitch site and terminating in the other." Id. As I discussed above, Elliott teaches inter-softswitch communication of address information needed for call setup. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have been led to implement Elliott's suggestion of inter-softswitch connectivity to facilitate address information needed to complete the call in scenarios in which the termination is not serviced by the originating softswitch. Elliott, 54:44-51. Elliott explicitly describes such communication to establish a connection for the call. Id. 204:10-15 ("Soft switch 304 can then communicate with soft switch 204 to establish connection 2312, between TG 234 and TG 232."). I note that a POSITA would have had a reasonable expectation of implementing Elliott's suggestions, especially because Lakshmi already describes that its "softswitch" includes a "merge device" for communicating with other "softswitches." Such a modification would have led to efficient call set-up, in accordance with the objective of Lakshmi's and Elliott's "softswitches."

Moreover, a POSITA would have been led to implement Elliott's suggestion to facilitate connection of its system to a wider network of users made available to a calling party, because Elliott explicitly describes inter-softswitch communication to facilitate call set-up to a destination not handled by the originating softswitch. Elliott, 54:44-51; 204:10-15.

161. A POSITA would have implemented Elliott's teachings in Lakshmi in a fourth manner. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott a POSITA would have been led to implement "object-oriented programming" to organize the software code within each functional component of Lakshmi's softswitch in a modular configuration. Elliott, 57:39-64:67. Such architecture was conventional and known to be an effective way to manage software code, particularly complicated software, such as software code of a "softswitch." For example, a POSITA would have found it obvious to implement such an architecture in Lakshmi's softswitch, in accordance with Elliott's teachings, because respective modules/programs associated with specific functions could be developed, modified, maintained, debugged, etc., with less dependency on other modules/programs. Id.; see also Elliott 57:39-64:67. Indeed, Elliott describes "object oriented programming" principles generally that its softswitch system is based upon, as well as various classes/functions that handle

specific-tasks and that communicate appropriate information to one another to carry out their tasks. *Id*.

162. A POSITA would have been led to implement Elliott's teachings in Lakshmi such that the call coordinator/SPS would have included discrete programs that performed specific functions to "manage individual calls or sessions," "maintain call state," and "coordinate multiple device servers for accomplishing communication," respectively. Lakshmi, p.15. Likewise, the "device servers" would have included discrete programs that performed specific functions associated with different message types. Elliott illustrates examples of different message types and discrete software functions associated with the different message types. *See, e.g.* Elliott, FIG. 4D (ACKMsg; IAMMsg; ACMMsg; ANMMsg; RELMsg; RLCMsg); 4E.

163. I additionally note that a POSITA would have been prompted to implement Elliott's suggestions in the manners I discussed above, because doing so would have been merely the application of a known technique to a known system ready for improvement to yield predictable results. Elliott describes such features of querying route logic of a route server for routing information or address resolution, querying port status of a route server for resource availability, using a network gateway softswitch component to communicate address location information between softswitches to complete a call to an external network, and

organizing software components using object-oriented programming principles. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have been led to implement such features in the "softswitch" system described generally by Lakshmi, and would have found it obvious that applying the suggestions of Elliott to Lakshmi's system would have led to predictable results without significantly altering or hindering the functions performed by Lakshmi. I note that any additional modifications to implement Elliott's suggestions in Lakshmi's system would have been carried out by a POSITA with a predictable expectation of success.

164. In the resulting combination, the "routing database"/"directory coordinator" would have received routing information requests to establish calls, and provided routing information to the call coordinator in response, in accordance with Elliott's teachings. The call coordinator could thus establish a data session using an appropriate route, such as a "least-cost" route, or other criteria. "Lucent Softswitch can choose to complete most of the calls through a least-cost routing logic that chooses the egress gateway closest to the destination phone." Lakshmi, p. 10. As I discussed previously, Elliott describes that its soft switch communicates with a route server "to provide routing information for a customer call." Elliott, 30:46-48: 36:48-52 ("soft switch 204 can query RS 212 to retrieve the route having the least cost."); 49:12-17; 49:36-40 ("Route server 212 performs

the function of supporting the logic for routing calls based upon a phone number.").

The combination of Lakshmi and Elliott, as I discussed previously, 165. would have included a "port status" component of the softswitch that is queried to provide port status information of a particular resource (e.g., manage resources). Elliott describes that a soft switch can "determine whether a TG 232 has any ports available for termination by querying port status 292 of route server 212, and if so, can allocate the available port." Elliott, 208:35-42; see also id. 28:36-45("port status 298"); 53:4-11("port status 298"); 203:40-204:39; 207:1-14; 207:49-53; 208:35-59; 211:1-7. This information is used to set up an appropriate connection using the allocated port. *Id.* Table 15B provides an example of the "status" of various ports, which are listed as "avail" or "In-use." This information is stored in the "port status" component of the "route server." In other words, Elliott indicates that its "port status" component of the "route server" provides outgoing resource availability responses. Elliott, 50:51-54:51; Table 15A-15B.

	Port Status	
Circuit group	Port	Status
34 34 34 34	3-4-6-1 3-4-6-2 3-4-6-3 3-4-6-4	Avail In-use avail avail

TABLE 15B

Elliott, Table 15B (annotated). In the combined system, a "port status" component would have received outgoing resource requests from the call coordinator (e.g., directly or indirectly), and provided outgoing resource availability responses to the call coordinator, in accordance with Elliott's teachings. *Supra* III.B.2.

166. I note that Elliott's route server includes multiple components, including a "routing logic 294" in addition to the "port status" component. The "routing logic" 294" is queried "to determine a least cost route termination to the called destination," for example. Elliott, 208, 35-42. In other words, Elliott describes the distinct entities of a "routing logic" that responds with route information (e.g., a network directory server) and a "port status" that responds with resource availability (e.g., a resource manager). Based on my knowledge and experience and review of Lakshmi and Elliott, a POSITA would have found it obvious, based on Elliott's teachings of "routing logic" and "port status" components, that the "port status" provides additional and complementary functionality to Lakshmi's "routing database."

167. Elliott explicitly teaches that the "port status" component (and the route server that the port status is within) may be located together with the softswitch. For example, Elliott explains that the "functions of either or both of CS [configuration server] 206 and RS [route server] 212 can be performed by application logic residing on soft switch 204." Elliott, 49:12-18; 31:54-58; 58:41-

47 ("Other network components of telecommunications network 200, such as, for example, route server 212 and configuration server 206, can also be implemented using computer system 7008 shown in FIG. 70B."); 62:60-64:67.

As I discussed previously, Elliott describes number/address 168. translation, as well as translation of a number or circuit group into an egress port. "In step 267, in order to translate the translated number or circuit group into an egress port, soft switch 204 makes a route request to route server 212. The routing logic uses the NPA-NXX-XXXX to identify the terminating circuit group." Elliott, 52:30-48. Additionally, Elliott describes that "[r]outing logic selects the translation based upon the best match of digits in the routing tables." Elliott, 49:49-50:50. In other words, the "route server" receives requests to resolve the address to an egress port, and provides the egress port in response (and vice versa). Indeed, Elliott explicitly describes a request to "route server 212" as a "resolveRequest," which further highlights that Elliott's "router server" is operable to receive and respond to requests for address resolution. Elliott, FIG. 30. Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have found it obvious that the "routing database" in the combined system would have likewise received address resolution requests to resolve an address to an egress port, and provided the egress port in response, in accordance with Elliott's teachings. Doing so would have provided the call

coordinator with information needed to establish a data session using an appropriate egress port, for example. Lakshmi, p.10 ("Lucent Softswitch can choose to complete most of the calls through a least-cost routing logic that chooses the egress gateway closest to the destination phone.").

169. As I discussed previously, Lakshmi describes that each softswitch includes a "merge device" that provides an interface for "inter-softswitch connectivity" between call coordinators. Lakshmi, p.16. For example, Lakshmi describes that the merge device "is a dummy device server or link that connects one Lucent Softswitch site to another," and is "used for calls originating in one Softswitch site and terminating in the other." *Id.* The "merge device" provides an interface for communicating address location information between call coordinators of the respective softswitches, such as for calls that require multiple softswitch sites in order to complete the call. Communication of address location information needed to create a complete connection so that the call can be completed.

170. Moreover, in the resulting combination discussed previously, the "merge device" would have been operable to receive requests from the call coordinator for address locations of called parties in external networks, and to provide the address locations to the call coordinator, in accordance with Elliott's

teachings. For example, when another soft switch services the destination of the call, the originating softswitch makes a request via its "merge device" to the terminating softswitch so that the terminating softswitch can query its route server for routing information. Elliott, 54:44-51; 204:10-15. The routing information is likewise returned to the originating softswitch via its merge device. So that the routing information can be used to complete the call set-up, the information is in turn provided to the call coordinator. Id. I note that Huitema further describes communication between devices in order to set up a call in order to obtain information about IP addresses, ports, and codecs for the originating and terminating party that is necessary for completing the call. Huitema, p.4 ("each gateway participating in an Internet telephony call must have" information about the IP address, ports, and codecs "for the originating and terminating party"; "the call agents are responsible for ensuring this is so."). Based on my knowledge and experience in the field and my review of Lakshmi and Elliott, a POSITA would have found it obvious that the terminating softswitch returns address location information to facilitate call set-up by the originating softswitch, because the originating softswitch itself does not have this information until obtained via the terminating softswitch.

171. The logic engine of Lakshmi's "call coordinator"/"service provider servlet" and "call coordinator" is protocol independent. Lakshmi indicates that the

softswitch, and particularly the "call coordinator" manage a call using a protocol "agnostic" model. Lakshmi, pp.15-16. The softswitch "does not prefer any one set of signaling protocols, relying rather on protocol interworking." Lakshmi, p.21. Lakshmi further explains that the call coordinator uses a "canonical model" that "hides" implementation details of a particular protocol. Lakshmi, p.9. Lakshmi also explains advantages of this aspect of its "softswitch" which "allows for the development and evolution of the system in a way that is agnostic to the emergence and adoption of specific protocols or their varied implementations by different vendors." *Id.*

172. Lakshmi's "call coordinator"/"service provider servlet" is made up of various entities responsible for specific functions of the softswitch. In other words, each of these entities provides a function-specific logic control program. For example, the call coordinator and SPS are software components executed by a processor on a computer—they are logic control programs. Lakshmi identifies specific functions performed by these respective logic control programs, including to "manage individual calls or sessions," "maintain call state," and "coordinate multiple device servers for accomplishing communication," respectively. Lakshmi, p.15. Based on my knowledge and experience in the field, such a modular configuration of function-specific logic control programs was conventional, and would have been obvious to implement based on Elliott's

teachings of "object-oriented programming" principles, as I discussed previously. The resulting combination would have including modular software objects directed to specific functions carried out by the "call coordinator"/ "service provider servlet," in accordance with Lakshmi's and Elliott's teachings.

LAKSHMI, ELLIOTT, VOLFTSUN, AND BARCLAY

173. As I discussed previously, Volftsun describes a protocol converter that interconnects network components that use different communication protocols. Volftsun, Abstract. The system converts signaling between various protocol specific representations and a non-protocol specific representation used internally by the protocol converter. *Id.* Volftsun describes its system as a "scalable, programmable software based application run on a programmed general purpose digital computer." *Id.*

174. Volftsun's system includes "a conventional I/O (Input/Output) Subsystem 418" that provides an interface to external equipment. Volftsun, 8:58-9:27. "Comprised of a Call Instance 402 and a plurality of Protocol Adapters 404, 406, and 408, Protocol Conversion Engine 300 interfaces with external equipment, and therefore with interconnected networks and network elements, through a conventional I/O (Input/Output) Subsystem 418." *Id.* Incoming protocol-specific messages are received and passed to the I/O subsystem 710, which "transforms the Protocol Specific Message into Protocol Data Units." Volftsun labels the incoming protocol-specific messages as "PM" and the Protocol Data Units as "PDU" in FIG. 7. *Id.*, 13:63-14:50.



The I/O subsystem parses and formats incoming signaling ("PM") to output "PDUs"

Volftsun, FIG. 7 (annotated). The PDUs remain in a "protocol-specific" representation, and are routed first to a "protocol adapter" (as PDUs) and then to an "originating call control" (as Internal Primitives (IP)). There, the IPs are further processed and converted to "non protocol-specific Internal Primitives." *Id.*, 9:22-27.



Fig. 4

Volftsun, FIG. 4 (annotated).

175. Lakshmi, Elliott, Volftsun and Barclay are analogous references describing interworking signaling between protocol-specific formats. Based on my knowledge and experience in the field and my review of these references, a POSITA would have been led to have the "device interface" of Lakshmi's "device servers" parse and format incoming signaling, based on Volftsun's suggestions of converting incoming signaling to Protocol Data Units. Lakshmi's "device interface" serves as an interface between an external "network element" and other components of Lakshmi's "device server." This is shown explicitly in FIG. 12 of

Lakshmi, for example, and this arrangement is similar to Volftsun's I/O subsystem. The I/O subsystem of Volftsun's protocol converter likewise interfaces with external network elements via protocol-specific signaling. Especially in view of this similar arrangement, a POSITA would have had a reasonable expectation of success incorporating implementation details suggested by Volftsun into Lakshmi's "device interface." Moreover, based on my knowledge and experience in the field and my review of Lakshmi and Volftsun, a POSITA would have found it obvious that the "device interface" would advantageously accomplish its interfacing function by parsing and formatting protocol-specific signaling. For example, parsing and formatting the incoming protocol-specific signaling in accordance with Volftsun's description would have facilitated a number of interfacing functions, including, for example, detection of the type of message and confirmation that the message was not corrupted, which in turn would have allowed the device server to process the message. I note that Volftsun teaches that such parsing and formatting of protocol-specific signaling be performed by the I/O subsystem as an initial step in handling incoming, protocol-specific signaling. Volftsun, 8:58-9:39; 12:63-13:34; 13:63-14:50; 15:7-17:2. In other words, in order to properly handle incoming signaling messages, the "device interface" must understand what is being received. Parsing and formatting the incoming signaling messages facilitates this understanding. Volftsun provides an example

implementation of such parsing and formatting by its analogous component that interfaces with external network elements to perform the initial processing and facilitate reception and transmission with the external network element. *Id*.

176. I additionally note that a POSITA would have been led to implement Volftsun's parsing and formatting of protocol-specific signaling because doing so would have been merely the application of a known technique to a known system ready for improvement to yield predictable results. Volftsun describes an interface with external network entities that parses and formats protocol-specific signaling into protocol data units. Lakshmi describes a "device interface" that likewise interfaces with external network entities to receive protocol specific signaling. A POSITA would have found it obvious to incorporate Volftsun's specific implementation details into Lakshmi's system, described more generally. Moreover, based on my knowledge and experience in the field, and my review of Lakshmi, Elliott, Volftsun, any additional modifications to implement Volftsun's suggestions in Lakshmi/Elliott's system would have been carried out by a POSITA with a predictable expectation of success.

177. Lakshmi's "device servers" include a logic control executing a logic control program. As I discussed previously, they are operable to process signaling messages of a particular signaling protocol. For example, Lakshmi teaches that its "device servers" are "software components" that "run on commercial standard

computers." Lakshmi, p.7. "Commercial standard computers" include a generic state machine processor configurable to execute the "software components" and carry out the functions of the "software components." *Id*; p.1 ("a software-based distributed switching-and-control platform"); p.13 ("The Lucent Softswitch system can be viewed as consisting of a set of software components, including call coordinators, device servers, and directory coordinators. All of these components can be distributed across a set of one or more geographically separated hardware platforms."); p.14 ("protocol handlers," "network signaling mechanisms," "end point handlers"); p.15. The "device server" is one of the "software components" of the softswitch, and includes logic control programs that define what the computer processor is to do. Lakshmi, p. 13; see also Elliott, 58:63-59:7 ("Computer programs (also called computer control logic), including object oriented computer programs, are stored in main memory . . . Such computer programs, when executed, enable computer system 7008 to perform the features of the present invention."). In the combined system, the software logic control programs of the "device server" include data associated with incoming and outgoing messages and how to process the messages, transitions prompted by incoming messages, and actions that result from processing performed on the incoming messages. Id. Indeed, Lakshmi describes that the "device servers" (e.g., due to the logic control program software) serve as a "model for bringing an endpoint that is foreign to the

system into the call," and that abstract and normalize all incoming and outgoing signaling information. Lakshmi, p.13-15.

178. Each of Lakshmi's "device server's" performs a number of functions. For example, the "device server" executes different actions depending on a type of signaling message that is received. In the case of the "SS7 device server," the "device server" receives a variety of different signaling messages used by the SS7 signaling protocol. These messages include call request messages (i.e. IAM), answer messages (i.e. ANM), release messages (i.e. REL), etc., as well known by a POSITA. See, e.g. Elliott, FIG. 4D (illustrating different signaling messages and respective software functions); FIG 4E (IPDC signaling messages). Lakshmi also describes an example of a call request, and the associated function of the "device server" of generating a "call-request event" to send to the "call coordinator." Lakshmi, pp.15. The device server includes multiple logic control programs specific to these respective message types in order to process the message. Lakshmi, p.15. I further note that Lakshmi illustrates yet additional examples of logic control programs within the device server, illustrating a "policy enforcement point" (PEP) and "policy event manager" (PEM) which perform functions related to the system policy server. Lakshmi, FIG. 12; p.18. These components are responsible for actions related to the policy system that are different than the actions for generating and transmitting events to the call coordinator based on

incoming signaling messages, such as "call-request events," and additionally provide logic control programs of the "device server" logic control.

179. Lakshmi's "device servers" are operable to process signaling messages of a particular signaling protocol. Lakshmi describes multiple "device servers" that are each associated with a different protocol-specific signaling protocol. In FIG. 11, for example, Lakshmi illustrates an "SS7 device server" that processes SS7 signaling messages and a "SIP device server" that processes SIP.



Lucent Softswitch system architecture.

The "device servers" include a logic control executing a logic control program and are operable to process signaling messages of a particular signaling protocol, such as SS7 and SIP protocols Lakshmi, FIG. 11 (annotated). Additionally, Lakshmi describes its "device servers" as the "Lucent Softswitch entity that translates telephony protocols to Mantra [used by the call coordinator]. Protocol translation also involves translating the Mantra semantics to protocol-specific behavior." Lakshmi, pp.13-14; pp.9-10 ("Signaling and Communications Protocol Agnosticism").

180. Lakshmi's "device servers" operate using the well-known component of a codec in order to parse and format the incoming, protocol-specific signaling messages. As I discussed previously, the protocol-specific signaling travels between the "device interface" of the "device server" and external network elements. Lakshmi, FIG. 12. To carry out the signaling, the "device interface" provides an interface that receives and parses signaling to detect the type of messaging it contains and performs initial formatting, so that it can process the message.

181. As I discussed previously, Volftsun also makes use of the well-known concept of a codec and, based on my knowledge and experience in the field and my review of Lakshmi and Volftsun, a POSITA would have been led to similarly use a codec in Lakshmi's "device interface." The resulting "device servers" would each code and decode signaling messages between an incoming format and another format, such as the protocol data units described by Volftsun. In other words, the "device servers" of the resulting combination would have been specialized to parse

and format signaling messages according to particular signaling protocols (e.g. SS7, SIP, etc.). In this way, the "device servers" would have effectuated transmission and reception of signaling messages with the outside world— communicating with external network entities. Lakshmi, FIG. 12.

182. I note that in both Lakshmi's softswitch and the '441 patent, a "device server" / "signaling agent" is provided for each particular signaling protocol of each access network that the softswitch interconnects. Additionally, I note that the '441 Patent describes its codecs merely as "coders/decoders" that are "specialized communication modules." '441 Patent, 8:25-26. Lakshmi's "device servers" provide specialized communication modules that function to code and decode outgoing and incoming signaling. Lakshmi, pp.13-14.

183. In the resulting combination, signaling messages from the codec of the "device interface" are routed to appropriate device server logic control programs so that the messages can be further processed. I note here again that Lakshmi's "device server" includes multiple logic control programs to handle respective functions of the "device server," such as functions carried out by the "device server" in response to different types of signaling messages that it receives. For example, SS7 signaling includes call request messages. Lakshmi explains that the "device server," based on a call request message it receives, generates a "callrequest event" (which is in turn provided to the "call coordinator" to initiate call

processing). Lakshmi, p.15. The call request signaling message received by the "device server" is thus filtered and routed to the appropriate logic control program that is able to process this message type and responsible for generating the "callrequest event." Id. SS7 signaling includes a number of other signaling message types, such as incoming answer messages (i.e. ANM) and release messages (i.e. REL) that are used to manage a particular call. See, e.g. Elliott, FIG. 4D. Incoming messages from the device interface/codec are likewise filtered and routed to the appropriate logic control program of the "device server" so that these messages can likewise be processed further. Id. I also note that describes that the "device servers are capable of multiplexing interactions," further highlighting the device server's organization that includes multiple components that handle discrete functions. Lakshmi, p.13. If a filter were not present, incoming signaling messages would not be directed to the appropriate destination among multiple possible destinations within the device server.

184. Software filters were a well-known mechanism to filter and route information, such as signaling messages, and Lakshmi itself provides an example of a software filter. Lakshmi indicates that the "policy enforcement points" act as "event filters." Lakshmi, p.18. They receive "events" and trigger responses to those events based on a set of rules for handling the events, providing a filter that filters and routes between various logic control programs of Lakshmi's softswitch

Id. Based on my knowledge and experience, a POSITA, in view of Lakshmi, Elliot, and Volftsun would have recognized that a similar software "filter" perform a similar function of filtering and routing signaling messages from the "device interface" to an appropriate logic control program of the logic control. As I discussed previously, the filter would likewise filter and route depending on characteristics of the signaling, such that the signaling message type, content, and so forth.

185. In addition to filtering and routing incoming messages to a particular logic control program destination as I discussed above, Lakshmi's "device servers" would, in view of Barclay (See, e.g., Barclay, 6:9-6:38), include a filter that filters and routes in a second manner. For example, messages would be filtered to prevent further dissemination, to the "call coordinator," for example, of extraneous, erroneous, or misdirected signaling messages, and signaling messages that do not relate to call control and do not need to be processed by the "call coordinator." The problem of such extraneous messages would have been well known to a POSITA. See, e.g., Barclay, 6:9-6:38; NEWTON'S TELECOM DICTIONARY, 228 (describing file transfer error checking and correction so that "damaged packets are discarded"). For example, Barclay explicitly describes "telephone signaling protocols include many messages which are not call processing messages." Id. Barclay explains that, in response to such messages, an

error message can be returned, or messages can be dropped where they do not need to be processed.

186. Based on my knowledge and experience in the field and my review of Lakshmi, Elliott, Volftsun, and Barclay, a POSITA would have recognized, based on Barclay's teachings, that a filter can be included in Lakshmi's "device servers" to filter erroneous, misdirected or extraneous signaling messages, as in Barclay. Doing so would facilitate efficient use of the device server logic control and call coordinator resources, and avoid wasting such resources on messages that need not be processed by these entities. Barclay, 6:9-6:38; NEWTON'S TELECOM DICTIONARY, 228 (describing file transfer error checking and correction so that "damaged packets are discarded"). A POSITA would have had a reasonable expectation of success in implementing such a filter, because similar filters are ubiquitous in in various areas of networking, and locating the filter after initial parsing and formatting of the message would have facilitated the filter's function of filtering and routing the messages. Id.

187. Lakshmi indicates that its system can interwork with a number of different signaling protocols, including SS7 and session initiation protocol ("SIP"). Lakshmi describes that the softswitch provides "interconnection with the SS7 network." Laskhmi, p.7. This interconnection is also illustrated in the figures. *See, e.g.* Lakshmi, FIGS. 4, 6-11; p.11 ("through standard SS7 links."). Lakshmi

explicitly describes that "SS7 links refer to physical links that connect an SS7 device server [of the softswitch] to the SS7 network." *Id.*; p.15 ("Currently device servers are implemented for . . . SS7 signaling interfaces.").

188. Lakshmi describes that its system can interwork with session initiation protocol ("SIP"). Lakshmi's softswitch supports "IP phones on a cable network from the Lucent Softswitch through SIP." Lakshmi, p.11; FIG. 6. This is also shown in FIG. 11, for example. Lakshmi, FIG. 11; Lakshmi, p.10; p.15 ("Currently device servers are implemented for . . . SIP devices.").

189. Lakshmi's softswitch includes MGCP and IPDC "device servers." These "device servers" control gateways that handle transmission of voice data, and are analogous to the conventional network gateway recited in the '441 patent that interfaces with a media gateway. Lakshmi describes "device servers" implemented for various gateways, including IPDC and MGCP "trunking gateways." Lakshmi, p.15; p.8 (describing that the softswitch "controls external trunking gateways"); p.10 ("command the trunking gateways"). The '441 patent likewise describes that "[n]etwork gateway 146 includes gateway agents 180 for interfacing with MGCP media gateway switch, IPDC media gateway switch, etc. Each gateway agent 180 also includes a logic control 182 executing a logic control program, a filter processor 183, and a codec 184." '441 patent, 8:26-34.

190. I note that Lakshmi illustrates that the MGCP and IPDC "device

servers" process messages of a particular transport protocol. Specifically, MGCP and IPDC protocols are used by the MGCP and IPDC device servers to control the corresponding gateways. Lakshmi explicitly indicates that the "trunking gateway itself is controlled by the Lucent Softswitch using a master/slave protocol such as IPDC or MGCP," and illustrates such links in FIGS. 6 and 7, for example. Lakshmi, p.10; *id*.("control the access gateway" using IPDC or MGCP.); FIGS. 6, 7.

191. The combination includes a codec that parses and formats messages according to the transport protocol of the media gateway, such as the codec included in the "device interface" of the MGCP and IPDC "device servers," respectively. As I discussed previously regarding the SS7 and SIP "device servers," the device servers each function to code/decode during processing of the associated signaling protocols. Here again, the "call coordinator" and respective external network entity (e.g., gateway) can understand the transmission. *Supra*, [5.e]. I note that Lakshmi's system includes a respective "device server" that is specialized for the particular protocol associated with the gateway that the device server communicates with. Lakshmi, p.15. ("device servers are implemented for access gateways (H.323 v1/v2), trunking gateways (IPDC 0.12, MGCP, and Sapphire)").

192. As I discussed previously, Lakshmi describes multiple transport

protocols used to communicate between respective "device servers" and gateways, including media gateway control protocol ("MGCP") and Internet protocol device control protocol ("IPDC"). Lakshmi explicitly indicates that the "trunking gateway itself is controlled by the Lucent Softswitch using a master/slave protocol such as IPDC or MGCP." Lakshmi, p.10.

LAKSHMI AND SESTAK

193. Sestak describes call detail record (CDR) generation and its contents in a telecommunications system. Sestak, Abstract. Sestak describes two modes of "generating call detail records (CDRs)." In both modes, Sestak describes generation of CDRs in response to "termination" of call. For example, Sestak indicates that "[e]ach PBX involved in a call generates a CDR at call termination which records its own involvement in the call." Sestak, p.3; see also id. ("it is necessary to generate CDRs at the beginning of a call as well as at termination"); ("a single CDR is generated at call establishment and at call termination"); ("At call termination, a single CDR is generated by the terminating PBX"); see also p. 2("Neither of our Architectures imply any impairment of the ability to carry out the normal billing functions for which CDRs are used. . . . Our approach is first of all to develop a traffic model which can be applied to any specific network topology."). Sestak provides examples of the type of content included in CDRs, such as "call type," "start time," and "end time." Sestak, FIGS. 1, 2; pp. 1-4.

"End time" is an example of CDR content that becomes known at the time the call is disconnected.

194. Lakshmi and Sestak are analogous art, both describing features of telecommunication systems related to storing call information. Lakshmi explains that its softswitch "has programmable back-office features" including "[p]rogrammable event-detail recording" and "[c]all-detail events written to a service provider's event-collection mechanism." Lakshmi, p.8. Based on my knowledge and experience and my review of Lakshmi and Sestak, a POSITA would have been led to have the billing subsystem of Lakshmi's softswitch generate call detail records, in accordance with Sestak's suggestions. A POSITA plainly would have recognized that the "call-detail events" recorded by the softswitch provide call detail records. Additionally, a POSITA would have recognized, in view of Sestak's teachings, that CDR generation in this manner would have reliably and effectively provided CDRs that could be used for billing and/or network monitoring functions.

195. Based on my knowledge and experience in the field and my review of Lakshmi and Sestak, a POSITA would have additionally been led to generate call detail records in response to disconnecting a call. The process of generating CDRs, their content, and their uses, were well understood by a POSITA. Lakshmi describes generation of CDRs (e.g., recording "call-detail events"), but does not

recite complete implementation details of this well understood task. Lakshmi, p.8. Sestak provides additional details of specific ways to generate CDRs, and particularly explains advantages of its techniques that are resource-efficient. Sestak, p.3. Notably, Sestak explicitly teaches generating CDRs in response to call termination. Moreover, Sestak teaches the content of CDRs include information such as call "end time," which becomes available only upon disconnecting the call. The combination system of Lakshmi and Sestak would likewise generate CDRs in response to call termination, driven by the call coordinator responsible for maintaining call state, including call set-up and take down processes.

196. As I discussed previously, I note that CDR generation was a widely known and practiced feature in order to track call information and prepare bills needed to generate revenue from the operation of a telecommunications system. Lakshmi, itself teaches its softswitches should include this feature. Moreover, generation of a CDR in response to disconnecting a call was also commonplace. Sestak, pp.1-6 ("generates a CDR at call termination); Janning, 4:4-11 ("When the call is disconnected, the unformatted raw information and the capture map contained in the RU 26 are transmitted to a formatter 28....[T]he formatter 28 formats the raw information into a selected data structure commonly referred to as a call detail record (or "CDR")."); Brockman, 3:4 ("Typically, the CDR is

generated when a call is completed."). A POSITA would have had a reasonable expectation of success incorporating these common features in Lakshmi's system.

197. I also note that Lakshmi describes including the functionality of a traditional switch—which would include functions like CDR generation of a PBX as taught by Sestak—in its softswitch. For example, Lakshmi describes "unbundling of the core functionality of a conventional circuit switch and the distribution of this functionality across the backbone of a packet network in the form of software components that run on commercial standard computers." Lakshmi, pp.6-7. In FIG. 4, Lakshmi illustrates "how the functionality of the circuit switch [on the left] is unbundled and distributed across the packet backbone using the Lucent Softswitch model on the right." Likewise, the billing subsystem of Lakshmi's softswitch would have been in communication with other billing components or entities involved in generation of a bill using the CDRs, for example.

198. Based on my knowledge and experience in the field and my review of Lakshmi and Sestak, a POSITA plainly would have been led to generate CDRs in response to disconnecting the call because critical content stored within the CDR becomes available at this time. Sestak, in addition to describing CDR generation when the call is terminated, also describes that the CDRs include call "end time," which is only available upon disconnecting the call. Generation of the CDR in

response to disconnecting the call would have facilitated efficient and timely CDR generation while including critical information that is only available upon call disconnection. "End time", for instance, is a critical parameter because it is needed to accurately bill a call based on duration.

199. I additionally note that a POSITA would have been led to implement Sestak's CDR generation in response to disconnecting the call in the manner I discussed above because doing so would have been merely the application of a known technique to a known system ready for improvement to yield predictable results. It would have been obvious to a POSITA that implementing Sestak's suggestions to generate CDRs in response to disconnecting the call in Lakshmi's system would have led to predictable results without significantly altering or hindering the functions performed by Lakshmi's system. This is also true of application of Sestak's teachings with the combination of Lakshmi, Elliot, and Capers, discussed below.

200. As I discussed previously, Lakshmi's "softswitch" includes a subsystem in communication with the call coordinator that generates call detail records. Lakshmi describes its softswitch provides support for back-office systems "including billing," and characterizes this as a "basic requirement." I note here again that Lakshmi explicitly teaches "[p]rogrammable event-detail recording",

and describes "[c]all-detail events written to a service provider's event-collection mechanism."

201. Lakshmi describes that "[f]ull connectivity is assumed within a Lucent softswitch." Lakshmi, p.13. This is true as between the billing subsystem of the softswitch and the call coordinator, which are in communication because information from the call coordinator can be obtained by the billing subsystem and vice versa, driving CDR generation. Moreover, a POSITA would have found it obvious, in view of Lakshmi's disclosure, that the call coordinator and billing subsystem are in communication (e.g., directly or indirectly) such that information related to call events can be collected and stored by the billing subsystem. Based on my knowledge and experience in the field and my review of Lakshmi, a POSITA would have recognized that the call coordinator and billing subsystem are in communication as functional components of the softswitch.

202. The combination of Lakshmi and Sestak would have included CDR generation. As I discussed previously, Sestak expressly describes CDR generation. A POSITA plainly would have found it obvious for the call coordinator/SPS to drive the generating of CDRs in view of Lakshmi's teachings of "[p]rogrammable event-detail recording" and "[c]all-detail events written to a service provider's event-collection mechanism."

LAKSHMI, ELLIOTT, CAPERS, AND SESTAK

Based on my knowledge and experience in the field and my review 203. of Lakshmi, Elliott, Capers, and Sestak, a POSITA would have been motivated to apply Capers' suggestions of confirming an incoming circuit could handle inbound calls. For example, a POSITA would have been led, based on Capers' teachings, to confirm the incoming circuit is valid by verifying that the incoming circuit is not in an administratively "blocked" state. When a circuit is in a "blocked" state, the circuit is not in a state appropriate to handle transmission of the voice data to set up a call. Doing so would have enhanced the reliability and efficiency of the system of Lakshmi, Elliott, Sestak, because the incoming circuit would have been checked to confirm usability for the inbound call before proceeding further with call processing. Capers describes that "when requests may not be accomplished due to resource limitations," appropriate responses can be generated by TCL 214 and/or appropriate remedial action taken, such as generating an error message. Capers, 9:48-52. A POSITA additionally would have been motivated to incorporate the advantages associated with identifying and knowing the circuit is not valid, as I discussed previously. Rather than the call simply failing or otherwise not being connected, an appropriate message could be generated, an alternative circuit could be used, or other action taken, for example. Capers, 3:1-7 ("Yet another advantage of the present invention is that is closely monitors the state of calls and resources.

Therefore, the reason a call or circuit is blocked or otherwise unavailable can be known").

204. Additionally, based on my knowledge and experience in the field and my review of Lakshmi, Elliott, Capers, and Sestak, a POSITA would have been led to confirm the incoming circuit is valid by using the circuit identification code to verify that the incoming circuit is not "unequipped" to handle calls via the platform, in accordance with Capers' teachings. Doing so would have similarly enhanced reliability by confirming usability of the inbound call before proceeding further with call processing. If the circuit is not one that is equipped to be used with the softswitch and the associated gateways of Lakshmi, the invalidity is identified and known, in accordance with the advantages described by Capers. Capers, 3:1-7.

205. I additionally note that a POSITA would have been prompted to implement Capers' circuit validation as I discussed in the preceding paragraphs, because doing so would be merely the application of a known technique to a known system ready for improvement to yield predictable results. Based on my knowledge and experience in the field and my review of Lakshmi, Elliott, Capers, and Sestak, a POSITA would have found it obvious that applying the suggestions of Capers to Lakshmi/Elliott/Sestak's system would have led to predictable results without significantly altering or hindering the functions performed by

Lakshmi/Elliott/Sestak's system. I note that any additional modifications to implement Caper's suggestions in Lakshmi/Elliott/Sestak's system would have been carried out by a POSITA with a predictable expectation of success.

206. In the combination, as I discussed previously, the "call coordinator" would have verified the validity of incoming circuits by verifying that the incoming circuit has not been "blocked" and is not "unequipped" on the platform, in accordance with Capers' teachings. I note here again such validation is analogous to the embodiment described by the '441 Patent, which "confirms the call is being processed from a circuit in a valid state" to "prevent processing a call from a circuit that has been administratively locked or through fault management has been disabled." '441 Patent, 9:9-13. Additionally, the "call coordinator" of the combination verifies the validity of incoming circuits by ensuring inbound messages do not include a circuit identification code (CIC) of a circuit not equipped on Lakshmi's softswitch/gateway system. Capers, 9:18-25.

207. As I discussed previously, the '441 patent describes that "[n]etwork gateway 146 includes gateway agents 180 for interfacing with MGCP media gateway switch, IPDC media gateway switch, etc." '441 patent, 8:26-29. Lakshmi's device servers that communicate with gateways to establish a call operate similarly. The call coordinator "arranges media paths between device servers and gateways" and "coordinates multiple device servers for accomplishing

communication." Lakshmi, p.15; p.7("controls the switching and routing of media packets between media gateways."); p.8("controls external trunking gateways, access gateways, and remote access servers (RASs)"); p.9 (describing "device servers" as "supporting" gateways"); p.10 ("identifies the best possible egress gateway to be used for terminating the call and uses this information to command the trunking gateways to perform specific functions."); p.15("in charge of call processing."). The "call coordinator" does this by make requests to the appropriate "device server," which in turn communicates with the gateway to set up an open session. *Id.* I note that Lakshmi explains that the softswitch "can choose to complete most of the calls through a least-cost routing logic that chooses the egress gateway closest to the destination phone." *Id.*

208. Lakshmi provides examples of a number of different device servers used by the call coordinator to control gateways. As one example, Lakshmi describes an "H.323 device server" that interfaces with an access gateway using an H.323 protocol. Additionally, Lakshmi explains that "[c]urrently device servers are implemented for access gateways (H.323 v1/v2), trunking gateways (IPDC 0.12, MGCP, and Sapphire), SS7 signaling interfaces, and SIP devices." Lakshmi, p.15; FIG. 6 (showing an H.323 link between the softswitch and an access gateway); FIG. 8 (showing a PRI device server and an "IPDC (PRI tunneling)" link). 209. The combination of Lakshmi, Elliott, Capers, and Sestak describes that the call coordinator/SPS terminates the data sessions on the requested outgoing resources. For example, Lakshmi explains that the call coordinator "arranges media paths between device servers and gateways" and "coordinates multiple device servers for accomplishing communication." Lakshmi, p.15; p.7("controls the switching and routing of media packets between media gateways."); p.8("controls external trunking gateways, access gateways, and remote access servers (RASs)"); p.10("command the trunking gateways to perform specific functions"); p.15("in charge of call processing."). The "call coordinator" accomplishes this be send signaling to establish the call on selected device servers, gateways, associated channels, etc.

210. The combination of Lakshmi, Elliott, Capers, and Sestak generates a call detail record in response to disconnecting the data session, for the same reasons I discussed above regarding Lakshmi and Sestak. (refer to ¶¶196-205).

LAKSHMI, ELLIOTT, CAPERS, SESTAK, VOLFTSUN, AND BARCLAY

211. Based on my knowledge and experience and my review of Lakshmi, Elliott, Capers, Sestak, Volftsun, and Barclay, a POSITA would have found it obvious to combine these references in the manners I discussed previously. The combinations, and factors that would have motivated a POSITA to implement the
combinations, apply with equal force to the combination of Lakshmi, Elliott, Capers, Sestak, Volftsun, and Barclay.

ADDITIONAL REMARKS

212. I currently hold the opinions expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

213. I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare 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 the Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

December 4, 2018 Dated:

Hours By:

Dr. Vishal Sharma, of Union City, CA

EXHIBIT A

Vishal Sharma, Ph.D., Senior Member, IEEE¹, Fellow, IETE²

Phone: +1 650-641-0082 Cell: +1 408-394-6321 Fax: +1 650-641-0082 Email: v.sharma@ieee.org, vsharma@metanoia-inc.com

Current Position

Principal (2001 – Present) Metanoia, Inc. – Critical Systems Thinking ™ 34906 Herringbone Court Union City, CA 94587-4626, USA. http://www.linkedin.com/in/vishalsharma http://www.metanoia-inc.com/

PROFILE

Synopsis

International technologist and entrepreneur with 20+ years of experience in networking and telecom technologies, spanning research, industry, labs, and academia.

Focus Areas

Packet- and circuit-switched system & network architectures, protocol design, system analysis and optimization, software prototyping, network design & planning techniques and algorithms, and intellectual asset management, with applications to traditional and virtualized: Layer 1 – Layer 7 (optical, IP/MPLS, Ethernet, TCP and above) networks, wireless backhaul, wireless broadband & packet-core networks, IoT networks, and inter- and intra-data center networks.

Specific Areas of Expertise

Analysis and design of telecom and data-center systems and networks: high-speed switch/router architectures for Layers 2-7, switch scheduling and flow management algorithms, devising switch scheduling schemes and virtualization techniques; infrastructure security in SDN/NFV-enabled networks and emerging 5G networks; Carrier network roadmaps and service evolution; QoS algorithms and resource allocation schemes for wireless broadband networks (3G, WiMAX, 4G/LTE, and emerging 5G) and wireline (IP/Ethernet/ATM, optical, and next-generation SONET/SDH and OTN) networks; mobile backhaul techniques for 2G/3G and 4G/LTE networks, LTE network evolution; evaluating security issues in 3G cellular data networks; design of IP-based signaling and routing protocols for optical TDM and WDM networks, recovery schemes for MPLS and optical mesh networks; traffic

¹ The Institution of Electrical and Electronics Engineers, Inc.

² The Institution of Electronics and Telecommunications Engineers, India.

engineering principles, protocols, carrier approaches, planning tools, and algorithms; analysis of all-optical switching schemes, and connection- and flow-control protocols for packet and optical networks; applying queueing theory to analyze telecommunication system design issues; frequency assignment algorithms and capacity analysis for cellular radio; patent investigation and evaluation, patent drafting, and prior art research, including claims review/de-construction, claim construction, infringement deep-dive, evidence of use audits, technology applicability and violation.

Key Achievements

- **SDN/NFV Professional Certification**, MEF, June 2018.
- "Intensive Wireless Communications Engineering: Current Practices," 3-day Intensive IEEE short-course for communications professionals, successfully completed Dec. 4, 2017;
- Multiple IEEE Communications Society courses on wireless engineering, wireless networking, wireless communications, IoT successfully completed: Network Function Virtualization (NFV), Software-Defined Networking (SDN) and the Road to 5G (January 31, 2018), Wireless Evolution of the Overall Network Architecture (February 7, 2018), LTE Fundamentals: The Essentials (February 21, 2018), and Beyond LTE: LTE Advanced, LTE Advanced Pro, and 5G (February 28, 2018); IoT and M2M Essentials (June 6, 2018);
- **12 US patents awarded** in: high-speed switch architectures, switch scheduling, optical routing, MPLS recovery, and IP control of SONET/SDH networks;
- **10 IETF RFCs published**; core contributor in the IETF to the development of IPbased signaling and routing standards for packet, TDM and optical networks; early-contributor to the Optical Internetworking Forum (OIF)'s evolving UNI and NNI signaling/routing standards;
- **Furnished first analytical (probabilistic) framework** characterizing limited wavelength translation in WDM optical networks;
- **Guest Editor of 6 Special Issues of the IEEE Communications Mag.** (IEEE's most highly cited publication with a circulation of 50K+ professionals worldwide);
- **Senior Member (2001)**, IEEE, the highest professional grade of the IEEE and a distinction held by less than 8% of the over 423,000+ IEEE members worldwide;
- Life Fellow (2005), Institution of Electronics and Telecommunications Engineers (IETE), India, a distinction held by less than 7% of the approximately 70,000+ IETE members worldwide;
- Served as an expert witness, have been deposed, and have written expert reports.

- Group Owner & Moderator, Carrier Ethernet Group on LinkedIn: nurtured and grew the Group to 11,710+ telecom professionals from 140+ nations, 3,128+ companies, and 6 continents, and made it a venue for discussions of IP/MPLS, packet-optical, wireless/5G, and Carrier Ethernet systems, architecture, technology, and network deployment issues of contemporary significance.
- Subject Matter Expert at the Broadband Forum (2002);
- Numerous tutorials, conference and journal papers, and book chapters published.

Organizations Worked With or Consulted With

Multi-disciplinary Optical Switching Technology (MOST) Center at UCSB, Tellabs, Ciena, Fujitsu, Jasmine Networks, Digital Instruments, ACT Networks, Mahi Networks, Cariden Technologies, Cypress Semiconductor, Covad Communications, Xilinx, ETSA (Electricity Trust of South Australia) Telecoms (now part of Silk Telecom), SBC/AT&T, France Telecom/Orange, Wipro Technologies, CTS Telecom, BTI Systems, OPNET/Riverbed, and the Indian Institute of Technology Bombay (IITB). Done work with some of the highest-ranking law firms in the US on both the East and West-coasts of the country, providing intellectual property evaluation and assessment.

EDUCATION

Ph.D., Electrical & Computer Engineering, University of California, Santa Barbara.

1997

Thesis: "Efficient Communication Protocols and Performance Analysis for Gigabit Networks."

Advisor: Professor Emmanouel (Manos) Varvarigos.

M.S. (Computer Engineering), University of California, Santa Barbara.	1993
Thesis: "Frequency Assignment and Capacity Analysis for Cellular Radio."	
Advisors: Professors Allen Gersho and Emmanouel (Manos) Varvarigos.	

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B.Tech., **Electrical Engineering**, Indian Institute of Technology, Kanpur. 1991 Project: "Design, Fabrication, and Testing of an Ethernet Repeater." Advisors: Professors K. R. Srivathsan and R. N. Biswas.

PROFESSIONAL POSITIONS

Principal, Metanoia, Inc.	Silicon Valley, California.	2001 – present

- -- Define company focus, devise strategy and growth plans, and develop customer outreach programs in niche-telecom advising for Metanoia, Inc. interaction with C-level client executives
- -- Facilitate deep-technical interaction with senior architects, planners, and design engineers at vendors and carriers
- -- Technical expertise to telecom chip, system, and software companies and to service providers. Including:
 - Drive hardware/software architecture of multi-service systems switches, routers, packet-optical gear used in WAN and metro networks, in data-center interconnects, and inside data centers
 - Advise service providers and telecom/datacom chip, system, and software vendors on:
 - Network architecture roadmap and services definition for Tier 1/2/3 carriers networks evolving to new services and/or products
 - System and network architecture, algorithm and protocol design, system analysis, standards
 - Analyzing advanced architecture issues to facilitate smart design: e.g., SDN or NFV applied to the WAN and the data-center, packet-optical integrated systems, next-generation Ethernet and/or SONET/SDH chip design, mobile 3G/4G/LTE and emerging 5G architectures, RAN virtualization, mobile backhaul strategies
 - Guide companies and industry professionals on topics at the forefront of contemporary networking, covering the latest advances in the design of systems, protocols, and architectures
 - IP networks and systems design: switch architectures, traffic engineering, IPbased VPNs, WiMAX/LTE/4G evolution/design, broadband wireless, 5G core and edge network architecture & design
 - Cloud-based technologies: intra- and inter-data center design principles, methodologies, technologies – best-practices, public- and private-cloud technologies, hybrid cloud, tradeoff study
 - Virtualization technologies: software-defined networking (SDN) and network functions virtualization (NFV) technology insights and applications, deployment tradeoffs, and applications to, for e.g., RAN virtualization, 5G network slicing, EPC virtualization
 - Participate in the Diffserv, MPLS, Traffic Engineering, L2/L3 VPNs, CCAMP WG's of the IETF (2001-2006)

Associate Professor (Contract), Dept. of Electrical Engineering, IIT Bombay, Mumbai, India and Silicon Valley, USA. 2004 – 2007

- -- Lead research in wireline- and wireless-broadband access technologies, based on my past and ongoing industry experience. Established and lead the WiNETS (Wireless Networks) Research Group. Areas of focus and activities included:
 - Metro/Access networks
 - Design of scheduling algorithms for 802.16 (WiMAX)-based broadband networks
 - Investigation and development of efficient traffic management schemes
 - Wireless and Sensor networks
 - Development of an IEEE 802.15-based (Zigbee-based) ad-hoc wireless network testbed
 - Blueprint an indigenous sensor node, modeled after Berkeley MOTES
 - Architecture, modeling and analysis of stable routing protocols for ad-hoc networks
 - Large-scale simulations of QoS schemes in broadband wireless access (BWA) networks
 - Network infrastructure security
 - Experiments and algorithms to assess security in 3G cellular networks
 - Scrutiny of security loopholes in Internet protocols (e.g., routing and signaling protocols)
 - Inference algorithms and tools for proactive detection of network security problems (e.g., in the RAN and backbone) in cellular data networks
 - Mobile applications and architecture
 - Application development challenges in smart mobile devices
 - Research novel mobile software architectures to meet these challenges
- -- Developed and taught junior- to- graduate-level courses, spanning digital circuits, basic electronics, and electronics laboratories to queueing theory, scheduling algorithms, circuit- and- packet-switching, and advanced networking protocols and systems to different class sizes, several exceeding 100+ students and a half-dozen+ teaching assistants.
- -- Performed departmental service as Coordinator of Masters and Dual-Degree seminars and thesis allocation, evaluation, and assessment.
- -- Served on Departmental Committees to interview incoming Masters and Ph.D. candidates, sat on evaluation committees for multiple Masters and Ph.D. students
- -- Guided over a dozen graduate course research projects, two of which were accepted for publication in national conferences, and an extended version of one was accepted for publication at IEEE Globecom'06, one of IEEE's largest gatherings of researchers and practitioners of telecommunications.

- -- Supervised graduate and undergraduate research and theses (remotely and/or in person when in India)
 - Eight students graduated; also co-guided two graduate/Ph.D. students.
 - Research focused on scheduling and traffic management algorithms for: highspeed switches and networks, broadband wireless (Wi-Max) networks, ad-hoc and sensor networks; network infrastructure security, and mobile applications and architecture.

Principal Architect, Jasmine Networks, Inc., San Jose, California. 2001

- -- Architected and designed a common MPLS-based control plane for both packet and TDM data.
- -- Strengthened Jasmine's industry standing by my leadership role in numerous MPLS forums

Research Engineer, Tellabs Research Center (TRC), Cambridge, Massachusetts.

1998 - 2000

- -- Lead the IP networking research effort at the Cambridge office of the Research Center. Projects included:
 - Analysis and design of high-speed switch router architectures, conducted architectural evaluation of routers from over 10 leading core- and edge-router startups.
 - Strategic technical guidance to Tellabs' Advanced Business Development for acquisitions in the terabit router space.
 - Designed an IP flow management algorithm for application in parallel high-speed switches (patented).
 - Devised path protection schemes for multiprotocol label switching (MPLS) (patented) and formulated MPLS-based recovery framework.
- -- Supervised a summer project for a Ph.D. student from MIT that produced a novel scheduling algorithm for parallel cross-bar switches that is part of the student's Ph.D. dissertation (patented).
- -- Participated in the Diffserv, MPLS, Traffic Engineering, L2/L3 VPN WG's of the IETF. Contributed to MPLS recovery; eventually published as RFC 3469.
- -- Responsible for selecting, screening, and phone interviewing a dozen candidates for the position of IP Networking Research Engineer at the Research Center.

Post-Doctoral Researcher, Multi-disciplinary Optical Switching Technology (MOST)Center, UCSB, Santa Barbara, California.1997 – 1998

- -- Designed and evaluated all-optical switches and switching schemes for WDM/DWDM networks, based on MEMS technologies.
- -- Published one conference (IEEE MPPOI'98) and one journal (IEEE TON) paper.

INTELLECTUAL PROPERTY and PATENT ADVISING

- -- Patent analysis and evaluation for investment houses, companies, and patent attorneys in a variety of circumstances -- portfolio acquisition and expansion, licensing, portfolio value assessment, patent strategy, and patent litigation.
- -- Work has included: prior-art research in complex technology patents, claims review/de-construction, claim chart dissection, claim chart construction.
- -- Infringement analysis, evidence-of-use investigation, technology analysis and violation, scrutinizing validity.
- -- A major contribution of my work has been enabling complex telecommunications patents (in my areas of expertise) to be succinctly and easily understood by legal and investment experts.
- -- Have served as an expert witness; have provided expert reports (e.g., on invalidity and non-infringement), and have been deposed.

AWARDS and HONORS

- 1. **Judge, MEF Ethernet Excellence Awards**, Announced at MEF GEN 17, Orlando, FL, November 13-16, 2017.
- 2. **Invited Speaker** on *"Intellectual Property Challenges and IoT,"* IoT World, May 12, 2016.
- 3. **Invited Attendee**, Open Networking Innovation Forum³ (ONIF), Open Networking Summit (ONS), April 4, 2017, and March 27, 2018.
- 4. **Group Owner & Manager**, Carrier Ethernet Group on LinkedIn, March 2012 present. (11,910+ members spanning 140 nations, 3,128 companies, 6 continents)
- 5. **Judge, MEF Ethernet Excellence Awards**, Announced at MEF GEN 16, Baltimore, MD, November 7-10, 2016.
- 6. **Judge, MEF Ethernet Excellence Awards**, Announced at MEF GEN 15, Dallas, TX, November 16-19, 2015.

³ From the ONIF website "an invitation-only think-tank, gathering an elite group of open networking visionaries for a valuable dialog on the state of open networking." http://events.linuxfoundation.org/events/open-networking-summit/extend-the-experience/onif

- 7. Judge, MEF Ethernet Excellence Awards, Announced at MEF GEN 14, Washington, D.C., November 17-20, 2014.
- 8. **IETE Fellow**, Elected by IETE Memberships Committee, February 2005.
- 9. **Subject Matter Expert**, MPLS Forum (now Broadband Forum), October 2002.
- 10. **IEEE Senior Member**, Elevated by IEEE Admissions & Advancement Committee, August 2001.
- 11. Key Contributor Award, Tellabs Operations, Inc., December 1999 and July 2000.
- 12. **Innovation Certificate**, Tellabs Operations, Inc., June 2000.
- 13. Who's Who in Information Technology, Inducted, February 1999.
- 14. **Judging Committee**, STC Student Technical Writing Contest, Santa Barbara, May 1996 & 1997.
- 15. **Winner**, STC Student Technical Writing Contest, Santa Barbara, May 1994 and 1995.
- 16. **Motorola Paul V. Galvin Fellow**, Sept. 1991-June 1993. (Fellowship awarded to only two engineers (a male and a female) throughout India for Masters study in the US.)
- 17. **Best B. Tech. Project** in Electrical Engineering, Indian Institute of Technology, Kanpur (IITK), 1991.
- 18. **National Talent Search Scholarship**, Govt. of India, 1985-1991 (Awarded, at that time, to only 330 candidates throughout India for undergraduate study.)

PATENTS GRANTED (US)

- 1. Method and Apparatus for Validating a Path Through a Switched Optical Network, 7,095,956, Issued August 22, 2006.
- 2. Method and Apparatus to Switch Data Flows Using Parallel Switch Fabrics, 7,123,581, Issued October 17, 2006.
- 3. **High-Speed Parallel Crossbar Switch**, *7*,123,623, Issued October 17, 2006.
- 4. **Reverse Notification Tree for Data Networks**, 7,298,693 B1, Issued November 20, 2007.
- 5. **Method and Apparatus for Detecting MPLS Network Failures**, 7,315,510 B1 Issued January 1, 2008.

- 6. System and Method for Network-Layer Protocol Routing in a Peer-Model Integrated Optical Network, 7, 457, 277, Issued November 25, 2008.
- 7. **Method for Establishing an MPLS Data Network Protection Pathway**, *7*,796,504, Issued September 14, 2010.
- 8. **Protection/Restoration of MPLS Networks**, 7,804,767, Issued September 28, 2010.
- 9. **Reverse Notification Tree for Data Networks**, 7,881,184, Issued February 1, 2011.
- 10. **Method and Apparatus for Detecting MPLS Network Failures**, 8,130,637 B1 Issued March 6, 2012.
- 11. **Reverse Notification Tree for Data Networks**, 8,588,058, Issued November 19, 2013.
- 12. **Method for Establishing an MPLS Data Network Protection Pathway**, 8,737,203, Issued May 27, 2014.

CONFERENCE SESSIONS CHAIRED/INVITED

- 1. **NFV and Zero Touch Forum**, Session Chair, NFV World Congress, San Jose, CA, April 26, 2018.
- 2. **SD-WAN & Business Forum**, Session Chair, NFV World Congress, San Jose, CA, May 4, 2017.
- 3. **Forum-2 Operations**, Session Chair, NFV World Congress, San Jose, CA, April 21, 2016.
- 4. "Virtualization for 5G Network Architecture" Invited Panel Chair, 5G Forum USA, Palo Alto, CA, April 12, 2016.
- 5. "How do NFV and MEC Play Together? How Can Advances in NFV Synergistically Help in Advancing MEC?" Leader, Interactive MEC Roundtable, MEC Focus Day, Carrier Network Virtualization, Palo Alto, CA, December 3, 2015.
- 6. "**CNV 2015 Day Two, Track A**," Session Chair, Carrier Network Virtualization, Palo Alto, CA, December 2, 2015.
- 7. **"Service Provider Technology Track 2**," Track Chair, MEF GEN 15, Dallas, TX, November 18, 2015.
- 8. **"Open Source IoT in the Cloud**," Session Chair, IoT Open-Source Summit at IoT World Summit, San Francisco, CA, May 13, 2015.

- **9. "IP Management in Open Source,"** Chair, IoT Open Source Summit, IoT World, San Francisco, CA, May 13, 2015.
- 10. **SDx Summit**, Chair, Carrier Network Virtualization (CNV 2014), Palo Alto, CA, December 9, 2014.
- 11. "**If We Don't Have a Definition of What It Is, What Isn't SDN?**," Chairman, Debate/Roundtable, MPLS & Ethernet World Congress, Paris, France, March 13, 2013.
- 12. Carriers World Middle East, Chairman, Day One, Dubai, UAE, October 1, 2012.
- 13. "**MPLS End-to-End: A Realistic Paradigm?**," Chairman, Debate/Roundtable, MPLS & Ethernet World Congress, Paris, France, February 9, 2012.
- 14. **"Smart Management for Carrier Health and Reduced TCO!**" Panel, NANOG54, San Diego, CA, February 5, 2012.
- 15. "MPLS-TP OAM and Use Cases," Chairman, Debate/Roundtable, MPLS & Ethernet World Congress, Paris, France, February 2011. (I could not make the final event due to a last-minute client scheduling conflict. The event was chaired by Carsten Rossenhoevel of EANTC, AG.)
- 16. **"Services, Session Resiliency & Convergence, OAM and Management,**" Chairman, Day Three, MPLS & Ethernet World Congress, Paris, France, February 13, 2009.
- 17. "MPLS/Ethernet Convergence, PBB-PBT-T-MPLS, Case Studies BT, Wind, Belgacom," Chairman, Day One, MPLS & Ethernet World Congress, Paris, France, February 6, 2008.
- 18. "**Resiliency, Case Studies, MPLS & Mobile Networks, Multicast Issues, Enterprise MPLS, and Testing**," Chairman, Day Three, MPLS & Ethernet World Congress, Paris, France, February 9, 2007.
- 19. "Convergence, MPLS@10, Carrier Migration Strategies, Metro Ethernet & Access Network Issues," Chairman, Day One, MPLS World Congress, Paris, France, February 7, 2006.
- 20. "Next-Generation Multi-service Edge, Voice over MPLS, Interdomain Routing, Multicast Issues, BT Real-time Broadcast Video," Chairman, Day One, MPLS World Congress, Paris, France, February 16, 2005.
- 21. **"Traffic Engineering, High-Availability Solutions, Optical, and New Applications for MPLS, and Case Studies**," Chairman, Day Three, MPLS World Congress, Paris, France, February 7, 2003.
- 22. "Carrier Migration Strategies, Advances in Optical Components, Management & Planning of Optical Networks, Optical Network Evolution," Co-Chairman,

Industry Watch Program, SPIE Int'l Conference on Optical Networking and Communications (Opticomm 2002), Boston, MA, August 1, 2002.

PANELS CONCEIVED, DEVELOPED, & MODERATED, AND/OR PARTICIPATED

- 1. **"Intellectual Property Ramifications in the Age of IoT**," Invited Chair/Moderator, Eoc-System Center Stage, IoT World, Santa Clara, CA, May 17, 2018.
- 2. "How LPWAN Fills the Gap between Wide-Area Cellular and Local Area Short-Range Wireless Technologies," Invited Panelist, IoT Architecture Symposium, IoT World, Santa Clara, CA, May 17, 2017.
- 3. **"Understanding Customer Data and Anticipating Needs**," Invited Panelist, IoT Analytics Symposium, IoT World, Santa Clara, CA, May 12, 2016.
- 4. "Is NFV an Enabler for 5G and Mobile Edge Computing (MEC)?," Leader Rountable, 5G Forum USA, Palo Alto, CA, April 13, 2016.
- 5. "**Roadmap and Requirements for Mobile Edge Computing (MEC): 2016 and Beyond**," Invited Panelist, Mobile Edge Computing (MEC) Focus Day, Carrier Network Virtualization, Palo Alto, CA, December 3, 2015.
- 6. "**Status of NFV Transformation Going Into 2016**," Invited Chair/Moderator, Carrier Network Virtualization, CNV 2015, Palo Alto, CA, December 2, 2015.
- 7. "Network Functions Disaggregation: Innovations in NFV, SDNs, and Optical Networks," Invited Moderator, MEF GEN 15, Dallas, TX, November 18, 2015.
- 8. "Reliability in the NFV World How Can 100% Service and Application Reliability be Achieved," Invited Chair/Moderator, NFV World Congress, San Jose, CA, May 6, 2015.
- 9. "**The SDN & NFV Promise to Make the Network Agile and Optimum**," Invited Chair/Moderator, 5G Forum USA, Palo Alto, CA, April 15, 2015.
- 10. "**Evolution to a Software-Enabled Age**," Invited Moderator, SDx Summit, Carrier Network Virtualization, Palo Alto, CA, December 9, 2014.
- 11. "**Commercial Opportunities Posed by SDx**," Invited Moderator, SDx Summit, Carrier Network Virtualization, Palo Alto, CA, December 9, 2014.
- 12. "Evolution of the Carrier Ethernet Professionals Community," Invited Moderator, MEF's GEN 14, Washington, D.C., November 17, 2014. (Panelists from PLDT, Telin Singapore, & Sri Lanka Telecom.)

- 13. "Mobile Backhaul Energy Efficiency, Small Cells; Traffic Optimization Multi-Layer Network Optimization & Capacity Planning," Chairman, Day Three (morning), MPLS & SDN World Congress, Paris, France, March 22, 2013.
- 14. **"SDN: Reality Check!**," Chairman & Moderator, On-line Int'l Roundtable Series involving a dozen+ experts from, among others, IBM, Juniper, Alcatel-Lucent, CIMI Corp, Infinera, Cyan, Ericsson, RAD, MRV Communications, and Current Analysis, February-March 2013.
- 15. "**Network-Centric Performance Management- So Near and Yet So Far**," Moderator & Coordinator, NANOG56, Dallas, TX, October 25, 2012.
- 16. "End-to-End Performance Management & Monitoring for Operational Efficiency," Moderator & Coordinator, On-line International Panel, involving a dozen+ experts from TELUS, Tata Communications, Twitter, Cisco, InfoVista, Packet Design, OPNET, CTS Telecom, LinkedIn, July 25, 2012.
- 17. "Assessing Carrier Network Health for Reduced TCO," Moderator & Coordinator, India Telco Summit, Mumbai, India, December 11, 2011.
- 18. "**Capacity Planning Panel**," Moderator & Coordinator, NANOG52, Denver, CO, June 11, 2011.
- 19. "Access, Transport & Carrier Ethernet," Invited Panelist, Debate, MPLS & Ethernet World Congress, Paris, France, February 11, 2009.
- 20. "MPLS and Carrier Ethernet: Where and How? A Fruitful Conversation between Carrier Ethernet and MPLS Vendors Mediated by Service Providers," Chairman, Debate/Roundtable, MPLS & Ethernet World Congress, Paris, France, February 7, 2007.
- 21. "Carrier Ethernet and MPLS: Metro Access, Layer 2 VPNs, Pseudo-Wires and MS-PWs, VPLS, Inter-domain Issues & GMPLS Perspectives," Chairman, Debate/Roundtable, MPLS World Congress, Paris, France, February 7, 2006.
- 22. "Security & Scaling of MPLS, MPLS Network Migration & OSS and Billing, Edge/Metro/Access Network Issues for MPLS-based Services," Chairman, Debate/Roundtable, MPLS World Congress, Paris, France, February 16, 2005.
- 23. "**Future Directions**," Invited Panelist, MPLS 2002, Washington, D.C., October 29, 2002.
- 24. "**The Optical Revolution: When?**," Invited Panelist, MPLSCon'02, March 2002, McLean, VA.
- 25. "**MPLS: State of the Art and Evolutions**," Invited Panelist, MPLS Forum, Paris, France, March 7-10, 2000.

TECHNICAL ONLINE SEMINARS DEVELOPED & CONDUCTED

- 1. "SD-WAN Validation Using Network Emulation Tools", CE Live! ™, Nov. 9, 2017. (With Neal Roche, CEO, Apposite Technologies, and Tom Nadeau, Principal, Lucidvision.)
- 2. "The What, Why, and How of Open Networking and a Peek at the Open Networking Summit 2017", CE Live! [™], March 16, 2017. (With Arpit Joshipura, GM Networking & Orchestration, Linux Foundation.)
- 3. "Carrier Ethernet Network Management Systems Architecture & Demo," CE Live! ™, December 16, 2015. (With Roy Silon, VP Engineering and Yuri Denisov, Director, Product Management, Atrinet, Israel.)
- 4. "**The Business Case for Direct Connect**," CE Live! [™], October 22, 2015. (With William B. Norton, VP Research, IIX, CA; and Dumisani Dlamini, Dimension Data, Johannesburg, South Africa.)
- 5. "**Bandwidth Profiles in MEF 6.2, SDN Data Plane Design, State of Broadband, Industry News, and More**," CE Live! [™], June 26, 2015. (With Jon Fieffer, Fujitsu Network Communications, TX; Ralph Santitoro, MEF Distinguished Fellow, MEF & Fujitsu Network Communications, TX.)
- 6. "Unraveling the MEF's Third Network & LSO Initiatives," CE Live! ™, June 3, 2015. (With Rami Yaron, Co-Chair MEF Global Marketing Committee & VP of Strategy & Technology, Telco Systems, NJ.)
- 7. "**How Emerging Operators Could Evolve Towards the Cloud**," CE Live! ™, May 20, 2015. (With Amy Copley, Director of Service Provider Solutions, BTI Systems, Boston, MA.)
- 8. "Carrier-Grade SDN, ALU-No … More?, Ethernet Speeds, More NFV, and the "CE in the Cloud Age!" - Exclusive Workshop," CE Live! ™, May 5, 2015 (With Chandra Sekhar Mallela, Altera, Penag, Malaysia, Abdul Ravoof, Aricent, Pune, India.)
- "Network Performance, Lifecycle Service Orchestration, Viva Net Neutrality (?), Service Chaining, & Exploding Mobile Video!," CE Live! ™, March 11, 2015.
- 10. "SDN/NFV Technology Considerations, L2CP Matters, FB DC Designs, & Mobile Video," CE Live! [™], February 25, 2015. (With Marcus Friman, Netrounds, Sweden; Khurram Shahzad, Technology Architect, Australia.)
- 11. "Old School Telcos, Wheeler(ing) & Dealing, Virtual VNF's, SDDCs, 5G Small Cells! Part 2," CE Live! ™, February 18, 2015.

- 12. "Old School Telcos, Wheeler(ing) & Dealing, Virtual VNF's, SDDCs, 5G Small Cells! – Part 1," CE Live! [™], February 17, 2015. (With Hashiem Croeser, Neotel South Africa; Paolo Volpato Alcatel-Lucent, Italy; Larry Samberg, Twinspruces Consulting, Boston, MA.)
- 13. "QoS & Traffic Mgt., Cloud WAN, SDN/NFV Strategy, Virtual CPEs, and More!," CE Live! [™], February 4, 2015. (With Scott Raynovich, Rayno Media, Inc., Bozeman, MT.)
- 14. "Carrier Ethernet: Questions & Issues for Today," CE Live! ™, December 28, 2012.

TECHNICAL ONLINE VIDEOS DESIGNED & PRODUCED

- 1. "How Do Schedulers in Routers Work? Understanding RR, WRR, WFQ, and DRR Through Simple Examples," Metanoia, Inc., Network Design & Architecture Series, March 9, 2016.
- "Which Scheduling Mechanisms are Implemented in Routers & Most Widely Deployed by Service Providers?" Metanoia, Inc., Network Design & Architecture Series, March 9, 2016.
- 3. **"TC3 Carrier Case Studies Part 3: Cloud Infrastructure (NTTI3 (USA, Japan) , TeliaSonera (Finland), BT (UK)),"** Metanoia, Inc., Network Design & Architecture Series, October 6, 2015.
- 4. **"TC3 Carrier Case Studies Part 2: Improving Customer Experience (Bouygues Telecom (France), and Rogers (Canada),"** Metanoia, Inc., Network Design & Architecture Series, October 6, 2015.
- 5. **"TC3 Carrier Case Studies Part 1: Wireless Infrastructure (EE(UK) and Telstra (Australia)),"** Metanoia, Inc., Network Design & Architecture Series, October 6, 2015.
- 6. "What You Should Know About Working with Telcos Today! (Lessons from the TC3 Summit Operator Panel)," Metanoia, Inc., Network Design & Architecture Series, October 5, 2015.
- 7. "**Key Takeaways for the Carrier Ethernet Ecosystem from TC3 Summit 2015**," Metanoia, Inc., Network Design & Architecture Series, October 4, 2015.
- 8. "Understanding AIA, Alice & Open-Source: An Intellectual Property Troika for IoT (&Beyond!) Success," Metanoia, Inc., February 20, 2015.

- 9. "Why Are CIR/EIR Called Average Rates? What Does "Average" Really Mean?: Understanding Policer Rates," Metanoia, Inc., Network Design & Architecture Series, February 13, 2015.
- 10. "**How Not To Configure Committed Burst Size (CBS) On Your Network**," Metanoia, Inc., Network Design & Architecture Series, February 11, 2015.
- 11. "Monitoring Service Uptime in a Multipoint-to-Multipoint Carrier Ethernet Service," Metanoia, Inc., Network Design & Architecture Series, February 11, 2015.
- 12. "**Performance Requirements for a PSN Delivering TDMoIP Traffic**," Metanoia, Inc., Network Design & Architecture Series, February 10, 2015.

WORKSHOPS/SEMINARS/TUTORIALS - designed, developed, and delivered

- 1. "Understanding Military Grade Optical-Ethernet Networks: A Versatile Solution for Achieving DoD's Net-Centric Operations Strategy," Industry Tutorial, IEEE Milcom'10, San Jose, CA, November 1, 2010. (With S. Davari, Broadcom Corp.)
- "Elements of Cross-Layer System & Network Design for QoS-Enabled Wi-Max Networks," Industry Tutorial, IEEE Milcom'07, Orlando, FL, October 29, 2007. (With Prof. A. Karandikar, IIT Bombay.)
- 3. "Appreciating Key Design Aspects of Wi-Max Networks," Metanoia, Inc. "Next-Generation Systems and Networks" Workshop Series, Bangalore, India, July 17, 2007.
- 4. "Metro Ethernet: Understanding Key Underlying Technologies," Metanoia, Inc. "Next-Generation Systems and Networks" Workshop Series, Bangalore, India, July 17, 2007.
- 5. "Facts You Should Know About QoS Enabled Wi-MAX Networks," Metanoia, Inc. Workshop Series, Bangalore, India, January 25, 2007.
- 6. "Unraveling QoS in 802.16 Wireless Broadband Networks: The Role of MAC, Scheduling and Cross-Layer Design," Industry Tutorial, IEEE Globecom'06, San Francisco, CA, November 27, 2006. (With Prof. A. Karandikar, IIT Bombay.)
- 7. "**Multi-Protocol Label Switching: Basics and Applications**," Invited Seminar, Executives Meeting, Mahanagar Telephone Nigam Ltd. (MTNL), Mumbai, India, April 26, 2006.
- 8. "**Modern IP-Based VPNs: Technology, Operation, Implementation & Design**," Metanoia, Inc. "Next-Generation Networking Technologies" Workshop Series, Bangalore, India, July 22-23, 2005.

- "High-Performance Switch Architectures: Theory & Practice," Metanoia, Inc. "Next-Generation Networking Technologies" Workshop Series, Bangalore, India, July 19-20, 2005.
- 10. **"Traffic Engineering: Techniques and Current Practices**," Short Course, Usha-Martin Academy of Communication Technology, Chennai, India, December 3, 2002.
- 11. "Introduction to Optical Control Plane Standards & Technology: Overview, Discovery, Routing, Path Computation, Signaling, Inter-Domain Routing," Short Course, Opticomm'02, Boston, MA, July 29, 2002. (With Dr. Greg Bernstein, Ciena.)

KEYNOTES & INVITED TALKS

- 1. "**The Role of Zero Touch in NFV-Based Cloud Networking**," Chair's Market Highlights, NFV and Zero Touch Track, NFV World Congress, San Jose, CA, April 26, 2018.
- 2. **"The Evolution of SD-WAN and Implications for the Future**," Chair's Market Highlights, SD-WAN and Business Track, NFV World Congress, San Jose, CA, May 4, 2017.
- 3. **"Intellectual Property Challenges and IoT**," Invited Speaker, IoT Eco-System Center-Stage, IoT World, Santa Clara, CA, May 12, 2016.
- 4. **"Challenges and Opportunities in Operationalizing NFV**," Chair's Market Highlights, Forum 2 Operations, NFV World Congress, San Jose, CA, April 21, 2016.
- 5. "**Virtualization for 5G Network Architecture An Introduction**," Opening Panel presentation, 5G Forum USA, Palo Alto, CA, April 12, 2016.
- 6. "Software and Virtualization: Benefitting the Data Center and Beyond," Opening Talk, SDx Summit, Carrier Network Virtualization, Palo Alto, CA, December 9, 2014.
- 7. "**Making the Intangible Tangible via R&D Innovation**," Invited Talk, 2nd Futurewei Vision Summit, Santa Clara, CA, November 6, 2014.
- 8. "A WiMAX Shindig: Discussing Contemporary Technological and Market Issues," Invited Talk, Forschungszentrum Telekommunikation Wien (FTW), Vienna, Austria, February 4, 2008.
- 9. "Network Planning or Design: An Art or a Science," SANOG (South-Asian Network Operators Group) 9, Plenary Keynote Talk, Colombo, Sri Lanka, January 23, 2007.

- 10. **"A Survey of Canonical Features of, and Recent Advances in, IP Network Planning and Traffic Engineering (TE) Tools**," Invited Talk, Western Australia Telecom Research Institute (WATRI), Curtin University of Science & Technology, Perth, Australia, March 3, 2006.
- 11. "Network Infrastructure Security in Cellular Data Networks: An Initial Investigation," Invited Talk, CSIRO (Commonwealth Scientific and Industrial Research Organization), Sydney, Australia, February 28, 2006.
- 12. **"Inter-Domain TE and QoS: Some Key Aspects & Challenges**," Invited Talk, Australian Communication Industry Forum (ACIF), Sydney, Australia, February 27, 2006.
- 13. "Inter-Domain Traffic Engineering: Motivation, Key Aspects & Challenges," Invited Talk, Acreo AB, Stockholm, Sweden, May 27, 2005.
- 14. "Does Self-Similarity of Internet Traffic Matter at Timescales Relevant to QoS?," Invited Talk, Forschungszentrum Telekommunikation Wien (FTW), Vienna, Austria, February 15, 2005.
- 15. **"Is Internet Traffic Self-Similar at Timescales Relevant to Quality-of-Service**," Invited Talk, Infosys Technologies & Wipro Technologies, Bangalore, India, December 22, 2004.
- 16. "**Recent Advances in Network Planning/TE Tools: A Discussion**," Invited Seminar, SBC Network Services Engineering Group, San Ramon, CA, April 20, 2004.
- 17. "Carrier Strategies for Backbone Traffic Engineering and QoS," Cisco NERD Lunch, San Jose, CA, February 26, 2004.
- 18. **"Internet Traffic is Not Self-Similar at Timescale Relevant to QoS**," Invited Seminar, SBC Labs., San Ramon, CA, February 25, 2004. (Joint work with Arman Maghbouleh, Cariden; Thomas Telkamp, Global Crossing; Steve Gordon, SAIC.)
- 19. **"Considerations for Inter-Domain Optical Routing**," Invited Talk, Fujitsu Labs. of America, Santa Clara, CA, May 17, 2002.
- 20. "**Modern Carrier Strategies for Traffic Engineering**," Invited Talk at Infosys Technologies, Cisco Systems India Limited, Tejas Networks, Bangalore, India, November 28-December 1, 2002.
- 21. "**Approaches to Designing a High-Performance Switch Router**," Invited Talk, HCL Technologies, Chennai, India, December 2, 2002.
- 22. "Approaches to Designing a High-Performance Switch Router," Invited Talk at Wipro Technologies, Tata Elxsi Limited, Indian Institute of Science (IISc), Bangalore, India, November 28-December 1, 2002.

- 23. "**Approaches to Designing a High-Performance Switch Router**," Invited Talk at IIT Bombay, Mumbai, India, November 21, 2002.
- 24. "An Assessment of QoS and Protection in MPLS," Invited Talk, Tata Infotech Limited (now part of TCS), Mumbai, India, July 26, 1999.

CONFERENCE COMMITTEES

- 1. Advisor, Speaker & Contributor, IoT World, Informa Telecoms & Media/365Knect, April 2014 Present.
- 2. Advisor, Speaker & Contributor, Carrier Network Virtualization, Informa Telecoms & Media/365Knect, August 2014 August 2016.
- 3. Advisor, Speaker & Contributor, 5G Forum USA, Informa Telecoms & Media, January 2014 2016.
- 4. **Co-Chair, Cloud Infrastructure Track**, TiECon 2014, Santa Clara, CA, May 16, 2014.
- 5. Advisory Board Member, Cloud Infrastructure Track, TiECon 2014, December 2013 May 2014.
- 6. **Member, Scientific Committee,** MPLS & SDN World Congress, Paris, France, 2013 2014.
- 7. Advisory Board Member, Software-Defined Infrastructure Track, TiECon 2013, December 2012 May 2013.
- Advisory Board Member, Carrier's World Asia, Terrapinn, Inc., November 2011

 March 2012.
- 9. **Steering Committee**, India Telco Summit, Mumbai, India, August December 2011.
- 10. **Member, Scientific Committee,** MPLS & Ethernet World Congress, Paris, France, 2003-2012.
- 11. Member, Scientific Committee, Wi-Max Summit, Paris, France, 2005-2008.
- 12. Board Member, Conference Advisory Board, MPLSCon/FutureCon, 2001-2010.
- 13. Technical Program Committee (TPC) Member
 - iPOP (Int'l Conference on IP and Optical Networks), 2005-2012, 2014, 2015
 - IEEE Globecom, 2006, 2007, 2008
 - IEEE LAN/MAN Workshop, 2005, 2006, 2007
 - 1st International Workshop on Bandwidth-on-Demand, 2006.

- SPIE Opticomm, 2002, 2003.
- PATHNets, 2004.
- Internetworking, 2003.
- Int'l Workshop on Design of Reliable Communication Networks (DRCN) 2003, 2005.

INDUSTRY SERVICE

- 1. **IEEE eCareerMentor**, IEEE Mentor Centre, Advising IEEE members on career and professional matters, April 2013 present.
- 2. **Program Coordinator**, IEEE ComSoc SCV (Santa Clara Valley) Chapter, September 2013 present.
- 3. **Group Moderator & Owner**, Carrier Ethernet Group on LinkedIn, March 2012 present.
- 4. **Contributing Author**, "Generalized MPLS" MFA Forum (MPLS, Frame Relay, ATM Forum) Tutorial, June 2004.
- 5. **Core Contributor**, "Migrating to MPLS," MFA Forum (MPLS, Frame Relay, ATM Forum) Tutorial, December 2002
- 6. **Mentor, Stanford IEEE Mentor Program**, Stanford University, 2001-02 and 2002-03.
- 7. Over 145+ invited talks, seminars, workshops, tutorials, colloquiums at numerous organizations in the US (e.g., Cisco Systems, SBC Communications, Tellabs, Univ. of Colorado, George Washington Univ., Bell Labs, BBN/GTE, Fujitsu Labs., Cypress Semiconductor, RazaFoundries) and abroad: Europe: Acreo AB, Sweden, MPLS World Congress, France, FTW, Vienna, Austria; India (e.g., Indian Institute of Science, Indian Institutes of Technology (Bombay, Madras, Kanpur, Delhi), TataInfotech, Sasken Systems, Motorola India, Infosys, Wipro, Tata Elxsi, Cisco India, Tejas Networks, and HCL Technologies, MTNL (Mahanagar Telephone Nigam Ltd.), Tata Indicom/VSNL); Australia: Australian Communications Industry Forum (ACIF), Sydney, Australia, CSIRO (Commonwealth Industrial Scientific and Research Organization), Australia, Western Australian Telecom Research Institute (WATRI), Perth, Australia.

INDUSTRY COURSES COMPLETED

- 1. "**IoT and M2M Essentials**," IEEE ComSoc, Training Course, June 6, 2018.
- 2. "Beyond LTE: LTE Advanced, LTE Advanded Pro, and 5G," IEEE ComSoc, Training Course, February 28, 2018.

- 3. **"LTE Fundamentals: The Essentials**," IEEE ComSoc, Training Course, February 21, 2018.
- 4. **"Wireless Evolution of the Overall Network Architecture**," IEEE ComSoc, Training Course, February 7, 2018.
- 5. "Network Function Virtualization (NFV), Software-Defined Networking (SDN) and the Road to 5G," IEEE ComSoc, Training Course, January 31, 2018.
- 6. **"Intensive Wireless Communications Engineering: Current Practices**," IEEE ComSoc Continuing Education for Communications Professionals, IEEE Short-Course, Dec. 2-4, 2017.

CERTIFICATIONS EARNED

1. "SDN/NFV Professional Certification," MEF⁴, June 15, 2018.

EDITORSHIPS

- 2. **"SDN Use Cases for Service Provider Networks: Part 2**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, April 2017.
- 3. **"SDN Use Cases for Service Provider Networks: Part 1**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, October 2016.
- 4. **"Next-Generation Carrier Ethernet Transport Technologies**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, March 2008.
- 5. **"Advances in Virtual Private Networks**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, April 2007.
- 6. **"Challenges in Enabling Inter-Provider Service Quality on the Internet**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, June 2005.
- 7. **"OAM in MPLS-based Networks**," Co-Guest Editor, IEEE Communications Mag., Feature Topic Issue, October 2004.

BOOK CHAPTERS

 V. Sharma and A. Karandikar, "Quality-of-Service in Wireless Networks," Invited Chapter in Technical, Commercial, and Regulatory Challenges for QoS: An Internet Service-Model Perspective, by Xipeng Xiao, John Wiley & Sons, September 2008, Chapter 13, pp. 225-246.

⁴ MEF's first operator-grade, industry-wide certification that validates professionals' knowledge, skills and abilities in the domains of software-defined networking (SDN) and network functions virtualization (NFV).

 V. Sharma and R. Sharma, "Web Switching," Invited contribution to Enterprise Networking: Multi-layer Switching and Applications, Idea Publishing Group, PA, USA, Eds. V. Theoharakis and D. Serpanos (Editors), January 2002, pp. 86-104.

INDUSTRY PUBLICATIONS

Industry Articles

- 1. V. Sharma, "5 Fundamental Schedulers for Every System/Network Architect's Toolkit," LinkedIn Pulse, March 23, 2016.
- 2. V. Sharma, "4 Questions Network/System Architects Should Answer about Scheduling," LinkedIn Pulse, March 21, 2016.
- 3. V. Sharma, "What Challenges Do Carriers Face in Realizing an SDN/NFV Vision (Part 2 of 2)," LinkedIn Pulse, November 6, 2015.
- 4. V. Sharma, "What You Should Know About Working with Telcos Today," LinkedIn Pulse, November 1, 2015.
- 5. V. Sharma, "A Software-Defined (Kitchen) Sink!: Benefitting the Data Center and Beyond (Part 1 of 2)", LinkedIn Pulse, October 15, 2015.
- 6. V. Sharma, "SDN Protocol Wars, 4K IPTV, Open Ethernet for DCs, M2M for IoT, Open Media Alliance and More," LinkedIn Pulse, October 4, 2015.
- 7. V. Sharma, "**On Mindmaps, Social Media, and SDN/NFV**," LinkedIn Pulse, July 30, 2015.
- 8. V. Sharma, "**Demystifying the MEF's Third Network and LSO**," LinkedIn Pulse, June 23, 2015.
- 9. V. Sharma, "Smartly Defined Networks (SDN): How Rural Carriers Can Benefit from SDN, NFV and Cloud," Invited Blog, Telecom Council of Silicon Valley, September 2014.
- 10. V. Sharma, A. Naveed, A. Udunuwara, A. Lior, "Evolving Operator Network Architectures with Carrier Ethernet," Industry Paper, Carrier Ethernet Academy, June 2013.
- 11. V. Sharma, "**Provider Network Health Assessment**," Intercomms Journal, October 2012, pp. 51-54.
- 12. V. Sharma, "The Data Center Opportunity for Wholesale Carriers: But Performance Management is Key," Wires & Waves, July 23, 2012.

- 13. V. Sharma, and A. Hadfield, "**How Does the Middle-Eastern Carrier Regain** their Share of Enterprise Services," Wires & Waves, May 27, 2012.
- 14. V. Sharma, and A. Hadfield, "Where are the Next Big Profits Coming From?," Wires & Waves, May 24, 2012.
- 15. V. Sharma, and A. Hadfield, "**Building the Future of the Wholesale Carrier**," Wires and Waves, May 23, 2012.
- 16. V. Sharma and M. Allen, "**Packet-Optical Integration**," Metanoia, Inc. Technology Paper, February 2011.
- 17. V. Sharma and M. Allen, "Packet-Optical Integration The Key to Evolving Towards Agile Optical Networks," Photonic Tech Briefs, January 2011.
- 18. V. Sharma and S. Davari, "**Illuminating Optical Ethernet Networks!**," Metanoia, Inc. Technology Paper, March 2010.
- 19. V. Sharma and S. Davari, "**Demystifying Optical Ethernet Networks**," Photonic Tech. Briefs., February 2010.
- 20. V. Sharma, "Smart Utilities: What Next-Generation Utilities are Gearing Up For," Utility Products Magazine, Vol. 6, Issue 1, January 2009.
- 21. V. Sharma, "Smart Utilities: What Are Next-Generation Utilities Gearing Up For?," Metanoia, Inc. Technology Paper, June 28, 2008.
- 22. V. Sharma and A. Gumaste, "Design considerations for converged optical Ethernet networks," Photonic Tech. Briefs., February 2008.
- 23. V. Sharma and D. Sharma, "**Photonic switching, distributed routing and ultrafast packet forwarding: key advances or pipe dream**," Communications Design Conference (CDC), September 30 - October 2, 2003, San Jose, CA.
- 24. D. Sharma and V. Sharma, "Next-generation SONET/SDH: Impact on network deployment," ChipCenter (an EE Times publication), Networking Series, Technical Note, April 2003.
- 25. V. Sharma, "**Building resilience in MPLS-controlled multi-layer networks**," Technical Focus, MPLSWorld, June 2002.
- 26. V. Sharma, "Considerations for dynamic path establishment in MPLScontrolled multi-service networks," Technical Focus, MPLSWorld, August 2001.
- 27. V. Sharma, "**Multiprotocol lambda switching: The role of IP technologies in controlling and managing future optical networks**," Tutorial in the First Online Symposium for Electronics Engineers (OSEE), January 2001.

Conference Presentations

- 1. V. Sharma, "Software and Virtualization: Benefitting the Data Center and Beyond ..." SDx Summit, Carrier Network Virtualization, Palo Alto, CA, December 9, 2014.
- 2. K. Barapatre, N. Koshta, V. Sharma and F. Ricciato, "**Case study: Infrastructure security in cellular data networks**," APRICOT'06 (Asia-Pacific Regional Internet Conference on Operating Technologies), Perth, Australia, March 1-2, 2006.
- 3. V. Sharma, "A survey of recent advances in traffic engineering/network planning tools," APRICOT'06 (Asia-Pacific Regional Internet Conference on Operating Technologies), Perth, Australia, March 1-2, 2006.
- 4. K. Barapatre, N. Koshta, V. Sharma and F. Ricciato, "**Infrastructure security in cellular data networks: An initial investigation**," SANOG 7 (South-Asian Network Operators Group), Mumbai, India, January 23-24, 2006.
- 5. R Hartani and V. Sharma, "State-of-the-art router design techniques for efficient MPLS network design and traffic engineering," MPLS World 2004, Paris, France, February, 2004.
- 6. R. Papneja and V. Sharma, "Characterizing MPLS VPNs: Analysis and role of core routers," MPLS 2002, Washington, D.C., October 27-29, 2002.
- 7. V. Sharma and C. Srinivasan, "Applications and Solutions for Point-to-Point Multiple Connection Setup in UNI 2.0," OIF Booth, Supercomm 2002, Atlanta, GA, June 4, 2002.
- 8. V. Sharma, "Survivability considerations in MPLS-controlled multi-service networks," MPLSCon Spring 2002, McLean, Virginia, March 25-28, 2002.
- 9. G. Bernstein and V. Sharma, "Inter-domain routing considerations for MPLScontrolled optical networks," MPLS World 2002, Paris, France, February 4-8, 2002.
- 10. S. Dharanikota et al, "**Inter-domain routing with shared risk groups**," MPLS World 2002, Paris, France, February 4-8, 2002.
- 11. V. Sharma, "Dynamic path establishment in MPLS-controlled multi-service networks," MPLSCon'01, San Jose, CA, March 26-29, 2001.
- 12. G. Bernstein, E. Mannie, V. Sharma, and B. Mack-Crane, "Issues in MPLS-based control of SDH/SONET optical networks," MPLS World Congress, Paris, France, February 6-9, 2001.
- 13. V. Sharma, V. Makam, C. Huang, and K. Owens, "**Protection and restoration in MPLS networks**," MPLS Forum 2000, Paris, France, March 7-10, 2000.

14. V. Sharma, V. Makam, C. Huang, and K. Owens, "MPLS: Much potential leading somewhere: An assessment of QoS and protection in MPLS," MPLS'99, Paris, France, June 22-25, 1999.

REFEREED PUBLICATIONS

Conferences

- 1. M. Veerayya, V. Sharma, and A. Karandikar, "A novel stability-based routing algorithm for QoS support in ad-hoc wireless networks," Proc. IEEE Milcom'08, San Diego, CA, November 19-21, 2008.
- 2. H. Rath, A. Karandikar, V. Sharma, "Adaptive modulation-based TCP-aware uplink scheduling in IEEE 802.16 (Wi-Max) networks," Proc. IEEE ICC'08, Beijing, China, May 2008.
- 3. V. Sharma and N. Vamaney, "**The uniformly-fair deficit round-robin scheduler for IEEE 802.16 WiMax networks**," Proc. IEEE Milcom'07, Orlando, FL, October 2007.
- 4. A. Gumaste, J. Chandarana, P. Bafna, N. Ghani and V. Sharma, "**On control plane for service provisioning in light-trail WDM optical networks**," Proc. 42nd IEEE Intl Conf on Commun. (ICC), Glasgow, United Kingdom, June 2007.
- H. Rath, A. Bhorkar, V. Sharma, "An opportunistic uplink scheduling scheme to achieve bandwidth fairness and delay for multiclass traffic in Wi-Max (802.16) broadband networks," IEEE Globecom'06, San Francisco, CA, November 27 –December 1, 2006.
- H. Rath, A. Bhorkar, V. Sharma, "An opportunistic deficit round robin (O-DRR) uplink scheduling scheme for Wi-Max networks," Proc. IETE Int'l Conf. on Next-Generation Networks (ICNGN'06), Mumbai, India, February 9-11, 2006.
- 7. V. Bhedaru and V. Sharma, "**Packet classification algorithms for next-generation networks: A perspective**," Proc. IETE Int'l Conf. on Next-Generation Networks (ICNGN'06), Mumbai, India, February 9-11, 2006.
- 8. R. Rabbat, V. Sharma, F. Ricciato, R. Albanese, "**Strategies for rapid and scalable recovery in next-generation networks**," Proc. of Workshop 4, Protection and Restoration: From SDH/SONET to Next-Generation Networks, IEEE Globecom 2003, San Francisco, CA, December 1, 2003.
- 9. V. Sharma, A. Das, and C. Chen, "Leveraging IP signaling and routing to manage UPSR-based SONET networks," Proc. IEEE ICC 2003, Anchorage, Alaska, May 11-15, 2003.

- 10. B. Rajagopalan, D. Saha, G. Bernstein, and V. Sharma, "Signaling for fast restoration in heterogeneous optical mesh networks," Proc. SPIE Asia Pacific Conf. on Optical Communication, Beijing, China, November 12-16, 2001.
- 11. S. Mneimneh, V. Sharma, and K. Y. Siu, "On scheduling using parallel inputoutput queued crossbar switches with no speedup," Proc. IEEE Workshop on High-Perf. Switching and Routing (HPSR), May 2001.
- 12. D. Levandovsky, V. Makam, and V. Sharma, "Physical constraints affecting connectivity in the dynamic optical network," Proc. National Fiber Optic Engineers Conf. (NFOEC) Denver, CO, August 7-11, 2000.
- 13. C. H. Yeh, E. A. Varvarigos, V. Sharma, and B. Parhami, "Scalable communication protocols for high-speed networks," Proc. IASTED Int'l Conf. on Parallel and Distributed Computing Systems, Cambridge, MA, November 3-6, 1999.
- 14. J. P. Lang, V. Sharma, and E. A. Varvarigos, "**A new analysis for wavelength translation in regular all-optical networks**," Proc. MPPOI'98 (Massively Parallel Processing Using Optical Interconnections), Las Vegas, NV, June 15-17, 1998, pp. 131-139.
- 15. V. Sharma and E. A. Vavarigos, "Limited wavelength translation in all-optical WDM mesh networks," Proc. IEEE Infocom'98, San Francisco, CA, March 29 April 2, 1998, pp. 893-901.
- 16. V. Sharma and E. A. Varvarigos, "Some closed form results for circuit switching in hypercube networks with input queueing," Proc. Euro-Par'96, Lyon, FR, August 27-29, 1996, pp.738-742.
- V. Sharma and Srirajshekhar Koritala, "Can distributed workgroups work without tears? Lessons learnt from coordinating a dispersed organization," Proc. IEEE Int'l Conf. on Professional Communication (IPCC'96), Saratoga Springs, NY, September 17-20, 1996.
- E. A. Varvarigos and V. Sharma, "A loss-free connection control protocol for the Thunder and Lightning network," Proc. IEEE Global Telecom. Conf., Singapore, November 13-17, 1995, pp. 450-456.
- 19. E. A. Varvarigos and V. Sharma, "An efficient reservation connection control protocol for gigabit networks," Proc. IEEE Int'l Symposium on Information Theory (ISIT), Whistler, BC, Canada, September 17-22, 1995, pp. 40.
- 20. E. A. Varvarigos and V. Sharma, "Loss-free communication in high-speed networks," Proc. Singapore Int'l. Conf. on Networks (SICON'95), July 3-7, 1995, pp. 230-236.

21. T. Kawashima, V. Sharma, and A. Gersho, "Network control of speech bit rate for enhanced cellular CDMA performance," Proc. Int'l. Conf. on Communications (ICC'94), New Orleans, LA, May 1-5, 1994, vol. 3, pp. 1276-80.

Journals & Magazines

- A. Gumaste, V. Sharma, D. Kakadia, J. Yates, A. Clauberg, M. Voltolini, "SDN Use-Cases for Service Provider Networks: Part 2," Guest Editorial, IEEE Commun. Mag., vol. 55, no. 4, April 2017, pp. 62-63.
- A. Gumaste, V. Sharma, D. Kakadia, J. Yates, A. Clauberg, M. Voltolini, "SDN Use-Cases for Service Provider Networks: Part 1," Guest Editorial, IEEE Commun. Mag., vol. 54, no. 10, October, 2016, pp. 80-81.
- 3. T. Nadeau, V. Sharma, and A. Gumaste, "Next-generation Carrier Ethernet transport technologies," Guest Editorial, IEEE Commun. Mag., vol. 46, no. 3, March 2008, pp. 67-68.
- 4. V. Sharma, N. Ghani, L. Fang, "Advances in Virtual Private Networks," Guest Editorial, IEEE Commun. Mag., vol. 45, no. 4, April 2007, pp. 24-25.
- M. Morrow, V. Sharma, and T. Nadeau, L. Andersson, "Challenges in enabling IP-service quality in the Internet," Guest Editorial, IEEE Commun. Mag., vol. 43, no. 6, June 2005, pp. 88-90.
- 6. M. Morrow, V. Sharma, and T. Nadeau, "**OAM in MPLS-based networks**," Guest Editorial, IEEE Commun. Mag, vol. 42, no. 10, October 2004, pp. 88-90.
- 7. V. Sharma, A. Das, and C. Chen, "On the issues in implementing the Peer Model in integrated optical networks," Photonic Network Communications, Special Issue on the IP-Centric Control and Management of WDM Optical Networks, vol. 8, issue 1, June 2004, pp. 7-21.
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- G. Bernstein, E. Mannie, V. Sharma, "MPLS-based control of SDH/SONET optical networks," IEEE Network, Special Issue on "IP-Optical Integration," vol.15, no. 5, July/August 2001, pp. 20-27.
- 13. J. P. Lang, V. Sharma, and E. A. Varvarigos, "A new analysis for oblivious or adaptive routing in all-optical networks with wavelength translation," IEEE/ACM Trans. on Networking, vol. 9, no. 4, August 2001, pp. 503-517.
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- 15. E. A. Varvarigos and V. Sharma, "An efficient reservation connection control protocol for gigabit networks," Computer Networks and ISDN Systems, vol. 30, no. 12, July 1998, pp. 1135-1156.
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- 18. T. Kawashima, V. Sharma, and A. Gersho, "Capacity enhancement of cellular CDMA by traffic-based control of speech bit rate," IEEE Trans. on Vehicular Technology, vol. 45, no. 3, August 1996, pp.543-550.

STANDARDS CONTRIBUTIONS

IETF RFCs Co-Authored

- 1. G. Bernsterin, E. Mannie, V. Sharma, E. Gray, "A framework for GMPLS-based control of SDH/SONET networks," RFC 4257, December 2005.
- 2. K. Kompella, Y. Rekhter (Editors) "Routing Extensions in Support of Generalized MPLS," RFC 4202, October 2005.
- 3. K. Kompella, Y. Rekhter (Editors) "**OSPF extensions in support of Generalized MPLS**," RFC 4203, October 2005.
- 4. K. Kompella, Y. Rekhter (Editors) "**IS-IS extensions in support of Generalized MPLS**," RFC 4205, October 2005.
- 5. E. Mannie (Ed.), "Generalized Multi-Protocol Label Switching (MPLS) Architecture," RFC 3945, October 2004.

- 6. E. Mannie, D. Papadimitrou (Editors), "Generalized MPLS Extensions for Synchronous Optical Networks (SONET) and Synchronous Digital Hierarchy (SDH) Control," RFC 3946, October 2004.
- 7. V. Sharma and F. Hellstrand (Editors), "A framework for MPLS-based recovery," RFC3469, February 2003.
- 8. L. Berger (Editor), "Generalized MPLS: Signaling functional description," RFC 3471, January 2003.
- 9. P. Ashwood Smith, L. Berger (Editors), "Generalized MPLS: Signaling CR-LDP extensions," RFC 3472, January 2003.
- 10. P. Ashwood Smith, L. Berger (Editors), "Generalized MPLS: Signaling RSVP-TE extensions," RFC 3473, January 2003.

Representative OIF Contributions

- 1. G. Bernstein, L. Ong, V. Sharma, "**Bandwidth Encoding for NNI Routing**," OIF Contribution, OIF.2002.522.00, November 2002.
- S. Dharanikota, R. Jain, C. Brownmiller, Y. Xue, D. Papadimitriou, G. Bernstein, R. Hartani, V. Sharma, "Inter-domain Routing with Shared Risk Groups," OIF Contribution OIF2001.227.1, April 23, 2001.

ACADEMIC COURSES/LABS DEVELOPED AND/OR TAUGHT

- Electronics Laboratory, EE219, Dept. of EE, IIT Bombay
 Junior-level course for electrical engineering majors (3 credits, 1 lab. per week) The course had 85 students and a dozen TA's, and was co-taught with Prof. Vishwesh Kulkarni of IIT Bombay.
- 2. **Digital Circuits Laboratory**, EE214, Dept. of EE, IIT Bombay Spring 2006 Junior-level course, offered to all electrical engineering majors (3 credits; one lab. per week). The course had 108 students, and was co-taught with Prof. Mukul Chandorkar.
- 3. **Telematics: Theory & Practice of High-Performance Circuit- & Packet-Switching**, EE612, Dept. of EE, IIT Bombay Spring 2006, Spring 2005 Advanced graduate-level course for electrical engineering and computer science majors (6 credits, 2 lectures per week). The course required students to do a substantive research project in teams of 2-3 each, with a report and final presentation, and had a dozen project research teams that were guided. One of the research reports was published in a national conference on networking.

4. Advanced Data Networks, EE740, Dept. of EE, IIT Bombay

Advanced graduate-level course for electrical engineering and computer science majors. (6 credits, 2 lectures/week) The course required students to do a substantive research project in teams of 2-3 each, with a report and final presentation, and had several project research teams that were guided. One of the research reports was published in a national conference on networking.

5. **Electronics for Engineers**, EE 004, Dept. of EE, IIT Bombay Fall 2006, Fall 2004 Junior-level course offered to non-EE engineering majors (4 credits; 2 lectures and 1 tutorial per week); the course had 100+ students both years, and over halfdozen TAs.

DEPARTMENTAL SERVICE AT IIT BOMBAY

- 1. Coordinator, Dual-Degree (Communications) Seminar Presentations & Evaluations, Fall 2005, Fall 2006.
- 2. Reviewer of a 30-lecture (1-1.5 hrs/lecture) course, Broadband Networks, for the Centre for Distance Engineering Education's (C-DEEP) National Program on Technology Enhanced Learning (NPTEL), Fall 2006.
- 3. Served on Departmental Interview Committee to screen and select M. Tech. applicants for Fall admission, May 2006.
- 4. Served on Departmental Interview Committee to screen and select Ph.D. applicants for Fall admission, May 2006.
- 5. Contributions to the Departmental 5-Year Growth Plan, Fall 2005.
- 6. Served on Faculty Interview Committee to interact with a number of potential faculty members visiting the Department, Fall 2005 Fall 2006.
- 7. Conceived, developed, and delivered the TA Orientation Workshop in the Dept. of EE, Spring 2005 and Fall 2006.

This established the first TA orientation program within the department, to effect a better matching between the expectations of the faculty and the incoming TAs, and provided incoming graduate students training in effective communication. (Jointly with Prof. S. D. Agashe.)

- 8. Examiner for a dozen+ B. Tech, Dual-Degree, M.Tech. & Ph.D. seminars, projects, and theses, Spring 2005 Fall 2006.
- 9. Contributed to Faculty Meeting discussions on enhancing the Department's TA system, leading to the institution of a TA Orientation Workshop for incoming graduate students, Spring and Fall 2005.

GRADUATED STUDENTS

Undergraduate Theses Supervised (B. Tech.⁵)

- 1. "Energy-Aware Routing Protocols in Ad-Hoc Networks," K. Jain, May 2007.
- 2. "Security and Performance Analysis of Cellular Data Networks," N. Agrawal, May 2007.
- 3. "**Designing and Implementing a Basic Ad-Hoc Wireless Network Testbed**," S. Chaudhari, June 2006. (Winner, Best B. Tech Project in Electrical Engineering Award at IIT Bombay for the academic year 2005-2006.)
- 4. **"Experiments to Assess Security in Cellular Data Networks**," N. Koshta, April 2006. Research published in SANOG'06 and APRICOT'06.

Graduate Theses Supervised (M. Tech.⁶ and Dual Degree (B. Tech./M. Tech.)⁷)

- 1. **"Energy-Aware On-Demand Routing Protocol for Ad-Hoc Wireless Networks**," M. Veeraya, July 2008. (Co-guided with Prof. Abhay Karandikar, IIT Bombay.) Research published in IEEE Milcom'08.
- 2. "**Realizing a Peer-to-Peer Mobile Multiplayer Game for 3G Networks**," P. Khandelwal, July 2007.
- 3. "Scheduling in IEEE 802.16 Metropolitan Area Networks," N. Vamaney, September 2006. Research published in IEEE Milcom'07.
- "Evaluation of Network Properties and Security in Cellular Data Networks,"
 K. Barapatre, August 2006. (Co-guided with Dr. Fabio Ricciato, FTW, Vienna, Austria.) Research published in SANOG'06 (South Asian Network Operators Group) and APRICOT'06 (Asia-Pacific Regional Internet Conference).

RESEARCH GUIDANCE

B. Tech Seminars

- 1. "Routing Protocols for Ad-Hoc Wireless Networks," C. Singla, Spring 2007.
- 2. "Metro Ethernet Networks," M. Shakya, Spring 2007.
- 3. "Routing in Ad-Hoc Wireless Networks," K. Jain, Spring 2006.
- 4. **"3G Cellular Networks Architecture and Security Issues**," N. Agrawal, Spring 2006.

⁵ B. Tech. = Bachelor of Technology, a 4 -year undergraduate program of study.

⁶ M. Tech. = Master of Technology, a 2-year graduate program of study.

⁷ Dual Degree = A combined B. Tech. and M. Tech. degree awarded at the end of a 5-year program of study.

- 5. "Design of MAC Protocols and PHY Layer in the IEEE 802.16 Standard," N. Koshta, Spring 2005.
- 6. "**Scheduling Algorithms in Broadband Wireless Networks**," S. Chaudhari, Spring 2005.

M. Tech Seminars

- 1. "**Traffic Management Techniques**," A. Bhattacharya, Fall 2006.
- 2. "Mobile Handset Architectures," S. Bandekar, Fall 2005.
- 3. "Investigation of Security Threats to Network Protocols," A. R. Dixit, Fall 2005.
- 4. **"Architecture of Mobile Platforms and Mobile Applications**," P. Khandelwal, Fall 2005.

Ph.D. Seminars

1. "Cross-Layer Based Resource Allocation in Wireless Networks," H. K. Rath, Annual Progress Report Seminar, August 2007.

Research Fellow Project

1. "Design and Specification of QoS Architecture Components for an IEEE 802.16 Compatible QoS Architecture," R. Nalwade, Fall 2005.

Course Research Projects (Graduate Courses)

- 1. "**Matching Algorithms for Clos Networks**," A. D. Rajan, O. V. S. Bharadwaj, Spring 2006.
- 2. "**Stability of Networks of Input-Queued Switches**," D. A. Sudhir, A. Bhattacharya, H. P. Shringarpure, Spring 2006.
- 3. "Optics Inside Routers," S. G. Bandekar, P. S. Kulkarni, Spring 2006.
- 4. **"Active Queue Management: RED and WRED**," S. Iyengar, B. K. Tejaswi, S. Sapavat, Fall 2005.
- 5. "**Modern Algorithms for Traffic Engineering in IP Networks**," N. Vamaney, BP Vipin Kumar, U. K. Pandey, Fall 2005.
- 6. "**Delay-Based Congestion Avoidance Algorithms for TCP**," P. Manohar, O. Kulkarni, A. Bhorkar, Fall 2005.
- 7. **"Packet-Classification Algorithms and Their Realization**," V. Bhedaru, S. R. Anil Kumar, K. Barapatre, Fall 2005.

- 8. "**QoS Mechanisms for Multi-media Delivery over Wireless IP Networks**," A. Singh, S. K. Das, P. K. Kapadia, Fall 2005.
- 9. "Video Traffic over Cellular Wireless Networks," A. Malewar, A. Gupta, B. Walia, Fall 2005.
- 10. "**QoS Monitoring/Tracking for Network Planning in 3G Cellular Networks**," A. Mukherji, D. Mehta, K. Mumru, Fall 2005.
- 11. **"Study of Routing and Congestion Control in SS7 Networks**," G. Kumar, T. D. Shiva, Spring 2005.
- 12. "MAC Layer Scheduling in IEEE 802.16e Networks," H. K. Rath, A. Bhorkar, Spring 2005.
- "Routing and Wavelength Assignment Issues in Optical Networks," A. Singh, S. K. Das, N. Vamaney, Spring 2005.
- 14. "Layering in Telecom Networks: G.805 and G.809," B. K. Tejasw, C. R. Parekh, Spring 2005.
- 15. "**Path Setup in Multi-Priority MPLS Networks**," S. Goyal, A. K. Gupta, R. R. Chowgule, Spring 2005.
- 16. "**Capacity, Routing and QoS in Indoor Wireless Mesh Networks**," G. Bhati, D. Angrula, Spring 2005.
- 17. "**VoIP: Architecture, Protocols/Subsystems, and Security**," S. Chakraborty, Ajishna G., B. S. Walia, Spring 2005.
- 18. "**Peering Strategies in IP Networks**," P. C. Mehta, C. M. Pujara, V. B. Bhedaru, Spring 2005.
- 19. "Peering and Interconnects in IP and Phone Networks," M. G. Kata, S. J. Deb, N. Dalmia, Spring 2005
- 20. "Content Delivery Networks: Design and Architecture Issues," D. Mehta, V. Kashyap, U. Pandey, Spring 2005.