

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS,
T-MOBILE USA, INC. T-MOBILE US, INC.
AND AT&T MOBILITY, LLC

Petitioners,

v.

ASPEN NETWORKS, INC.,

Patent Owner

Case No. IPR2025-00008
U.S. Patent No. 8,009,554

DECLARATION OF DR. IZHAK RUBIN

I, Izhak Rubin, hereby declare as follows:

I. BACKGROUND

1. I have been retained by Patent Owner in connection with the above-captioned *Inter Partes* Review (“IPR”) proceeding involving U.S. Patent No. 8,009,554 (“the ’554 Patent”) (Ex. 1001).

2. I have been asked by Aspen Networks, LLC (“Aspen”) to offer opinions regarding the ’554 Patent and Claims 1-28 (the “Challenged Claims”) of the ’554 Patent, as set forth in the Petition for IPR (“the Petition”). This declaration sets forth the opinions I have reached to date regarding these matters.

3. I am being compensated by Aspen at my standard hourly consulting rate of \$ 700 per hour for my time spent on this matter. My compensation is not contingent on the outcome of the IPR or on the substance of my opinions.

4. I have no financial interest in Patent Owner.

II. EDUCATION AND WORK HISTORY

5. I received BS and MS degrees in Electrical Engineering from the Israel Institute of Technology in 1964 and 1967, respectively, and a PhD degree in Electrical Engineering from Princeton University in 1970.

6. I previously worked as an electrical engineer in areas of telecommunications and electronics systems from 1964 to 1966, and in the Aerospace industry from 1966 to 1968. I thereafter carried out PhD level research

studies at Princeton University from 1968 to 1970. I joined the University of California Los Angeles (UCLA) as a Professor in 1970, serving as a Distinguished Professor in the Department of Electrical and Computer Engineering. I retired in July of 2019 but was recalled, and I have continued my work at UCLA since teaching courses in the Department, serving as a Distinguished Professor Emeritus. I have also been serving as Director of the area of Signal Processing and Communications in the UCLA Engineering MS Online program. Overall, I have served as a consultant, analyst, and system designer for many industrial, commercial, military and consulting organizations for over more than 50 years, contributing to the design, analysis and testing of telecommunications and computer communications network systems.

7. My research has involved studies, developments, analyses and designs of telecommunications and computer communications networking systems, including wireline and wireless networks, multi-media shared access systems, network protocols, routing and switching methods, multiple access and multiplexing systems, networked service systems, network simulations, network quality of service (QoS) schemes, queueing methods and models, networking for autonomous mobiles. I recently written and published a comprehensive book on these topics: Izhak Rubin, "Principles of Data Transfer Through Communications Networks,

Internets, and Autonomous Mobiles,” published by Wiley-IEEE Press, ISBN 978-1394267750, 2025.

8. Attached as Appendix A is a copy of my current C.V. further elaborating on my professional background and qualifications.

III. MATERIALS CONSIDERED

9. In forming my opinions, I have reviewed the '554 Patent and its prosecution history. I have also reviewed and considered the references cited by the Petitioners, the Petition itself, the Declaration of Dr. Daniel van der Weide (EX1003) submitted with the Petition, and other documents and information as set forth in this declaration.

10. In reaching my opinions, I have relied upon my experience in the field and also considered the viewpoint of a person of ordinary skill in the art (“POSITA”) at the time of the earliest claimed priority date of the '554 Patent. As explained below, I am familiar with the level of a person of ordinary skill in the art regarding the technology at issue as of that time.

IV. OVERVIEW OF THE TECHNOLOGY, THE '554 PATENT, AND THE PRIOR ART

A. Technical Background

11. The '554 Patent provides a method and system for quality of service based IP networking operation in supporting voice and video calls over the Internet. Non-mobile and mobile calls are supported. It provides for the switching of a call

that is carried out across one network path to a higher quality network path. At least one Network Address Translation (NAT) and/or Port Address Translation (PAT) is performed. At the time of the invention, applying for the purpose of this discussion the same date as that mentioned by Petitioners, *i.e.*, March 13, 2008, such a switching process proved to be challenging. Switching schemes often caused calls to break in the midst of their sessions. Real-time audio and video calls transported over the Internet or other IP networks, such as Voice over IP (VoIP) calls, including those performed by using SIP/SDP (Signaling Initiation Protocol / System Description Protocol) in handling signaling packets for managing call session connections, and using the Real Time Protocol (RTP) for managing the network transport of payload media (including voice and video streams), proved to be challenging, and the switching to calls across other networks or along other network routes often resulted in their failure.

12. Traditional phone networks, such as the Public Switched Telephone Network (PSTN), used a signaling protocol such Signaling System No. 7 (SS7) to form and manage connections and to configure the switching tables of circuit switches that reside across configured end-to-end routes. Media messages were transmitted along pre-configured circuits. First generation (1G) mobile cellular networks were developed in the 1980s. Using IP protocols, 3G cellular wireless networks, also known to provide Universal Mobile Telecommunication Service

(UMTS), emerged around 1998-2000. Network access communications speeds then increased in a significant manner. The SS7 signaling protocol was also employed in 3G cellular wireless systems.

13. Internet use by a wide range of organizations, and in homes, exploded in the 1990s. Network layer packet transport across the Internet is based on the use of a connectionless Packet Switching method, employing the Internet Protocol (IP). Transport layer protocols, including Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) have been employed as connection oriented and connectionless protocols, respectively. For high quality end-to-end network transfer of real time streams, including voice and video flows, the Real Time Transport Protocol (RTP), and its secure RTPS version, as well as the associated Real Time Transport Control Protocol (RTCP) have been employed. RTCP is used for monitoring the end-to-end Quality of Service (QoS) experienced by RTP flows. The Session Initiation Protocol (SIP) was developed to enable the creation, management and termination of call sessions, such as those involving voice and video calls that are transported across IP networks. The latter include the Internet and various wireless local area networks (WLANs), cellular wireless networks, and other.

14. SIP is associated with the Session Description Protocol (SDP), which provides for the specification of a session's media parameters, including media codes, and end-points' IP addresses and port numbers. The SIP protocol was

standardized by the Internet Engineering Task Force (IETF) in 1999 as RFC 2543. Wireless Local Area Networks (WLANs) that are based on IEEE 802.11 protocols, such as WiFi WLANs, have been widely used by companies and in the home. They have been used to provide data communications that serves to connect local end-users as well as to locally connect end-user entities to the Internet through the use of IP routers. An IP router is often combined with a WLANs Access Point (AP). WiFi uses started in 1997. For example, a 1999 version, identified as IEEE 802.11b, provided users with a high access speed of 11 Mbps. Over time, advanced WiFi implementations have achieved significantly higher WLAN access speeds. In comparison with cellular wireless systems, WiFi configurations have been offering users significant cost savings, high capacity and access speeds.

15. The invention of the '554 Patent was developed against this backdrop. At that time, it was unclear which form of data communication and protocols would be appropriate for audio and video data. Adding to this complexity was the determination as to what process should govern the switching between various network paths, particularly when further data transitions took place, such as transitions involving address and/or port translations, *i.e.*, a NAT and/or a PAT.

16. The approach used by the inventors of the '554 Patent is directed to the use of IP network systems, and the employment of associated protocols, including those that enable the effective transport of realtime streams. These protocols include,

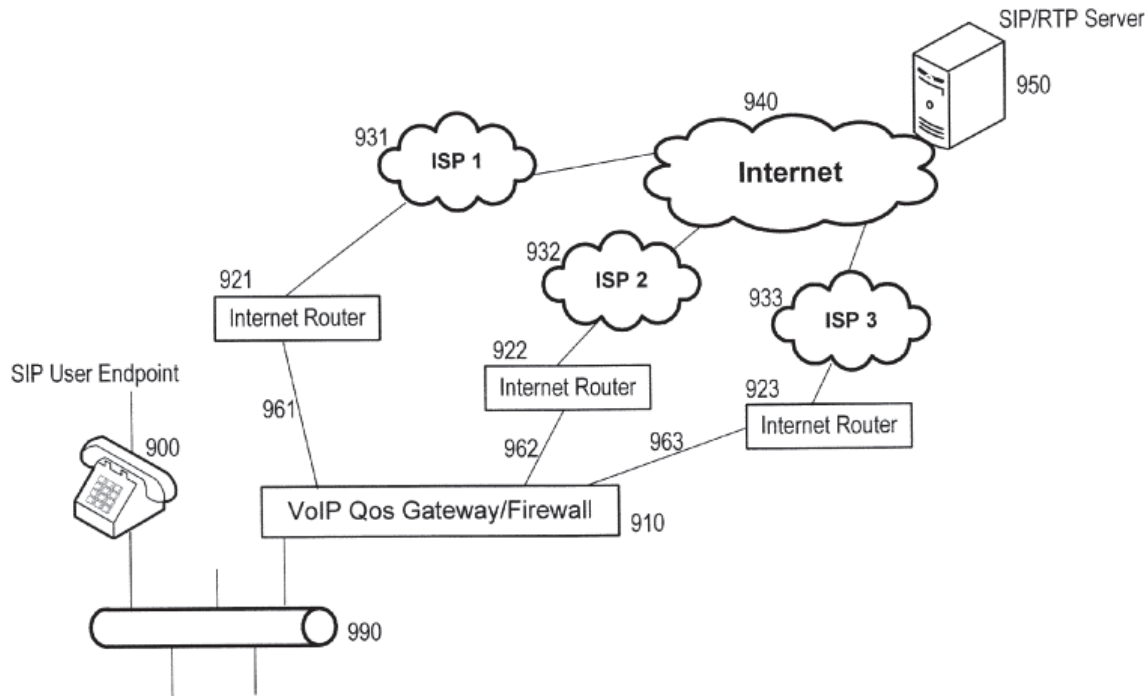
for the transport of both signaling data and media messages, the use of IP and UDP or TCP (or other transport layer protocols). SIP/SDP is used for signaling, enabling the initiation, management and termination of call sessions. RTP/RTCP protocol is used for managing the end-to-end transfer of media streams. The underlying problem of switching message flows from a network path to another network path, in aiming to improve quality of transfer or for another reason, was complicated by the fact that network address and port address translations (NAT/PAT) are performed. Accounting for these conditions, the underlying claims of the '554 Patent present methods and systems that offer for the effective transport of real-time IP streams when network routes are switched to enhance network transport quality. For the claimed processes to properly function, the inventors of the '554 Patent recognized the importance of maintaining the sequence numbers of signaling packets produced in a call session after switching of a network path.

17. As demonstrated by the references cited in the Petition, and as discussed in more detail herein, the method and system taught by the '554 Patent is different from those presented by other systems that aimed to solve the corresponding problem.

B. The '554 Patent

18. Fig. 9 of the '554 Patent depicts an embodiment of the invention.

Fig 9 A QoS Gateway Embodiment of Invention



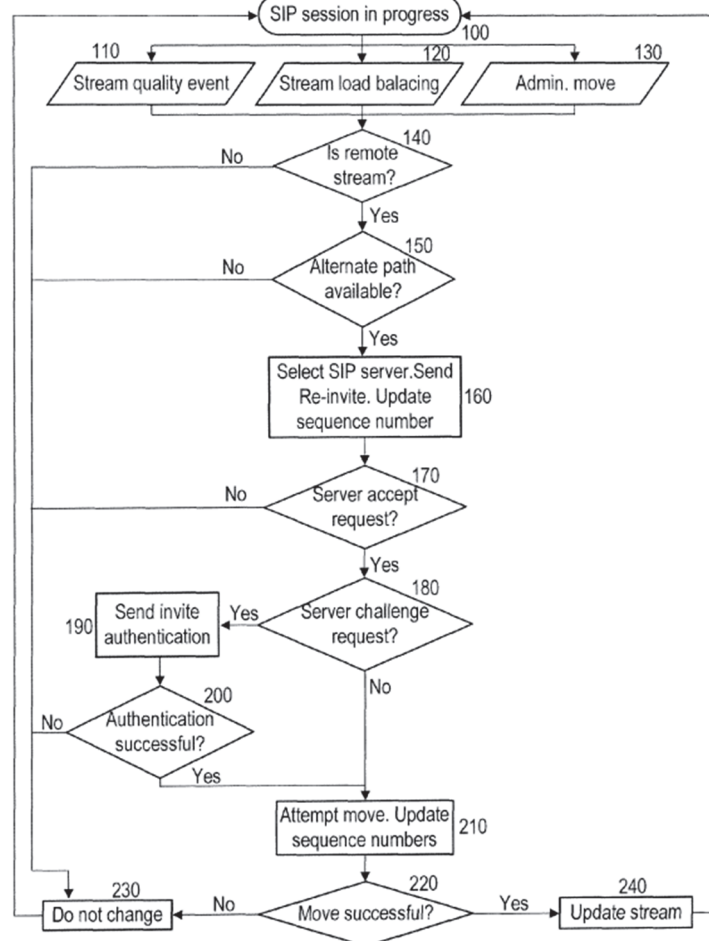
19. Figure 9 features a multi-link quality of service (QoS) gateway **910** that has 3 logical network interfaces **961**, **962**, and **963**. EX1001, 5:46-61; FIG. 9. In this configuration, 3 routers, denoted as **921**, **922** and **923**, are attached to the user local area network **990**, serving to connect the user to the public Internet **940**. *Id.* Network interfaces **961**, **962** and **963** correspond to globally routable public IP addresses belonging to the 3 access Internet Service Providers shown in FIG. 9, denoted as **931**, **932** and **933**, respectively. *Id.* A SIP user endpoint **900** is shown communicating with a SIP/RTP server **950**. *Id.* In this embodiment, 3 alternative paths, applicable for attaining preferred quality of service, over the non-mobile domain are shown:

Path 1: 900, 910, 961, 921, 931, 940, 950
Path 2: 900, 910, 962, 922, 932, 940, 950
Path 3: 900, 910, 963, 923, 933, 940, 950

Id. at 6:37-41.

20. The embodiments disclosed enable the proper switching of a call's network path while a SIP/RTP session is in progress. In particular, it teaches the use of post-move maintenance of consistent SIP packet sequence numbers, as depicted in FIG.4, step 210:

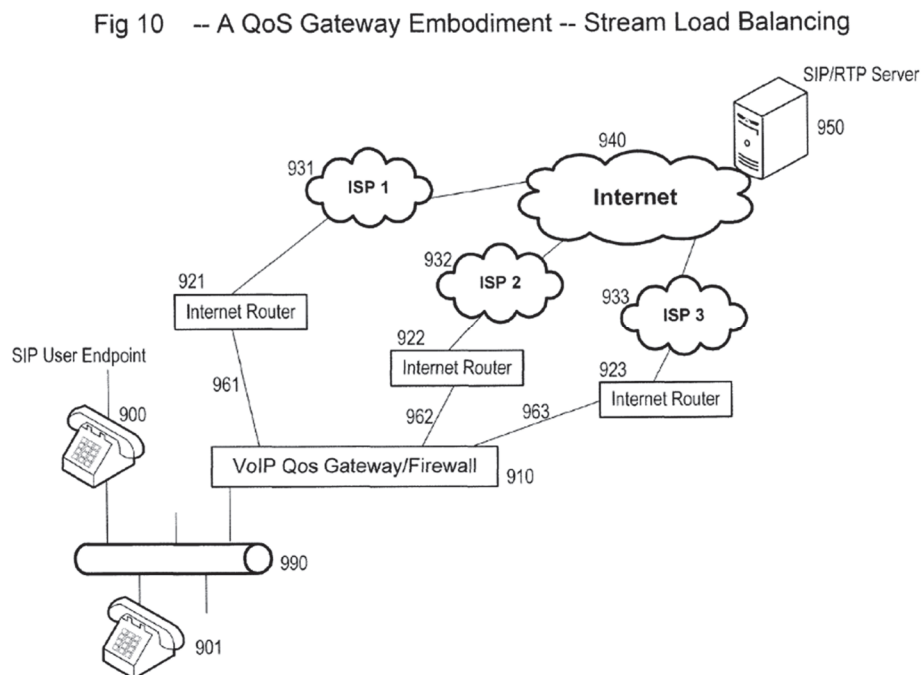
Fig 4 Move SIP Control Flow and RTP Stream. The Flow Chart



Id. at 7:1-4; FIG. 4.

21. The flowchart depicted in FIG. 4 is generally described in the Flow Chart Description table. *Id.* at 4:45 – 5:37. After an alternative path is determined to be available at **150**, the system selects a SIP server, sends re-invite, and updates the sequence number at **160**. *Id.* The sequence number is then updated again after the attempted move at **210**. *Id.* Thus, as captured by the independent claims of the '554 Patent, “[t]he SIP signaling sequence of the transmission is maintained after said switching from the first network path to the one of a plurality of alternative network paths” during this step. *Id.*

22. The '554 Patent also discloses path-switching as a means of load balancing, as depicted by Figure 10:



23. In this embodiment, initially the paths between the two phones are as follows:

Stream 1 Phone 900: 900, 910, 961, 921, 931, 940, 950
Stream 2 Phone 901: 901, 910, 961, 921, 931, 940, 950

Id. at 7:1-25.

24. As an example of a situation requiring load balancing, the '554 Patent describes a large PC file transfer taking place on the path represented by ISP 1. *Id.* The gateway becomes aware of this and decides to preemptively move Stream 2 to a better path represented by ISP 3. *Id.* As with the previous embodiment, this is done without breaking the RTP call in progress. *Id.*

1. Claims

25. The '554 Patent has 28 claims, with 4 independent claims. Claim 1 is reproduced below:

1. A method of enhancing the reliability of a transmission from a source to a destination in a communications network using a network protocol that operates on top of the Internet Protocol (IP), the method comprising:

transmitting data between a source and destination over a first network path made up of one or more network links where at least one of the network links is to a local area network that is remote from the transmission source; and

switching the transmission from the first network path to one of a plurality of alternative network paths;

wherein said transmission is not disrupted as a result of said switch to the one of a plurality of alternative network paths, said transmission contains audio or video data and at least one Network Address Translation (NAT) is performed on said transmission;

said transmission uses the Real Time Protocol (RTP);

said transmission uses the Session Initiation Protocol (SIP); and

the SIP signaling sequence of the transmission is maintained after said switching from the first network path to the one of a plurality of alternative network paths.

EX1001, Claim 1 (emphasis added).

26. Although the other issued independent claims (Claims 8, 15, 22) differ, they all include similar language to the language bolded above—the SIP signaling sequence limitation, identified as limitation 1.6 in the Petition.

2. Prosecution History

27. I have reviewed the prosecution history of the '554 Patent, and my opinions described herein account for the '554 Patent's prosecution history.

C. Cited References

28. The Petition cites to various references to demonstrate the background technology and its invalidity grounds. The processes disclosed in these references demonstrate the complexity associated with switching a VoIP call between networks. Each of these references focuses on using a different process. In particular, the references relied upon in the Petition's Grounds describe different processes that are used under the switching of network paths. These processes and references are discussed below.

1. Tagg Summary

29. Ground 1 of the Petition relies upon a single reference, US 2005/0286466 to *Tagg et al.* ("*Tagg*"), while using obviousness arguments for all of the independent claims. Petition at 14.

30. *Tagg* describes a Cooperative Tunneling Agent (CTA) that can be utilized on various devices to allow for an improved and standardized communication "pipe thru to the Internet." EX1005, ¶ [0079]. The *Tagg* CTA provides each member a unique identifier and allows communications between members efficiently and securely. *Id.* ¶ [0079]. This CTA provides users a wide range of functionality, which it claims to be useful to users and service providers. *Id.* ¶¶ [0079] – [0092]. *Tagg* describes how the CTA allows for a handoff process

for passing users between networks, which is the basis of one of the Petition's invalidity positions. *Id.* ¶¶ [0277] – [0285]; Petition at 39-41.

31. *Tagg* describes “handoff” to involve passing the user to a different network. EX1005, ¶ [0277]. Non-seamless handoff is described to mean (i) where the user has to make a decision and take some action, or (ii) where there is an appreciable break in the call. *Id.* ¶¶ [0282]-[0284]. Seamless handoff, on the other hand, is described to mean (i) where the user does not have to do anything, or (ii) where there is no break in the call. *Id.* ¶¶ [0278]-[0280].

32. *Tagg* describes a number of handoff methods, including “break-before-make” handoff and “break & make” handoff. *Id.* ¶ [0285]. In “break-before-make” handoff, by its definition, “there is a pause in packet sending as handoff is made.” *Id.* Additionally, “break & make” is described to mean “there is such a short time between the break and make that the user does not notice it even though it is technically a break before make event.” *Id.*

33. The *Tagg* handoff process of relevance here involves the use of a duplicative system via its teachings of a “make-before-break” handoff. In particular, the *Tagg* “make-before-break” handoff process sends duplicative packets via multiple networks. The use of this redundancy across various networks allows a link to be “made” and confirmed, before it is broken; thus, according to *Tagg*, allowing for an improved and seamless handoff. *See Id.* ¶ [0095] (“Another significant

advantage of a packet based system is that the packets may follow different routing paths providing for a high degree of redundancy and therefore reliability. For example, a packet may be forwarded at the radio layer via the Bluetooth, Wi-Fi and UMTS link simultaneously during handoff/over in the invented system.”).

34. In particular, *Tagg* defines the “make-before-break” process as one “where packet streams are sent via two paths during handoff/over.” EX1005, ¶ [0285]. *Tagg* further describes this process, stating: “A duplicate audio path to/from the proxy via another IP route is created when hand-off is looking likely, then when hand-off is confirmed, the handset switches over to the new audio-path and disconnects the old one. This does not require any re-invites or conferencing as the proxy is the client as far as the server is concerned and so never changes its IP address.” *Id.* ¶ [0296].

35. *Tagg* does not discuss SIP sequencing at all, much less as part of any network switching.

2. Kottilingal Summary

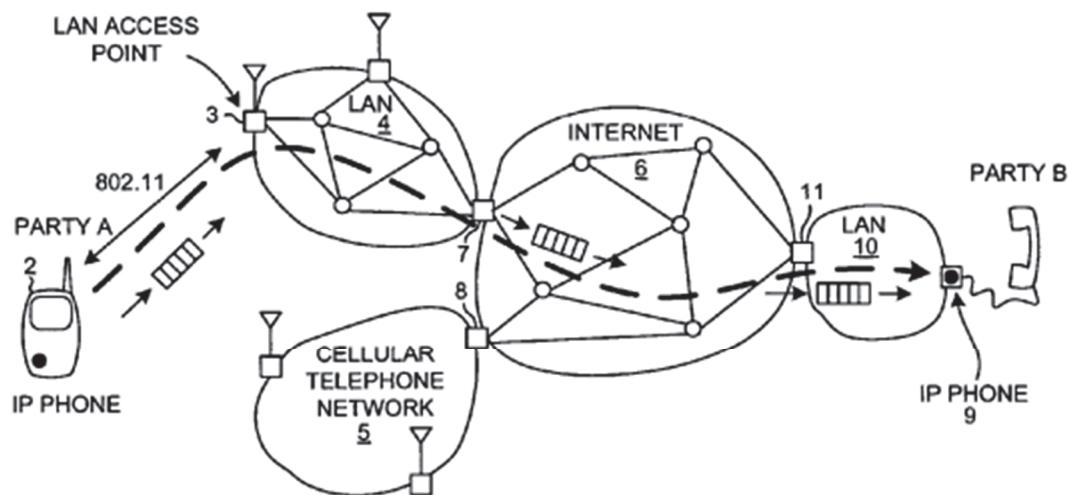
36. Petitioners’ Ground 2 relies on two references. The base reference is U.S. Patent No. 8,467,377 to Kottilingal (“*Kottilingal*”).

37. *Kottilingal* describes a mobile communication device (for example, a cellular telephone) that has one air interface for wireless communication with a wireless LAN (Local Area Network) and another air interface for telephone

communications across a cellular telephone network. EX1006 at 1:53-61. By using these two separate air interfaces, the *Kottilingal* device aims to increase quality of service in mobile devices. *Id.* at Title.

38. The *Kottilingal* mobile communication device discusses the transmission of VoIP packets of a media stream to a target communication device (for example, to another IP telephone that is coupled to the Internet at a remote location). EX1006, 1:62 – 2:5. The VoIP voice packets are communicated by using RTP over UDP (User Datagram Protocol) over IP (Internet Protocol). *Id.* at 1:62 – 2:5.

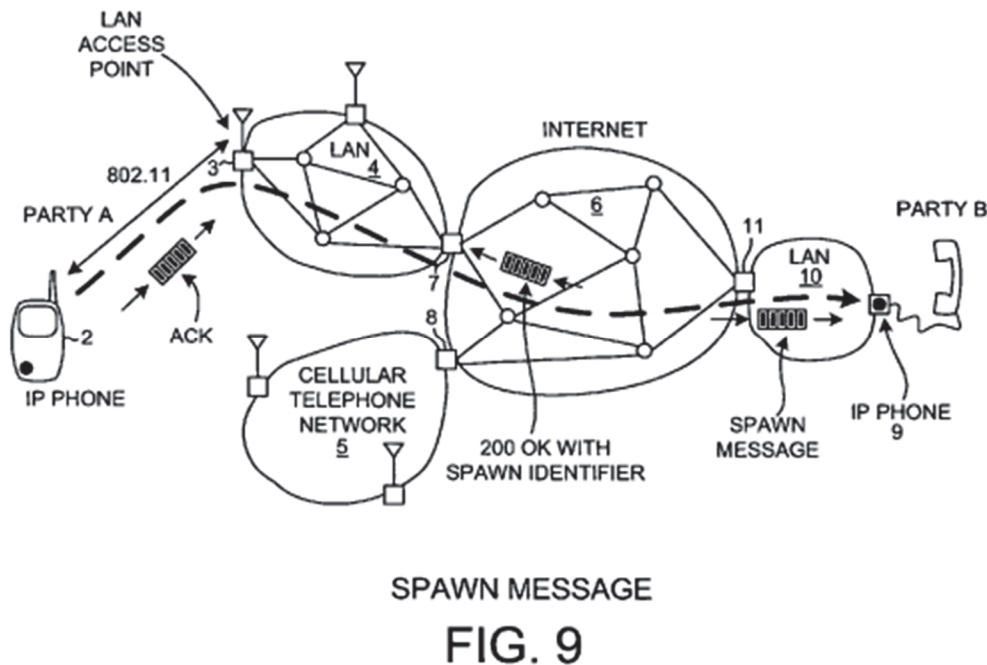
39. In one embodiment, *Kottilingal* describes the communication of VoIP/VIP IP data payload packets in a first SIP session, as illustrated by Figure 6:



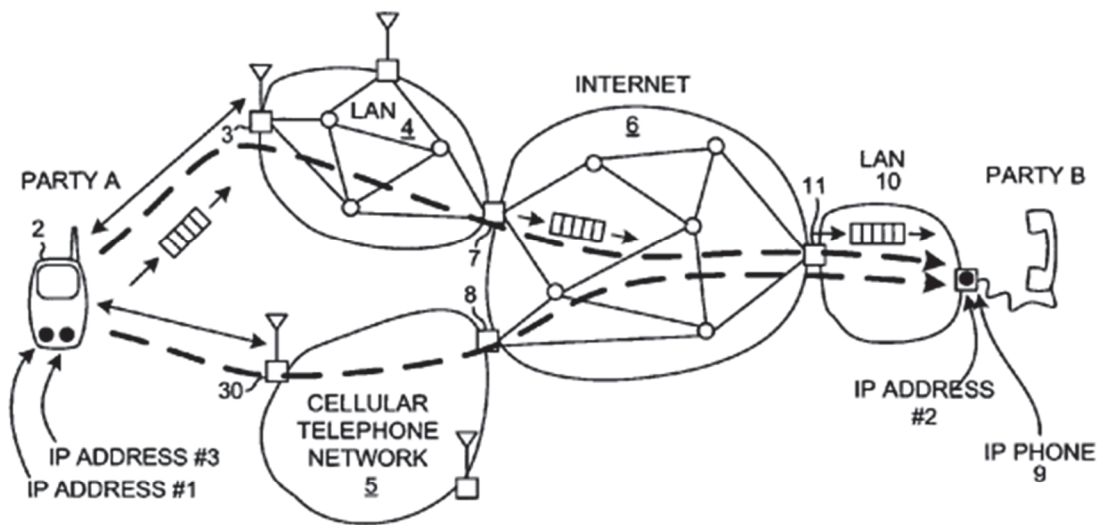
FIRST SESSION ACTIVE -
PARTY A MOVES AWAY FROM LAN ACCESS POINT

FIG. 6

40. Relevant here, *Kottilingal* discusses that it may be desired to continue the call by using the other air interface of the mobile communications device, such as when Party A moves farther and farther away from access point 3. EX1006, 2:6-41; *see also id.* at 8:18-25. To do so, PARTY A's mobile communication device sends a SPAWN SIP message to PARTY B's target communication device. *Id.* The transmission of the SPAWN SIP message is illustrated by Figure 9:



41. The mobile communication device may then establish a second session across the other air interface. EX1006, 2:6-41. The second session is initialized and both the first and second sessions are active VoIP sessions. As noted in the below figure, the first and second sessions are associated with different IP addresses within IP Phone 2. *Id.* at Fig. 10.



BOTH FIRST SESSION AND SECOND SESSION
ARE ACTIVE

FIG. 11

EX1006, 2:6-41.

42. Thereafter, the mobile communication device may stop transmitting VoIP packets for the media stream in the first session and may begin transmitting subsequent VoIP packets for the media stream in the second session. EX1006, 2:42-45. The termination of the first SIP session and resulting handoff to the second SIP session is illustrated by Figure 17:

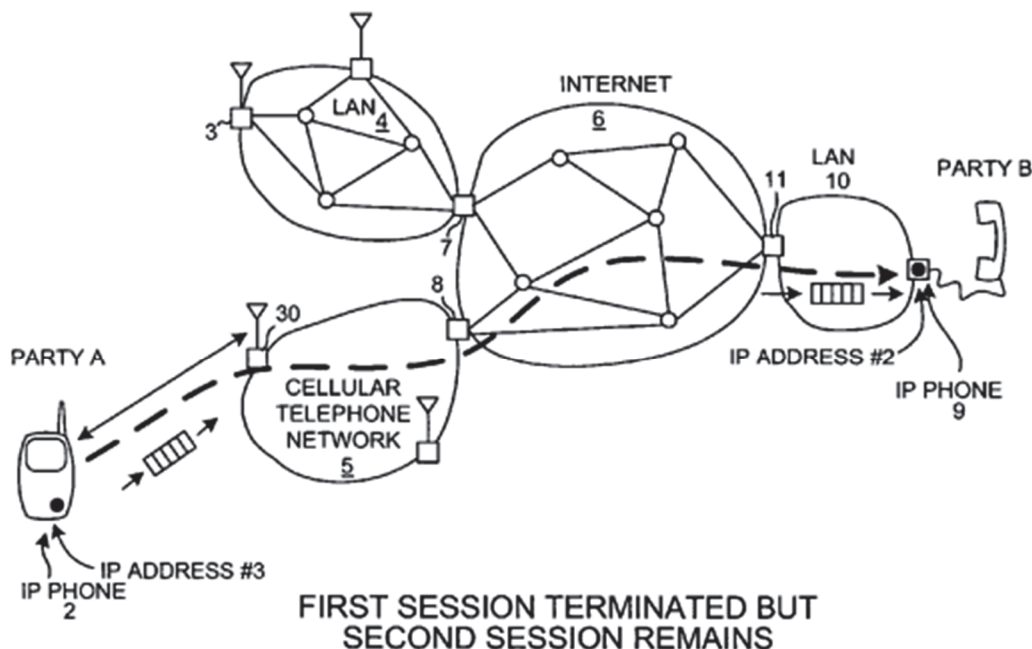


FIG. 17

3. Politis Summary

43. The other cited reference in the Grounds is a secondary reference, *Politis*, which is a conference paper published April 23, 2003, entitled: “Multilayer Mobility Management for All-IP Networks: Pure SIP vs. Hybrid SIP/Mobile IP” (“*Politis*”). *Politis* is cited in support of Ground 2 in combination with *Kottilingal* to support this invalidity position. *Kottilingal* is used as the base reference, with *Politis*, cited for limitation 1.3 associated with NAT/PAT.

44. *Politis* discloses two mobility management architectures based on SIP and Mobile IP Protocols. EX1007, 1. The two approaches, referred to as SIP-based and hybrid SIP/Mobile IP approaches, provide mobility in two different layers: the application and network layer. *Id.* The first approach utilizes SIP signaling to support

micromobility. *Id.* at 2. The second approach utilizes SIP in conjunction with Mobile IP functionality to support inter-domain mobility. *Id.* at 3. The second approach additionally utilizes NAT/STUN functionalities, which increase the overall signaling load. *Id.*

4. References Not Relied Upon by Petitioners

45. Petitioners include discussion of various other references but do not rely on any of them to form the basis of either Ground of alleged unpatentability. Thus, I have not been asked to opine on the applicability of those references to the challenged claims.

V. PERSON OF ORDINARY SKILL IN THE ART

46. I am informed and understand that in the field of patent law, a POSITA is a hypothetical person who is presumed to have known the relevant art at the time of the invention. I understand that the facts that may be considered in determining the level of ordinary skill in the art include: (a) the types of problems encountered in the art; (b) prior art solutions to those problems; (c) the rapidity with which innovations are made; (d) the sophistication of the technology at issue; and (e) the educational level of active workers in the field.

47. Petitioners and their expert propose a level of skill in the art that is somewhat unclear to me. I agree with the educational level and certain of the experiential level proposed by the Petitioners – that is, a bachelor's degree in

electrical engineering or computer science and two years of experience; a master's degree in electrical engineering or computer science, but having only one year of experience; or no formal education but experience in network service plan provisioning systems of at least four years. EX1003, ¶ 37.

48. However, the suggestion that a POSITA in the March 2008 timeframe would have “been familiar with designing rules for implementing policies for service plans for use of an access network and provisioning those rules to network elements for policy enforcement” is both ambiguous and too restrictive. For one, it is not clear what “designing rules for implementing policies for service plans for use of an access network” means. Second, it is not clear why Petitioners argue that such experience is necessarily required for a POSITA at the time of the invention.

49. In my opinion, the educational and experience level above relating to “network service plan provisioning systems” is more than sufficient for establishing the appropriate level of skill in the art for purposes of this proceeding. Nevertheless, to the extent Petitioners’ proposed level of skill can be understood, I was at least a POSITA in the field of technology of the ’554 Patent at the time of the invention and am qualified to offer opinions on the state of the art and what POSITAs would have known and understood in the March 2008 timeframe.

VI. LEGAL PRINCIPLES

50. I am informed and understand that a patent claim is invalid as anticipated under 35 U.S.C. § 102 only if each and every element as set forth in the claim is found, either expressly or inherently, in a single prior art reference, and that the elements must be arranged as required by the claim.

51. I am informed and understand that a patent claim is invalid as obvious under 35 U.S.C. § 103 if the differences between the claimed invention and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art. I am informed and understand that a claimed invention composed of several elements is not proven obvious merely by demonstrating that each of its elements was known independently in the prior art. A patent challenger must identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements. In determining whether a claimed invention is obvious, each claim must be considered separately, and hindsight may not be used, but only what was known at the time of the invention.

52. I am informed and understand that in making a determination whether a given patent claim is obvious, one must take 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 objective evidence (called

“secondary considerations”) that may have existed at the time of the invention and afterwards that shed light on the nonobviousness of the claimed invention, including:

(a) whether the invention was commercially successful as a result of the merits of the claimed invention; (b) whether the invention satisfied a long-felt need; (c) whether others had tried and failed to make the invention; (d) whether others copied the invention; (e) whether the invention achieve unexpected results; (f) whether others in the field praised the invention; among others.

VII. CONSTRUCTION OF CLAIM TERMS

53. I have been informed and understand that to properly evaluate the '554 Patent, the terms of the claims must first be interpreted.

54. I understand that neither party has proposed a specialized construction for the terms of the '554 Patent in this IPR at this time. Accordingly, the opinions set forth in this declaration are based the plain and ordinary meaning of the claim terms set forth in the '554 Patent. To the extent any specialized construction is presented or offered, I reserve the right to supplement the opinions set forth herein.

VIII. PETITIONER'S ASSERTED GROUNDS OF THE UNPATENTABILITY OF THE CHALLENGED CLAIMS

55. In my opinion, both Grounds of Invalidity presented by Petitioners fail to establish the unpatentability of the Challenged Claims. The independent claims of the '554 Patent require maintaining a transmission's SIP signaling sequence after

switching network paths, and neither ground asserted by Petitioners discloses or fairly teaches this feature.

56. Ground 1 of the Petition alleges *Tagg* “discloses or suggests” this feature. *See* Petition at 39-41. However, *Tagg* contains no express teachings of a SIP signaling sequence, nor does it include any discussion of maintaining a SIP signaling sequences as part of a network switching.

57. Ground 2 of the Petition similarly asserts that *Kottilingal* discloses or suggests the SIP signaling sequence limitation. *Id.* at 75-77. However, the SPAWN SIP message in *Kottilingal*, relied on by Petitioners for the limitation directed to maintaining a SIP signaling sequence, is sent prior to any network switching, not after as set forth in the claims. Furthermore, as shown in the comparison between Fig. 14 and Fig. 7 of *Kottilingal*, the SIP Sequence CSEQ numbers before the handoff (Fig. 7) are distinctly different from the CSEQ numbers after the handoff (Fig. 14) indicating the SIP signaling sequence is indeed not maintained as required by the independent claims.

A. GROUND 1 - *Tagg*

58. Ground 1 in the Petition relies on the *Tagg* reference. No other references are explicitly cited in support of Ground 1 for any of the independent claims. *See* Petition at 14. In this regard, the Petition primarily relies upon the “handoff” scheme presented in *Tagg*, employing its “make-before-break” process.

See, e.g., Petition at 19. That process does not teach or suggest the claimed processes set forth in the '554 Patent.

59. While other differences exist, at a minimum, *Tagg* does not teach or suggest “the SIP signaling sequence of the transmission is maintained after said switching from the first network path to the one of a plurality of alternative network paths” as set forth in the independent claims of the '554 Patent.

1. The *Tagg* Reference Does Not Include Any Discussion of a “SIP Signaling Sequence” or “CSeq”

60. *Tagg* does not teach or discuss SIP sequencing or any SIP signaling message numbering such as CSeq. *See* EX1005. No other references are cited for this limitation. *See* Petition at 39-41. The passages and figures of *Tagg* relied on in the Petition, which are discussed in more detail below, describe handoff techniques. Petition at 39-41. However, there is no discussion of SIP signaling sequencing and, more importantly with respect to the claims, maintaining a SIP signaling sequence.

2. The Petition Does Not Address the Deficiencies in the *Tagg* Reference

61. For this limitation, the Petition relies on an annotated version of Fig. 15 in *Tagg* and a general statement that a POSITA “would have understood” that *Tagg* disclosed SIP sequencing. Petition at 39-41. As described in the Petition, Fig. 15 illustrates the embodiment in *Tagg* that Petitioners rely upon. The annotated version from the Petition is reproduced below:

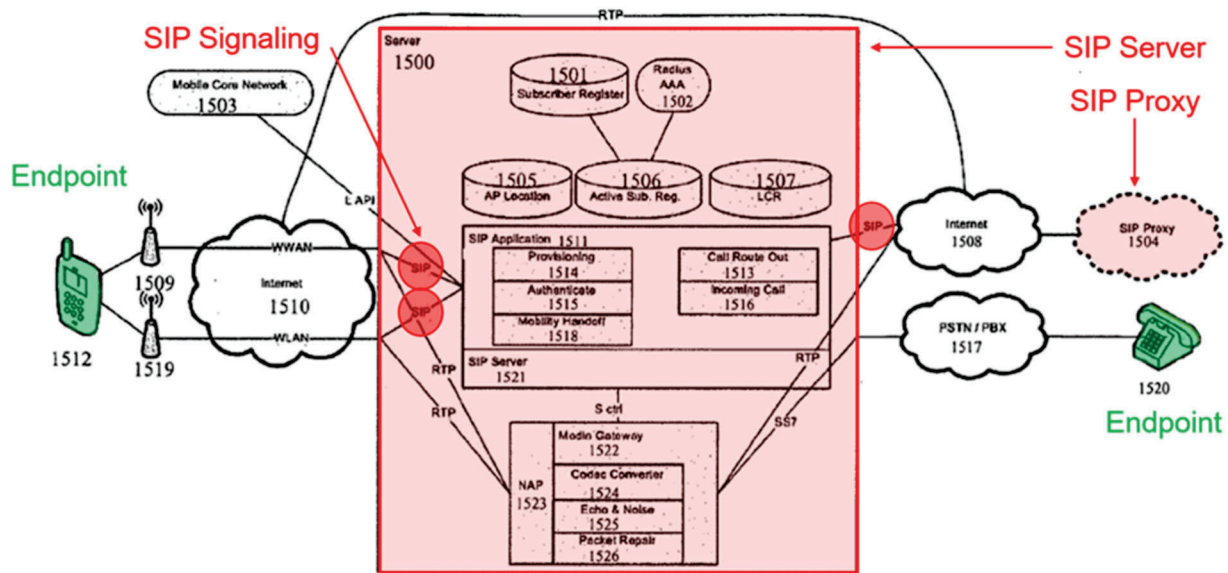


Figure 15

62. Petition at 40; EX1005, FIG. 15 (annotated by Petitioners). Petitioners take the position that this diagram shows that “the same SIP signaling sequence is preserved to and through a SIP server or SIP proxy regardless of switching from a WWAN to WLAN network or vice versa.” Petition at 40. Petitioners’ expert states the same. EX1003, ¶121.

63. Fig. 15 is a high-level representation of the duplicative handoff process taught by *Tagg*. However, *Tagg* does not provide any description of the associated SIP processes and of SIP sequencing maintenance. Rather than focusing on SIP or SIP sequencing, *Tagg* focuses on using a redundant process whereby data is sent in duplicate—one set sent via a LAN network and the other set sent via a WAN network. EX1005, ¶ [0324]. *Tagg* accomplishes its handoff by virtue of its make-before-break feature, which uses a duplicate audio path to/from the proxy via another

IP route that is created when hand-off “is looking likely.” EX1005, [0296]. According to *Tagg*, “[w]hen the hand-off is confirmed, the handset switches over to the new audio-path and disconnects the old one.” EX1005, ¶ [0296]. *Tagg* further states that this does not require any re-invites or conferencing as the proxy is the client as far as the server is concerned and so it never changes its IP address.” EX1005, ¶ [0296].

64. The position present by Petitioners that Fig. 15 illustrates maintaining a SIP signaling sequence during handoff is not supported. *See* Petition at 40. *Tagg* merely includes general statements regarding SIP (and RTP), that do not support Petitioners’ conclusion. For example, *Tagg* states that Session Initiation Protocol (SIP) and Real-time Transport Protocol (RTP) can be used and these protocols should be optimized for wireless transport. EX1005, ¶ [0100]. *Tagg* also states that its disclosed system “can be implemented quickly as no re-configuration is required or the packets can be simultaneously sent over both radio connections during the handoff to provide seamless handoff.” *Id.* ¶ [0129].

65. However, the “handoff” procedure discussed in *Tagg* does not rely on SIP sequencing. Rather, *Tagg* performs handoff by duplicating an audio path to/from a proxy via another IP route when hand-off “is looking likely.” *Id.* ¶ [0296]. *Tagg* describes this duplicative process multiple times and does not discuss SIP sequencing. *See, e.g., id.* ¶¶ [0296] - [0324].

66. A de-duplication sorting process that converts the two underlying RTP media streams into a single stream is shown in EX1005 at Fig. 24, whereby the sorting is performed by using *Tagg*'s Network Address Processor (NAP) 2401. The latter is shown to feed media gateway 2408. NAP is shown in Fig. 15 as module 1523. It is shown as a module included in the media's module of *Tagg*'s server 1500 that is identified by *Tagg* as the "server of the invention." EX1005, ¶ [0100]. Said NAP is noted to be employed for media packets' de-duplication. *Id.* ¶ [0343]. Only the de-duplication of media streams that carry RTP packets is shown. No discussion is presented of a de-duplication process and system that involves SIP message flows, and no mentioning is made of associated SIP packet sequencing maintenance.

67. Further supporting the fact that *Tagg* is not focused on maintaining a SIP signaling sequence are its teachings of other handoff methods, including "break-before-make" handoff and "break & make" handoff. *Id.* ¶ [0285]. In "break-before-make" handoff, by its definition, "there is a pause in packet sending as handoff is made." *Id.* Additionally, "break & make" is described to mean "there is such a short time between the break and make that the user does not notice it even though it is technically a break before make event." *Id.* *Tagg* also fails to suggest that a SIP signaling sequence is maintained during these handoff methods (that have pauses/breaks), which are also handoff methods described in *Tagg* Cases 1 and 6

which are relied on by the Petition. *Id.* ¶¶ [290]-[291], [0320]; *see also* Petition at 41.

68. In summary, *Tagg* fails to disclose or suggest maintaining a transmission's SIP signaling sequence after switching from a first network path to the one of a plurality of alternative network paths.

3. Petitioners' Expert Does Not "Fill in the Gap" in the Petition's Deficient "SIP Signaling Sequencing" Analysis

69. Petitioners' Expert's declaration similarly does not explain how maintaining a SIP signaling sequence during handoff is taught or suggested by *Tagg*. *See* EX1003, ¶¶ 117-124.

70. Petitioners' Expert makes the following assertions:

A POSITA would have understood that *Tagg*'s SIP protocol uniformity in directionality teaches that a "SIP signaling sequence...is maintained" regardless of switching between the WWAN and WLAN networks because this allows the user to "appear[] to the rest of the world as if they are not moving between networks" even when "flip[ping] back and forth freely" between WWAN and WLAN networks (*Tagg*'s cases 1 and 6). EX-1005, Fig. 15, ¶¶ 0247, 0320.

Id. at ¶ 123; *see also*, Petition at 40.

71. The cases (*e.g.*, cases 1 and 6) set forth in *Tagg* cited in support of this proposition do not disclose or suggest the maintenance of a SIP signaling sequence during handoff. While it is true that cases 1 and 6 of *Tagg* contemplate handing off a voice call from WLAN to WWAN (case 1) and vice-versa (case 6), the text that is

describing these cases includes no discussion that a SIP signaling sequence must be maintained. EX1005, ¶ [0285]. Instead, *Tagg* discusses that seamless handoff for case 1 is achieved by either (1) rapidly switching the IP stream from the WLAN socket to the WWAN socket connection “break-before-make”, or (2) copying the IP stream to two sockets and once end-to-end connectivity is proven stopping the stream to the WLAN socket “make-before-break.” *Id.* ¶ [0290]. Neither cases 1 or 6, nor FIG. 15 as described above, disclose or suggest post-switching maintenance of a SIP signaling sequence during handoffs.

B. Ground 2 - *Kottilingal*

72. Petitioners’ Ground 2 relies on two references—*Kottilingal* as the base reference, and *Politis* as a secondary reference that is used for limitation 1.3. Similar to Ground 1, only the Petition’s contentions with respect to the “SIP signaling sequence” limitation (1.6) are addressed here. It is noted, however, that other differences exist between this reference and the challenged claims.

73. For the “SIP signaling sequence” limitation, Petitioners’ second Ground relies on *Kottilingal*, and in particular, the Petition’s analysis relies on the “SPAWN” message process discussed in that reference. *See* Petition at 75-77. However, that message (and *Kottilingal* overall) is directed to a different process, distinct from that described and claimed by the ’554 Patent.

74. To address call quality problems, *Kottilingal* teaches the configuration of multiple parallel sessions. A duplicative process is formed, where parallel data transfers are carried out across separate paths, separate air interfaces, and separate SIP sessions. EX1006, 1:53-2:41. That process is different from the process claimed by the '554 Patent.

75. The “SPAWN” message relied on in the Petition is directed to establishing duplicative SIP sessions. *See* Petition at 75-77; *see also* EX1006, 9:1-22 & FIGs. 9-10. Thus, the feature relied upon in the Petition for Ground 2 to teach or suggest “...the SIP signaling sequence of the transmission is maintained after said switching from the first network path to the one of a plurality of alternative network path” fails to maintain the SIP sequence.

76. Instead, it establishes a new SIP session over another network path, in which SIP message sequence numbers and SIP signaling sequence are not maintained after the switching.

1. The “SPAWN” Message in *Kottilingal* Occurs Before Any Network Handoff/Over, in Contrast with the Claimed Feature

77. Petitioners’ position in Ground 2 with respect to “the SIP signaling sequence” limitation is based on Fig. 7 of *Kottilingal*. *See* Petition at 75-77.

Petitioners state:

For example, *Kottilingal*’s Figure 7 discloses a CSEQ value placed at the same sequential position (green) in SIP messaging between an IP phone 2 to

IP phone 9 (To→From→Call- ID→CSEQ parallels Master To→Master From→Master Call-ID→Master CSEQ):

```

SPAWN SIP:BOB@BILOXI.COM SIP/2.0
VIA: SIP/2.0/UDP PC33.ATLANTA2.COM;BRANCH=ADFS
MAX-FORWARDS: 70
TO: BOB <SIP:BOB@BILOXI.COM>
FROM: ALICE <SIP:ALICE@ATLANTA2.COM>;TAG=876767776
CALL-ID: D7878-0-A2@PC33.ATLANTA2.COM
CSEQ: 314160 SPAWN
CONTACT: SIP:ALICE@PC33.ATLANTA2.COM.
CONTENT-TYPE: APPLICATION/SDP
CONTENT-LENGTH: 142

MASTER VIA: PC33.ATLANTA1.COM;BRANCH=Z9HG4BK776ASDHDS
MASTER TO: BOB <SIP:BOB@BILOXI.COM>
MASTER FROM: ALICE <SIP:ALICE@ATLANTA1.COM>;TAG=1928301774
MASTER CALL-ID: A84B4C76E66710@PC33.ATLANTA1.COM
MASTER CSEQ: 314159 INVITE
MASTER CONTACT: <SIP:ALICE@PC33.ATLANTA.COM>
  
```

} SO CALLEE CAN
IDENTIFY WITH
FIRST SESSION

SPAWN MESSAGE

FIG. 7

Petition at 75-76 (annotations original in Petition).

78. Petitioners compare this image with the disclosure included in the '554 Patent columns 4 and 5 to conclude that *Kottilingal* teaches the maintenance of the SIP signaling sequence in accordance with the claims. Neither the Petitioners nor their Expert relies on any other portion of *Kottilingal* for this limitation. Petition at 75 -77; EX1003, ¶¶ 230 – 233.

79. This limited analysis does not align with the disclosure in *Kottilingal*. The SPAWN message shown in *Kottilingal* Fig. 7 is used to initiate a new SIP session, and it is sent before any switching occurs. This is made clear by examining Fig. 6 and the accompanying description which describe the use of the SPAWN message. See EX1006, 8:18 – 67. The process triggered by the SPAWN message is distinctly different from the claimed process in at least two key ways – it does not

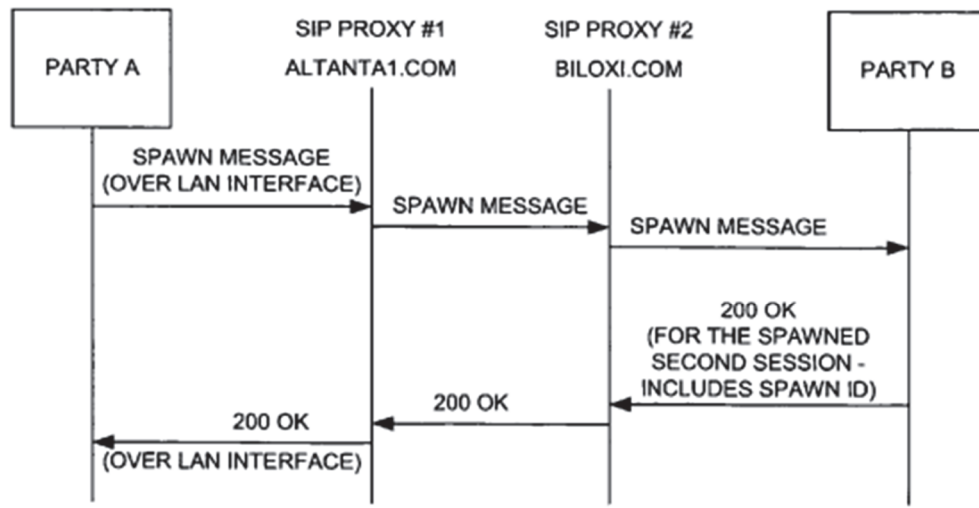
come after switching, and it is not part of maintaining the first SIP session but rather establishing a new SIP session.

80. The *Kottilingal* reference makes clear that the SPAWN message is sent before any switching occurs. For example, that reference states:

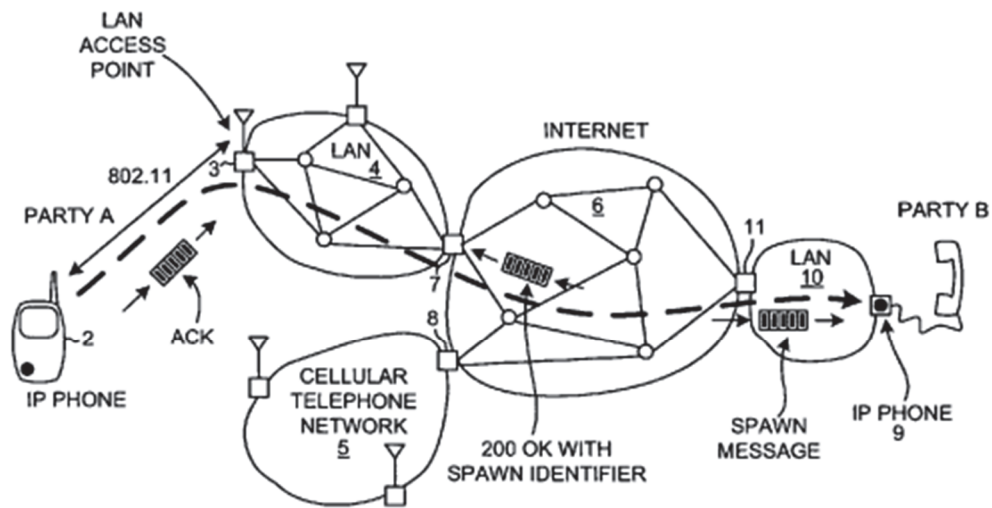
Once the threshold is reached, IP phone 2 determines that IP phone 2 should initialize a second SIP session using its long range cellular telephone transceiver. IP phone 2 initializes the second SIP session by sending a novel SIP message called a SPAWN message from PARTY A to PARTY B **in the first session**.

EX1006, 8:39-44 (emphasis added).

81. The accompanying descriptions associated with Figs. 6-9 demonstrate as well that the SPAWN message is configured in the first session and is sent before any switching has occurred. FIG. 8 of *Kottilingal* is a diagram illustrating the communication flow of the SPAWN SIP message from PARTY A to PARTY B, and FIG. 9 illustrates a flow involving the SPAWN SIP request:



SPAWN MESSAGE
FIG. 8



SPAWN MESSAGE
FIG. 9

EX1006, FIGS. 8, 9, 8:47-67.

82. As illustrated, the SPAWN SIP message is communicated from IP phone 2, across the 802.11 wireless link to access point 3 on LAN 4, across LAN 4

to SIP proxy **7**, and across Internet **6** to SIP proxy **11**, and across LAN **10** to PARTY B's IP phone **9**. EX1006, FIGS. 8, 9, 8:47-67. As shown in FIG. 9, the SPAWN SIP message is entirely communicated in the first session, using LAN 4 as its access medium and is sent before any switching has occurred. Only after the SPAWN SIP message is communicated (and the 200 OK SIP message is received by PARTY A's phone **2**) is there any communication with another network, as clearly shown in FIG. 10 in which PARTY A's phone **2** is shown to issue a second INVITE SIP request for handing off communications to the cellular telephone network **5**. *Id.* at FIG. 10; 9:5-32.

83. Hence, since the SIP SPAWN message in *Kottilingal* is sent prior to any path switching, it fails to teach or suggest a SIP sequence that is “maintained after said switching...” as set forth in the independent claims.

2. *Kottilingal* Focuses on a Different Handoff/Over Process

84. The handoff/handover process taught by *Kottilingal* is distinctly different than that set forth in the claims of the '554 Patent. For instance, in some examples the system of the '554 Patent can accomplish seamless network switching after an alternative path is determined to be available by selecting a SIP server, sending a re-invite, and updating the sequence numbers. EX1001, 4:45-5:37. The sequence number is then updated again after the attempted move. *Id.* Again, “[t]he SIP signaling sequence of the transmission is maintained after said switching from

the first network path to the one of a plurality of alternative network paths.” *Id.* On the other hand, *Kottilingal* makes use of separate SIP sessions conducted over separate network paths (and air interfaces). This setup is then used for the transfer between networks. This is distinct from the switching claimed by the ’554 Patent.

85. The process used by *Kottilingal* involves the establishment of multiple parallel SIP sessions. If the call quality of a first SIP session that uses a given path becomes lower than that offered along a second network path, a new second SIP session is initiated. Media packets may be sent in an interleaved manner across both paths. The abstract in *Kottilingal* provides a summary of the employed process:

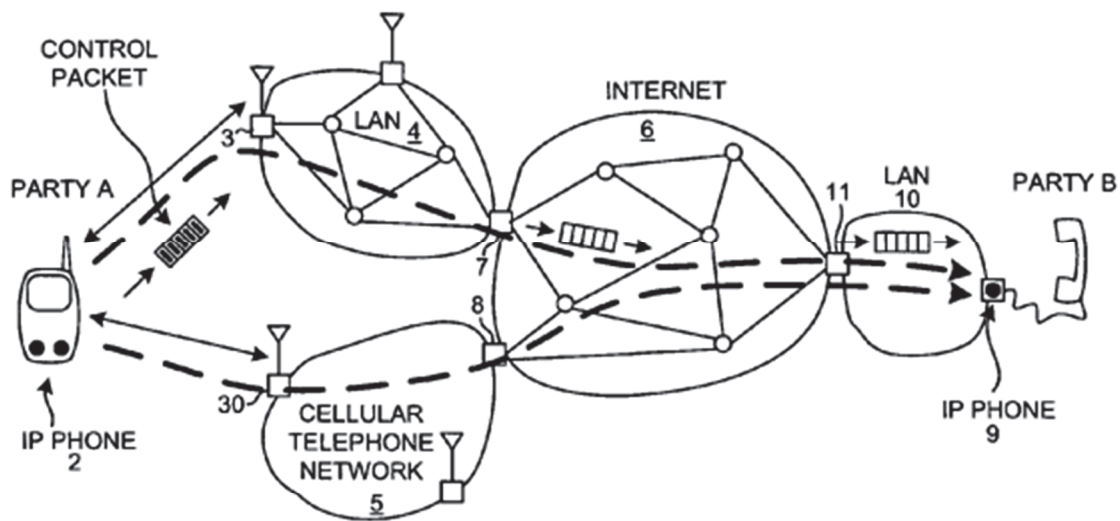
A first mobile device has two air interfaces. The first mobile device uses its first interface to transmit VoIP/VIP packets to a second device in a first session. If a quality of service decreases, then the first device causes a second session to be set up where the second session uses the second air interface. Both the first and second air interfaces are then used to communicate packets of a single media stream from the first device to the second device. The packets are transmitted in the first and second sessions in interleaved fashion, where the ratio of packets communicated in one session versus the other per unit time is adjusted in accordance with a quality of service afforded by one session versus a quality of service afforded by the other session. The second device orders the data payloads of the packets, thereby reconstructing the single media stream.

EX1006, Abstract.

86. The accompanying description in this reference provides additional details regarding how these various SIP sessions are initiated, describing how a given call’s data is transferred across these sessions and their corresponding paths.

For example, in one embodiment, once a subsequent SIP session is established, data transmission in the prior SIP session is terminated. *See* EX1006, 2:42-61. In another, the two SIP sessions are continued and data is transmitted across the two sessions in an interleave manner and ordered at the destination. *See Id.* at 3:32-44. In none of the embodiments described in *Kottilingal* is the SIP session configured across one network has its SIP signaling sequence maintained across the other network after switching. There is no teaching that the SIP sequencing should be maintained in any of the embodiments discussed in *Kottilingal*.

87. This is further confirmed by examining Figures 13 and 14 of *Kottilingal*:



MEDIA FLOW HANDOFF CONTROL PACKET

FIG. 13

```
SWITCH SIP:BOB@BILOXI.COM SIP/2.0
VIA: SIP/2.0/UDP PC33.ATLANTA2.COM;BRANCH=ADFD SGFSS
MAX-FORWARDS: 70
TO: BOB <SIP:BOB@BILOXI.COM>
FROM: ALICE <SIP:ALICE@ATLANTA2.COM>;TAG=876198
CALL-ID: D7878-0-A2@PC33.ATLANTA2.COM
CSEQ: 31401 SWITCH
CONTACT: SIP:ALICE@PC33.ATLANTA2.COM.
CONTENT-TYPE: APPLICATION/SDP
CONTENT-LENGTH: 142

SPAWN-ID: ASD14KLJLDK1567E409870

SWITCH-FROM: ALICE <SIP:ALICE@ATLANTA1.COM>
SPAWN-TO: ALICE <SIP:ALICE@ATLANTA2.COM>

MEDIA FLOW HANDOFF CONTROL PACKET
```

FIG. 14

EX1006, FIGS. 13, 14 (annotations added).

88. In this embodiment of *Kottilingal*, after the second session is established, a handoff control packet is sent from the mobile communication device to the target to alert the target that subsequent VoIP packets will no longer be received in the first session but rather will be received in the second session. EX1006 at 2:45-49. As shown in FIG. 13, the handoff control packet is sent over the first session in this embodiment. *Id.* at FIG. 13. As shown by the annotations at Fig. 14, the SIP sequencing number of the handoff control packet is 31401 SWITCH which is distinctly different than the CSEQ of the SPAWN SIP message (314160 SPAWN) and of the Master CSEQ of the SPAWN SIP message (314159 INVITE). *See id.* at FIG. 7; FIG. 14. In contrast with the Petition's assertions, this discrepancy

demonstrates that the SIP signaling sequence *is not* maintained after the transmission is switched from the first network path to a second network path, as it is handed off from the first session to the second session. For at least these reasons, the *Kottilingal* reference does not invalidate the claims of the '554 Patent.

I hereby declare that all statements of my knowledge made in this declaration are true and that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 1/22/2025

A handwritten signature in dark ink, appearing to read "I. Rubin", written over a horizontal line.

Izhak Rubin

APPENDIX

A

Dr. IZHAK RUBIN

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Biography



Izhak Rubin, Ph.D.

Izhak Rubin received the B.Sc. and M.Sc. from the Technion - Israel Institute of Technology, Haifa, Israel, in 1964 and 1968, respectively, and the Ph.D. degree from Princeton University, Princeton, NJ, in 1970, all in Electrical Engineering. Since 1970, he has been on the faculty of the UCLA School of Engineering and Applied Science where he is currently a Distinguished Professor Emeritus in the Electrical and Computer Engineering Department.

Dr. Rubin has had extensive research, publications, consulting, and industrial experience in the design and analysis of commercial and military computer communications and telecommunications systems and networks. At UCLA, he has been leading a research group and serving as *co-Director of the UCLA Public Safety Network Systems (PSNS) Laboratory*. In 2014, he received the excellence in teaching award at the UCLA School of Engineering and Applied Science. Recent R&D projects include design, simulation, management, and planning tools for network modeling and analysis, multi-task resource allocation, unmanned-vehicle aided multi-tier wireless communications networks; cooperating adaptive cross-layer cellular and ad hoc wireless networks; communications networking for self-driving vehicular systems; integrated traffic management and communications networking for autonomous highway transportation systems.

As a consultant, acting as Chief Scientist of the Xerox Telecommunications network, he developed breakthrough methods for the design and test-bed implementation of metropolitan-area wireless networks. He served as a leading contributor to the analysis and design of Air Traffic Control network systems. He developed network centric command and control and network management mechanisms for US Army and US Navy systems. He designed and analyzed high, medium and low altitude satellite networks. He innovated new architectures and algorithms for UAV (drone) aided

network systems and contributed to their implementations. He has been working with Caltrans engineers and engineering researchers in developing designs for autonomous highway transportation systems.

He served as co-chairman of the 1981 IEEE International Symposium on Information Theory; as program chairman of the 1984 NSF-UCLA workshop on Personal Communications; as program chairman for the 1987 IEEE INFOCOM conference; and as program co-chair of the IEEE 1993 workshop on Local and Metropolitan Area networks. He served as program co-chair of the 2002 first UCLA/ONR Symposium on Autonomous Intelligent Networked Systems, and has organized many other conferences and workshops. He has served as an editor of the *IEEE Transactions on Communications*, *Wireless Networks* journal, *Optical Networks* magazine, *IEEE JSAC* issue on MAC techniques, *Communications Systems* journal, *Photonic Networks Communications* journal, and has contributed chapters to texts and encyclopedia on telecommunications systems and networks. Dr. Rubin is a Life Fellow of IEEE. He is the author of the book: Izhak Rubin, “Principles of Data Transfer Through Communications Networks, Internets, and Autonomous Mobiles,” 22 chapters, 746 pages, published by Wiley – IEEE-Press, ISBN 978-1394267750, 2025.

Izhak Rubin

Professor Izhak Rubin joined UCLA as an Assistant Professor on July 1, 1970. Serving as a Distinguished Professor at the UCLA Electrical and Computer Engineering Department, he retired on July 1, 2019, while subsequently continuing to teach courses at the department and at the UCLA Engineering MS Online program and to engage in research developments. He has made numerous contributions to UCLA students, the University, the School, the Department, and to the research and engineering community at large.

Around 1980, he joined other faculty members of the UCLA System Science Department in merging with the UCLA Electrical Engineering Department. Following this transition, he has led the development of new undergraduate and graduate curricula of Electrical Engineering courses in the area of communications systems and networks. Among the courses that he developed and introduced are undergraduate courses on data communications and telecommunications networks, on Probability and on communications systems, and graduate courses on stochastic processes, queueing and switching systems, multiple access communications, wireless networking, autonomous transportation networks, and graph theory and network flows. While undergoing updates over the years, these courses continue to serve well the department's students.

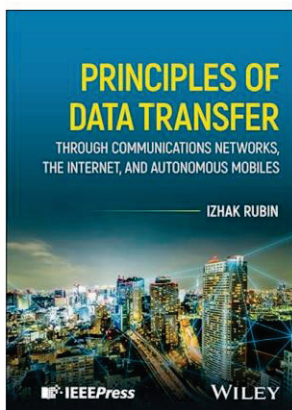
Professor Rubin has been making breakthrough research developments in a wide range of areas relating generally to communications and telecommunications networks. He has become well recognized as a pioneer in the development of communications networking algorithms, protocols and methods that are used for performance modeling, analysis, design and management of wireline and wireless computer communications networks. His many publications include the development of mechanisms for medium access control schemes, routing, topology synthesis, and cross-layer protocols for wireless networks. His ongoing research developments and recently introduced courses focus on traffic management and communications networking for autonomous systems.

His graduated students have been serving as university professors, researchers and leading industrial innovators throughout the country and the world. He received best paper awards and has been elected as an IEEE Life Member Fellow for his exceptional innovative developments in the area of communications networking and for his contributions to engineering education. He served as an editor of several leading professional journals, including IEEE Transactions of Communications, and has served on the boards of professional organizations and societies, including IEEE, and as co-Chair and Program Chair of leading conferences such as the IEEE Symposium on Information Theory and the prestigious IEEE INFOCOM conference.

Professor Rubin is a gifted teacher. He has received the UCLA Engineering Distinguished Teaching Award. Starting in 1980, he has been offering short courses at many organizations worldwide and at UCLA extension, serving to train engineers at a wide range of commercial and military organizations. He has been instrumental in founding the UCLA MS Online program, and has been serving as a Director in the areas of Electrical Engineering and of Signal Processing & Communications. At the department level, he served as a director of the area of Signals and Systems and has been leading the Public Safety Networked Systems and the Autonomous Intelligent Networked

Systems Laboratories, involving undergraduate and graduate students and participants from industrial and public organizations.

Professor Rubin has received numerous grants and contracts from government and commercial organizations for his research and industrial developments. He has served as a leading contributor to the development, analysis and design of key industrial and military networked systems. As a consultant, acting as Chief Scientist of the Xerox Telecommunications network (XTEN), he developed breakthrough methods for the design and test-bed implementation of metropolitan-area wireless networks, contributing as such to the early development of cellular wireless data networks. He served as a leading contributor to the analysis and design of Air Traffic Control network systems, including such that were selected by the FAA to update and replace en-route and airport based air traffic control systems in the US. He developed network centric command and control and network management mechanisms for US Army and US Navy systems and provided network tuning software tools for use by US Navy ship-board and satellite networks. He designed and analyzed high, medium and low altitude satellite networks. He innovated new architectures and algorithms for Unmanned Aerial Vehicular (UAV drone) aided network systems and contributed to their implementations. He has been working with Los Angeles Caltrans engineers and engineering researchers in developing designs for autonomous highway transportation systems. He has been developing new methods for adaptive integration of coding and networking techniques for the attainment of high quality video streaming over wireless networks. He has been engaging in the development of autonomous transportation networks that make use of mmWave communications. He has also been recognized for his contributions to industrial organizations in connection with the development and preservation of intellectual property assets, and for his service as an expert witness in key patent cases. He is the author of the book: Izhak Rubin, “Principles of Data Transfer Through Communications Networks, Internets, and Autonomous Mobiles,” 22 chapters, 746 pages, published by Wiley – IEEE-Press, ISBN 978-1394267750, 2025.



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Education

Ph.D., Electrical Engineering Department, Princeton University, 1970.

M.Sc., Electrical Engineering Department, Technion, Israel Institute of Technology, 1968.

B.Sc., Electrical Engineering Department, Technion, Israel Institute of Technology, 1964; Summa Cum Laude.

Employment and Consulting

Employment: University of California, Los Angeles (UCLA), Electrical and Computer Engineering Department, Distinguished Professor, 1970 - Present.

Leading a research group in the telecommunications and computer communications networking area; recipient of many research grants and contracts from Government and Industry (NSF, ONR, NRL, AFOSR, Pacific Bell, US WEST, Nokia, Conexant, Northrop-Grumman, Boeing, Lockheed-Martin, Intel, Raytheon, and others). Authored or co-authored more than 200 paper publications.

He serves as the Co-director of the UCLA Public Safety Network Systems Laboratory, 2010 - Present.

Employment: IRI Computer Communications Corporation, Los Angeles, California, President and Chief Engineer, 1979 – Present

Technical leader of IRI Computer Communications Corporation. Consulting services to industrial and R&D telecommunications and computer communications organizations. Development of the PLANYST program for the modeling, analysis, planning, design, testing and management of telecommunications and computer communications networks. Legal expert consulting services.

Consulting Services

UCLA Extension; commercial and governmental organizations: Presentation of courses on computer communications and telecommunications networks; 1980 - current.

Raytheon Corporation: Public safety network systems; 2011-2014.

Consulting services to law firms in patent cases and as expert witness.; 2000 - current.

US Navy: Simulation tool and performance evaluations of computer network systems; wireless networks; network management; 1991- 2008

Boeing Defense Systems and System Integration: Communications networking; simulation, analysis and design of mobile wireless networks and UAV aided network systems; Integrated System Management for network-centric systems, training courses. 2003 – 2007.

Hughes and Boeing Satellite Systems: Multiple access protocols and performance evaluation for satellite wireless communications network systems; 1998- 2001.

Acting Chief Scientist, Xerox Telecommunications Network, Xerox Corp., 1979-1980: Development of architecture and protocols for stationary wireless data networks.

JPL: Analysis, testing and evaluation of air traffic control circuit switches. 1986 - 1997.

TRW: Multiple access protocols and performance evaluation for satellite communications network systems. 1994 – 1998.

Hughes: Traffic and service modeling; 1996 – 1997.

US Army, Litton, Singer-Librascope, SAIC (Science Applications International Corp.), US Navy: Mathematical modeling and analysis for C3 systems; performance analyses and networking protocols for military wireless networks. 1984 - 1996.

SBC Pacific Bell: University oriented basic research investigations into the modeling, analysis, protocols and architectures of telecommunications networks using queueing and traffic engineering models; 1989 – 1999.

Rockwell International Science Center: University oriented basic research investigations into multiple access protocols for wireless networks; 1994 – 1996.

NORTEL Bay Networks: University oriented basic research investigations into performance modeling and analysis of computer networks; 1996-1998.

US WEST: University oriented basic research investigations of flow control and networking schemes for ATM and DQDB networks; 1989 – 1992.

Intelsat: Modeling, simulation and analysis of satellite networks; 1992.

Aerospace Corporation: Wireless networking, multiple access protocols and performance evaluation for satellite communications network systems. 1975; 1988.

Litton; Singer Librascope: Military wireless networks; 1982-1985.

KODAK: Local area networking for storage networks. 1985.

IBM: Mathematical modeling of queueing networks. 1974.

STI (Stanford Telecommunications, Inc.): Protocols for wireless networks. 1979.

Short Courses

2-day, 4-day and 5-day courses on the fundamentals of communications networking systems. Topics: network fundamentals; communications networking protocols; multiple access algorithms, protocols and systems; local area networks; wide area networks; ATM networks; TCP/IP networking; mobile ad hoc wireless networks, satellite networks; optical networks; network management.

Sample presentations made at the following locations, and organized by the indicated organizations.

Public offerings:

UCLA Extension: 1980 - 2000.

University of Maryland Extension, 1985-1990.

Society of Engineers (STF), Sweden; Stockholm, Sweden; Oslo, Norway;
Copenhagen, Denmark; 1988-1993.

Training courses company; Israel, fundamentals of networking; 1988

Training organization, Tokyo, Japan; 1986.

Monash University Extension, Canada; 1996.

In-house Offerings:

US Army CECOM, NJ: 1984; military wireless networks

Singer Librascope, Van Nuys, CA; 1986; military wireless networks.

3Com; training course on fundamentals of networking for sales engineers; 1991.

TRW: networking fundamentals; 1996 – 2000.

Arris-Interactive (training engineers in multiple facilities in the areas of IP networking and DOCSIS, CATV networking, 2000.

Hughes: basics of networking and satellite communications; 1998; 2000.

Boeing, Anaheim, California, 2003, 2006.

Northrop Grumman Corp., Los Angeles, 2006.

Legal Consulting

Services provided to leading legal organizations in areas of computer communications and telecommunications networking.

Consulting services include: review, evaluation, analyses, comparisons of patents and related claims. Also included are presentations to legal personnel, meetings with company engineers, review and evaluation of technical papers, reports and other material; summaries of claims and comparison reports; state of the art analyses.

Consulting services provided to the following legal organizations (law firm – end client):

Fish Richardson – SeaChange International, Inc.; SBC Technology resources (v. Inrange, discussion, 2004)

Folger, Levin & Kahn – Calix, Inc.;

Gibson Dunn & Crutcher – Nortel, Inc.;

Susman Godfrey – Simon, an individual (2000-2001);

Weil, Gotshal & Manges – CISCO, Inc.(Lucent v. CISCO, consulting service in 1999);

Clifford Chance (main office at 200 Park Ave, NYC) – Symbol Technologies, Inc. vs. Proxim Inc, C.A. No. 01-801-SLR (US District Court for the District of Delaware), on behalf of Symbol Technologies, Inc; 3 involved patents. Services included (during 2002-2003): technology consulting, patent analyses, expert reports; summary judgement reports, claim construction; briefs; claim analyses; depositions (March 2003); provision of testimony in court (September 2003) in two separate cases (one week trial in Wilmington, DE per case, in each case). Technologies involved: wireless networking; computer communications and communications system technologies.

Wilson Sonsini Goodrich & Rosati – Broadcom, Inc. v. Intel Inc, E.D. Tex Case No. 5:01-CV-302. Services, on behalf of Broadcom, Inc., included (during 2002-2003): technology consulting, patent analyses, expert reports; summary judgement reports, claim construction; briefs; claim analyses; depositions (May 2003); Technologies involved: wireless networking; Network Interface Cards; memory management and bus designs; switching systems; Ethernet systems and interfaces; switching systems; analysis, design and operation of computer communications systems, and processing/memory and OS technologies.

Howrey, Simon, Arnold & White – Lucent Technologies v. Foundry Networks, Inc. Services, on behalf of Foundry Networks, Inc., included (during 2004-2005): technology consulting, patent analyses, expert reports; summary judgement reports, claim construction; briefs; claim analyses; depositions (December 2004); Technologies involved: traffic monitoring and analysis; security based authorization in networks; Switching systems; network routing; broadcasting and multicasting in networks.

Gibson, Dunn Crutcher (consulting service in May 2007, case of Rembrandt v. Cablevision, Del. Case No. 06-635-GMS;on behalf of Cablevision; preliminary consulting);

Goodwin Procter (on behalf of CISCO, in CISCO v. Teles, 2006-2008).

Akin, Gump, Strauss, Hauer & Feld – 3Com, Inc. v. Realtek Semiconductors, Inc. Services, on behalf of Realtek Semiconductors, Inc., included (during 2005-2008): technology consulting, patent analyses, expert reports; summary judgement reports, claim construction; briefs; claim analyses; deposition; declarations; Technologies involved: network adaptor cards; VLAN; networking. Testimony in court as expert witness (April 2008).

O'Melveny & Myers / Morrison & Foerster - for Plaintiffs Fujitsu Ltd, LG Electronics, Inc., and US Philips Corporation, in the matter of Fujitsu et al v. Netgear, No. 07-C-0710-C (W.D. Wisconsin) (during 2007 - 2009); technology consulting, patent analyses, expert reports; summary judgement reports, briefs; claim analyses; deposition; declarations; Technologies involved: wireless networking.

WilmerHale - for Plaintiff Broadcom Corp. v. Emulex Corp., No. SAVC09-1058-JVS (ANx), 2010-2011; technology consulting, patent analyses, claim analyses; Technologies involved: networking.

Orrick, Herrington & Sutcliffe - 2005-2007, and 2010: for Foundry Networks, Inc., Case No. 05- CV-11298 (DPW), Enterasys Networks Inc. v. Foundry Networks, Inc.

Orrick, Herrington & Sutcliffe LLP/ McDermott, Will & Emery LLP – 2010-2012: for plaintiff Brocade Communications Systems, Inc., Case No. 10-cv-03428-PSG, Brocade Communications Systems, Inc. / Foundry Networks Corp. v. defendant A10 Networks, Inc. Expert services relating to infringement of patents and of trade secrets, including: technology consulting, patent analyses, expert reports; summary judgement reports, claim construction; briefs; claim analyses; depositions; declarations; Technologies involved include: networking, Internet, TCP/IP protocols, NAT, high availability switching systems, traffic distribution and management controllers, DDOS protection mechanisms, buffer management. Testimony in court as expert witness (San Jose, CA, July-August 2012).

Weil, Gotshal & Manges LLP; Fish & Richardson P.C.; on behalf of Intel; 2012-2013, expert consulting services, case of US Ethernet Innovations LLC v. Acer, Inc., Case No 5:10-cv-03724-JW (Northern District of California).

Gibson, Dunn, Crutcher; 2013, expert consulting services, on behalf of CSC Holdings; case of TRL (Telecommunications Research Laboratories) et al v. CSC Holdings, LLC, D.N. J. Case No. 12-CV-6830-PGS-DEA.

Perkins Coie LLP; on behalf of Intel; 2013, expert consulting services, case of Stragent LLC v. Intel Corp., Case No 6:11-cv-421-LED (E.D. Texas).

McDermott, Will and Emery LLP; on behalf of Radware, LTD, and Radware, Inc.; 2013 - 2015, expert consulting services; case of Radware, LTD, and Radware, Inc. v. F5 Networks, Inc.; Case No 5:13-CY-02024-RMW; and case of Radware, LTD, and Radware, Inc. v. A10 Networks, Inc., and v. A-10, Inc.; Case No 5:13-CY-02021-RMW (N.D. California). Consulting, analyses, expert reports, deposition. Testimony at trial, San Jose, CA, 2/22/2016 - 3/11/2016.

Gibson, Dunn, Crutcher; 2014 - 2016, expert consulting services, on behalf of AT&T Mobility, Nextel Operations, Inc and Sprint Spectrum L.P. (McGuireWoods LLP), Ericsson Inc. and Telefonaktiebolaget LM Ericsson ("Ericsson"), United States Cellular Corp. (U.S. Cellular), and T-Mobile USA Inc. (T-Mobile) (Baker Botts LLC). Case of Intellectual Ventures I LLC and Intellectual Ventures II LLC v. AT&T Mobility LLC et al. and Cricket Communications, Inc. et al., D. Del. Civil Action Nos. 13-1668 (LPS) and 13-1669 (LPS).

McGuireWoods LLP; 2016 - 2017: expert consulting services, on behalf of Nextel Operations, Inc and Sprint Spectrum L.P.; Matter of Intellectual Ventures I LLC and Intellectual Ventures II LLC v. AT&T Mobility LLC et al. D. Del. Civil Action Nos. 13-1668 – 13-1672 (LPS) and 14-1229 - 14-1233 (LPS).

McDermott, Will and Emery LLP; on behalf of Radware, LTD, 2017-2018: expert consulting services; F5 Networks, Inc. vs. Radware LTD; Case No. IPR2017-00124.

Network Managing Solutions, LLC (plaintiff) v. AT&T, US Cellular, T-Mobile, Verizon Wireless, Sprint Corporation and Sprint Spectrum L.P. Expert consulting services for defendants, via: DuanMorris on behalf of AT&T; McGuireWoods on behalf of Sprint Corp. and Sprint Spectrum; Sidley on behalf of U.S. Cellular Corporation; HK Law on behalf of T-Mobile USA and Celco partnership, d/b/a Verizon Wireless. Civil Action No. 16-295-RGA. 2017-2018.

Polsinelli LLP; on behalf of Radware, LTD, 2018: expert consulting services; F5 Networks, Inc. vs. Radware LTD; Case No. Case No. 3:17-cv-03166-VC.

Baker Botts LLC; 2018, expert consulting services, on behalf of T-Mobile USA, Inc., and T-Mobile US, Inc., Ericsson Inc., Telefonaktiebolaget LM Ericsson, in the case Intellectual Ventures I LLC v. T-Mobile USA, Inc., et al., 2:17-cv-577.

Womble, Bond, Dickinson LLC; 2024, expert consulting services, on behalf of Aspen Networks, Inc., in the case of Aspen Networks, Inc., v. AT&T Mobility, LLC, CASE NO. 2:23-CV-00476-RWS-RSP.

Recent Projects

Local, metropolitan and wide area telecommunications networks; high-speed communications networks; performance analysis; queueing and stochastic processes; network simulations; access, flow, congestion and routing control for computer communication networks; network management; multi-media networks; cellular wireless networks; satellite networks, CATV networks; the Internet and IP networks; ad hoc wireless networks; protocols and architectures; C3 (command, control and communications) networks; resource allocation in integrated network, sensing, transport, data-base, computing and processing networks.

Cross-Layer networking for Mobile ad hoc wireless networks and AINS (Autonomous Intelligent Networked Systems): Development of Next Generation Unmanned-Vehicle aided C4ISR networks

Professor Izhak Rubin has been leading a large research and development effort for the development of next generation Unmanned Vehicle (UV) aided (employing land, air and sea borne autonomous vehicles - UGVs, UAVs, and UUVs) ad hoc wireless networks. This is part of his network development project, (with the research component supported by research grants from ONR, ARO, NSF, and others), involving the development of new methods and procedures for Autonomous Intelligent Networked Systems (AINS). His new network architectures and protocols, including those of UV-aided Mobile Backbone Networks (MBNs) are now recognized as leading approaches for the implementation of next generation peer-to-peer autonomous military and commercial mobile wireless network systems. He has been invited to many key DoD C4ISR network-centric warfare organizations (including US Navy, Army and Airforce offices of chief operations, Pentagon OASD, JTRS PM, Army CECOM FCS) and to leading industrial developers to present the innovative developments of his group in this area.

Developments include new methods for system and network management, resource allocation to ensure quality of service (QoS) in a mobile UV aided networking environment, self-configuring topological synthesis protocols for access and backbone networks, dynamic inclusion of UGVs and multi-orbit UAVs in self-adapting wireless networks, QoS based routing, power-control spatial-reuse DA/TDMA/FDMA/CDMA and modified 802.11 oriented medium access control (MAC) protocols, and cross-layer adaptive networking algorithms and protocols. Development works are aided by innovative simulation mechanisms, and the use of the IRI Computer Communications Corp. Planyst and PlanRes PC-based tools for network planning, analysis, management and multi-mission multi-area resource allocation.

Adaptive Power and Rate Mobile Wireless Networking

Development of cross-layer adaptive power, rate and routing mechanisms for mobile wireless networks. Applications to the adaptive power and rate scheduling of packet transmissions across mobile ad hoc wireless networks and across cellular wireless networks. The latter include LTE enhanced cellular networks, and such networks that employ macro and micro base station nodes and dynamic topologies. Robust architectures and failover operations for such network systems. Energy aware wireless

networking. Hybrid wireless, wireline and satellite network systems. Quality of service (QoS) provisions for such networks.

Integration of macro and micro base stations and associated networking mechanisms. Autonomous mechanisms for resilient recovery of operations under base station nodal failures. Relay aided cellular wireless networks. Hybrid cellular and ad hoc networks. Micro base station aided integrated multicasting and unicasting wireless networks.

Public Safety Network Systems

Professor Izhak Rubin is a co-director of the UCLA Public Safety Network Systems Laboratory. The mission of this Laboratory is to bring together academia, industry, and public safety agencies to provide technical leadership to perform collaborative research and network system developments, and to establish standards for public safety networks based on the latest wireless networking technologies and standards.

Wireless Networking for Mobile Highway Vehicles

Development of cross-layer adaptive power, rate and routing mechanisms for vehicular mobile ad hoc wireless networks (VANET). Development of geo-based protocols, architectures and algorithms for dissemination of messages along highway systems using road side units (RSUs), vehicle-to/from-infrastructure and vehicle-to-vehicle newly developed networking methods. Multicasting applications for infotainment systems and public safety network systems.

Regulation, Control and Design of Autonomous Transportation Systems: Autonomous Networked Mobile Systems (ANMS) Laboratory

Development of mechanisms for joint vehicular traffic regulation and communications networking for autonomous highway transportation systems. Design and control of vehicular mobility and networking protocols to support the dissemination of critical safety message flows, to assure end-to-end fast accommodation of vehicular transports and to attain high vehicular throughput rates across highway systems.

These developments are tested in the Autonomous Networked Mobile Systems (ANMS) Laboratory, UCLA Electrical Engineering Department, for which Professor Izhak Rubin serves as the Lab developer, engineer and Director. Included are networked mobile systems of self driving and navigating vehicles and robotic platforms.

Adaptive Video Streaming over Wireless Networks

Development of mechanisms for adaptive video streaming over wireless networks, including cellular wireless networks. Development and optimization of mechanisms that serve to efficiently set video compression ratio in accordance with desired user Quality of Experience (QoE) objectives, while allocating wireless channel resources and configuring modulation/coding schemes to attain high quality and high throughput performance across wireless network systems.

Professional Activities

Fellow member, IEEE, elected January 1, 1987, with the citation: "For contributions to the analysis and design of computer communication systems and networks, and to engineering education." IEEE Life Fellow since Jan. 1, 2008.

Editor, IEEE Transactions on Communications, 1986-1992.

Co-Chairman, 1981 IEEE International Symposium on Information Theory.

Program Chairman, 1984 NSF-UCLA Workshop on Personal Communications.

Program Chairman, IEEE INFOCOM conference, 1987.

Program Co-Chairman, 1993 IEEE Workshop on Local and Metropolitan Area Networks.

Organizer and main lecturer in 5-day short courses on the system oriented fundamentals of "Modern Telecommunications Networking", "ATM Networks," "IP Networking," "IP and Ad Hoc Networking," offered through UCLA Extension and throughout the world.

Associate Editor, Wireless Networks journal, Baltzer Science Publishers, 1994 – 2010.

Editor, journal on Photonic Network Communications, Kluwer publications, 1999 - present.

Editor, International Journal on Communications Systems, Wiley InterScience, 1999 - present.

Editor, Optical Networks magazine, SPIE / Baltzer Science Publishers, 2000 – present.

Session organizer and member of program committees of numerous conferences, symposia and workshops.

Industrial and military related projects (including involvement through IRI Corporation)

C3 systems and networks for US ARMY, Ft. Monmouth, NJ

Military networks; works with US Navy, Litton, and Singer Librascope

Networking modeling and analysis, network planning, network testing and calibration, network simulation and performance and planning software tools, for US Navy.

Development of the IRI PLANYST (PC-based software) tool for modeling, analysis and planning of computer communications and telecommunications networks.

Analysis and design of GSO and NGSO satellite networks, and of terrestrial wireline and wireless networks. Development of network services and new applications. Related consulting works for TRW, Hughes, Intelsat, SBC Pacific Bell, US West, AMD, Rockwell, NORTEL Bay Networks. Evaluation, analysis, and design of air traffic control switching systems.

Joint works for the FAA and JPL on air-traffic-control switching systems.

Basic research investigations of networking architectures, protocols, flow control, routing and queueing methods for: WDM optical networks, next generation Internet, QoS based networks, hybrid wireline and wireless networks.

Courses

The following are courses in the field of Communications and Telecommunications Engineering, area of specialization in Telecommunications and Computer Communications Networks, taught by Professor Izhak Rubin in the UCLA Department of Electrical and Computer Engineering. Other courses taught by Professor Rubin include: information theory and coding, detection theory for communications systems, Probability theory.

EE132B - Data Communications and Telecommunications Networks

Basic principles of communications networks; multiplexing and multiple access; switching; error and flow control; routing; communications networking protocols; the OSI reference model. Traffic engineering and queueing models for the analysis and design of telecommunications and computer communications network systems; system simulation. Computer workouts and simulation facilities.

EE232A - Discrete Stochastic Processes

Discrete-time Markov chains. Renewal point and counting processes. Regenerative stochastic processes. Applications to the modeling and analysis of traffic processes and telecommunications systems and networks.

EE232B - Queueing Systems and Intelligent Transportation Networks

Basic queueing models. Continuous-time Markov chains. Regenerative processes and results for the modeling and analysis of queueing systems. Markovian and Non-Markovian queueing systems. Communications networking of connected mobiles and the autonomous highway. Applications to telecommunications systems, computer communications networks, Internets, switching networks and autonomous systems.

EE232C - Queueing Theory with Applications to Computer Communications and Telecommunications Networks.

Markov-Renewal, semi-Markov and semi-regenerative stochastic processes. Priority queueing systems. Queueing networks. Applications to the analysis and design of computer communications and telecommunications networks, including BISDN ATM network systems and datagram computer networks.

EE232D - Communications Networking and Traffic Management for Autonomous Mobile Systems

Network protocols. Network controls: flow, congestion, error and flow controls. Multiple access algorithms, schemes and protocols; modeling, analysis and design. Switching, scheduling and routing. Applications to wireline and wireless local area networks (LANs), metropolitan area networks (MANs), wide area networks (WANs). Satellite communications networks. Optical communications networks. The Internet. 4G and 5G cellular wireless networks. Mobile ad hoc networking. Networking for robotic systems. UAV (drone) based networking mechanisms. Communications networking among mobile vehicles and the design and control of autonomous highway transportation systems employing self-driving vehicles and the next generation automated highway system. Internets of things. Cloud based networking systems.

EE232E - Graphs and Network Flows

Basic elements of graph theory. Network flows. Synthesis of network topologies to achieve target levels of reliability (connectivity), delay (diameter), capacity (throughput), and performance sensitivity. Routing algorithms. Network algorithms.

University Laboratories and Student training

Development of the *Autonomous Intelligent Networked Systems* (AINS) laboratory, with Prof. Izhak Rubin as leader and director, at the UCLA Electrical Engineering department. Used to design, test and experiment with innovative ad hoc wireless network systems, autonomously employing unmanned vehicles.

Architectures, protocols and systems developed in the AINS laboratory have been successfully demonstrated in field trials and testbeds that took place in 2002-2004 in Arizona, Rhode Island and Los Angeles.

Professor Rubin has been serving as co-founder and co-director of the UCLA *Public Safety Network Systems* Laboratory (2011-2019). Research and development of service requirement models, concepts of operation, interoperability features, communications networking reconstitution algorithms, reference models, technologies, architectures, protocols and testing methods for public safety network systems. Since 2016, Professor Rubin has been serving as founder and director of the UCLA ECE *Autonomous Networked Mobile Systems (ANMS)* Laboratory, performing research, development, simulation and experimentations of innovative autonomous mobile systems, including autonomous transportation networked systems.

Training of undergraduate and graduate students in the area of computer communications networking and wireless network systems through extensive involvement in the development of networking based software, and through the conduct of network management, monitoring, control and experimental evaluations.

Professor Rubin served as the Director of the Area of Signals and Systems at the UCLA Electrical and Computer Engineering Department (2014-2017) and is serving as the Director of the Area of Signal Processing and Communications at the UCLA Engineering MS Online Program.

UCLA Extension Short Course and the PLANYST™ Tool

“Modern Telecommunications Networking,” and “IP Networking”- 5 day short courses with Professor Izhak Rubin as coordinator and lecturer. Attended by persons from around the world with wide range of background and interests. Offered since 1980. Provides high level extensive coverage of the methods, architectures, protocols, and network systems used and under development in providing computer communications

and telecommunications services. Incisive evaluations of the performance and operational features of network systems and of their evolution.

The course offers a system oriented coverage rather than detailed design of system components.

The IRI **PLANYST** hybrid analysis/simulation (PC based program) tool is used in illustrating the performance, analysis and design of network systems and subsystems.

The course has been offered by Dr. Izhak Rubin in-house at organizations throughout the USA and the world. It is also offered at UCLA Extension.

PLANYST is a unique tool developed by IRI Computer Communications Corporation for the integrated analytical and simulation modeling, analysis, management, testing, planning and design of computer communications and telecommunications networks.

MBNP_Simulator is a unique tool being developed at IRI Computer Communications Corporation for the modeling, analysis, design and management of mobile ad hoc wireless networks and for such UAV aided networks.

Brief Overview of Selective Research Areas and Breakthrough Developments

1. Stochastic Modeling and Detection of Stochastic Point and Jump Processes.
Development of fundamental stochastic models and likelihood ratios for the detection and processing of information processes that are modeled as stochastic point and jump processes.
2. Information Rates and Data Compression for Poisson Sequences and Processes
Derivation of the Rate-Distortion functions for Poisson sequences and processes, identifying the performance of the ‘best’ compression mechanism for information streams that are modeled as such stochastic processes.
3. Basic Queueing Delay Analysis for Communications Network Systems
Breakthrough development of methods for the modeling and calculation of packet and message queueing delay distributions in packet-switching networks.
4. Delay Capacity Product for packet-Switching Computer Communications Networks
Development of conservation and separation principles for the synthesis of packet switching networks relating to the network’s product of overall capacity and message delay performance.
5. Synthesis of Reliable Topologies for Communications Networks
Synthesis of optimal network topologies under diameter (delay), total link (capacity) and connectivity constraints.
6. ARQ Error-control for TDMA Multiple Access Communications Channels
Analysis and design of stop-and-wait, Go-Back-N (window based) and Selective-Repeat ARQ schemes.
7. Modeling, Analysis and Design of Medium Access Control (MAC) Protocols and Algorithms for Multiple Access Communications Channels
Extensive on-going developments of new architectures, algorithms and protocols to control the operation of a multiple access communications channels and

- network. Classes of algorithms include: fixed assigned (TDMA, FDMA, CDMA, SDMA); demand assigned: polling and reservation based; random access: pure and dynamic group random access, CSMA and CSMA/CA based, and many others; Hybrid protocols.
8. Modeling and Analysis of Communications Network Systems when subjected to Fluctuating Traffic Processes and to Traffic Characterized by Long Range Dependence
Analysis of queueing systems under bursty traffic conditions; modeling of LRD traffic by Multi-Fractal processes; performance behavior and design of communications network systems when subjected to traffic that is modeled by the latter processes.
 9. Integrated Data/Voice and Multimedia Multiplexers and Multiple Access Networks
Mechanisms and analytical modeling and evaluation methods for multiplexing and multiple access systems that are shared by data, voice and video processes as well as by other multimedia traffic flows.
 10. Network Management and Integrated System Management
Fundamental concepts, models and architectures involving monitoring and control management operations in communications networks. Tradeoffs involving monitoring precision, capacity utilization and control responsiveness and efficacy. Integrated system management for ad hoc wireless network systems that involve combined resource allocations for communications and sensor subsystems.
 11. Input-Rate Flow Control for Communications Networks and QoS based operations. Modeling and Analysis of ATM switching Systems and Networks
Analysis and design of input-rate flow control mechanism under desired user-perceived performance measures. ATM switching systems.
 12. Modeling, Analysis and Design of Cellular Wireless Network Systems
Analysis and design of networking protocols and algorithms for cellular wireless networks, including multiple access mechanisms, handoff methods, optimal selection of the Location Update zones; forward and reverse signaling channels.
 13. Analysis and Design of Load Adaptive Networking Protocols and Algorithms for Wideband Packet Satellite Networks
Load adaptive TDMA procedures and algorithms for efficient operation of packet based satellite networks. Development of the theory of capacity varying networks and its application to the analysis and design of low altitude satellite networks (including best paper award).
 14. Analysis and Design of Local Area Networks
Modeling and analysis of random access, token ring, FDDI and other local area networks.
 15. Combined Information Theory and Network Theory based models and Congestion Adaptive Compression Processing Ideally Characterized by the Delay-Distortion Function
Development of approaches for the design of communications network systems integrating and combining the use of information theory to characterize the error-rate vs. information rate behavior, and incorporating queueing theory to exhibit the system's delay-throughput behavior. Definition and characterization of the

Delay-Distortion function that described the ideally best combined compression (via a distortion measure) and congestion (via a packet delay measure) operation. Congestion state adaptive voice and video compression algorithms.

16. All-Optical Networking

Development of fundamental concepts and architectures for all optical circuit and packet switched operations across network systems, including ring and meshed ring network systems. Development of the concept of shuttle networking for all-optical operation across such network systems. Synthesis of all-optical ring and meshed ring networks.

17. MPLS-Plus networking

Concepts for networking operations that require reduced processing at the routers and switches.

18. Ad Hoc Wireless Networking using Mobile Backbones: Mobile Backbone Networks (MBNs)

New mechanisms for ad hoc wireless networking based on the dynamic formation of mobile backbones. On-going innovative developments include: topology synthesis algorithms for the backbone networks; robust routing; on-demand MBN based routing using flow control schemes to provide for guaranteed QoS support; hybrid backbone and non-backbone operation. Cross MAC/network layer operations.

19. Unmanned Vehicle Aided Multi-tier Ad Hoc Wireless Networks

Use of unmanned ground vehicles (UGVs) and unmanned airborne vehicles (UAVs) to best support the operation of MBN based ad hoc wireless networks. UAV swarm networks. Development of new measures for characterizing the desired performance of user streams and flows when served by mobile ad hoc wireless networks. Use of the new measures to control and guide the placement of UGVs and UAVs to best support client message flows and streams.

20. Adaptive Power and Rate Spatial-Reuse Scheduling and combined Routing/Scheduling MAC Algorithms for Multiple Access Channels, Wireless Cellular Networks and Ad Hoc Wireless Networks

Development of fundamental results of key theoretical and practical importance for the derivation of MAC schedules (channel resource allocations) and transmit power assignments based on realistic SINR based interference models. Substantial throughput upgrade of current scheduling oriented MAC operations. New adaptive power and rate scheduling algorithms. Centralized and distributed network operations. Applications to mobile ad hoc wireless networks and to LTE type cellular wireless networks.

21. Power-control Spatial-Reuse CSMA based MAC Algorithms for Multiple Access Channels and for Multi-Hop Ad Hoc Wireless Networks

Development of algorithms for the joint MAC scheduling and selection of transmit power levels in a IEEE 802.11 CSMA/CA type MAC system based on monitored channel congestion state. Significant improvement of throughput and fairness oriented behavior.

22. Use of UAV Swarms for Enhanced Search Operations

Synthesis and performance evaluation of area search layouts for UAV swarm teams. Comparisons with random search operations.

23. Cross Layer Networking for Next Generation Cellular Wireless Networks
Development of adaptive rate and power networking mechanisms and energy aware operations for next generation (including WiMax, LTE, and meshed WiFi) network systems. Coordinated multicasting algorithms for robust multicasting in LTE type cellular wireless networks.
24. Network Management for Multi Segment Networks
Management of multimedia traffic flows, under targeted Quality-of-Service prescriptions, across heterogeneous network segments that may involve terrestrial wireline and wireless networks, and may also include satellite and other space based networking platforms.
25. Micro Base Station Aided Failover for Cellular Wireless Networks
Adaptive power/rate, scheduling and networking mechanisms for micro base station aided failover operations for cellular wireless networks, including cooperations among neighboring macro and micro base station nodes. Robust multicasting and unicast messaging with applications to public safety network systems.
26. Vehicular Ad Hoc Wireless Networks (VANETs)
GPS based inter-vehicular mechanisms for inter-vehicular wireless networking along highway systems. Applications to infotainment networking and to public safety message distributions.
27. Regulation, Control and Design of Autonomous Transportation Systems
Development of mechanisms for joint vehicular traffic regulation and communications networking for autonomous highway transportation systems.
28. Adaptive Video Streaming over Wireless Networks
Development of mechanisms for adaptive video streaming over wireless networks, including cellular wireless networks.
29. Traffic Management and Networking for Autonomous Mobile Systems
Development of methods, models, analysis and design processes for connected autonomous mobile systems and the autonomous highway system.

Selected Earlier Publications

Rubin, I. "Regular Point Processes and Their Detection," IEEE Transactions on Information Theory, Vol. 18, pp 547-557, September 1972.

Rubin, I. "Information Rates for Poisson Sequences," IEEE Transactions on Information Theory, Vol. 19, pp 283-294, May 1973.

Rubin, I. "Path Delays in Communications Networks," Applied Mathematics and Optimization, Vol. 1, No. 3, 1974.

Rubin, I. "Information Rates and Data Compression Schemes for Poisson Processes," IEEE Transactions on Information Theory, Vol. 20, pp 200-210, March 1974.

Rubin, I. "Rate Distortion Functions for Non-Homogeneous Poisson Processes," IEEE Transactions on Information Theory, Vol. 20, pp 669-672, September 1974.

Rubin, I. "Regular Jump Processes and Their Information Processing," IEEE Transactions on Information Theory, Vol. 20, pp 617-624, September 1974.

Rubin, I. "Communication Networks: Message Path Delays," IEEE Transactions on Information Theory, Vol. 20, pp 738-745, November 1974.

Rubin, I. "Reduced Memory Likelihood Processing of Point Processes," IEEE Transactions on Information Theory, Vol. 20, pp 729-738, November 1974.

Rubin, I. "Multiterminal Path Flows for Packet Switching Communications Networks," Networks, Vol. 5, pp 205-236, 1975.

Rubin, I. "Message Path Delays in Packet-Switching Communication Networks," IEEE Transactions on Communications, Vol. 23-2, pp 186-192, February 1975.

Rubin, I. "Optimal Sequence Estimators for Statistically Unknown Binary Sources and Channels," IEEE Transactions on Information Theory, Vol. 21-2, pp 217-221, March 1975.

Ward, D.S., Rubin, I., and Scalabassi, R.J. "Applications of Queueing Theory to Some Problems in Neural Circuitry," Applied Mathematics and Computations, 1976.

Rubin, I. "The Delay Capacity Product for Message Switching Communication Networks," J. of Combinatorics, Information & System Sciences, Vol. 1-2, pp. 48-68, 1976.

Rubin, I. "The Delay Capacity Product for Store-and-Forward Communication Networks: tree Networks," Applied Mathematics & Optimization, Vol. 2-3, pp 197-222, 1976.

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Rubin, I. "Group Random Access Disciplines for Multi-Access Broadcast Channels," IEEE Transactions on Information Theory, Vol. 24-4, pp 578-592, September 1978.

Rubin, I. "Message Delays in FDMA and TDMA Communication Channels," IEEE Transactions on Communications, Vol. 25-5, pp 769-777, May 1979.

Rubin, I. "Access Control Disciplines for Multi-Access Communication Channels: Reservation and TDMA Schemes," IEEE Transactions on Information Theory, Vol. 25-5, pp 516-536, September 1979.

Meerkov, S.M., Rubin, I. "System Theoretic Properties of Large Communication Networks with Markovian Multiaccess Control Disciplines," Systems & Control Letters, Vol. 1-5, pp 340-346, March 1982.

Saeki, B.H., Rubin, I. "An Analysis of a TDMA Channel using Stop-and-Wait, Block and Select-and-Repeat ARQ Error Control," IEEE Transactions on Communications, Vol. 30-5, pp 1162-1173, May 1982.

Rubin, I., Louie, M.Y. "A Hybrid TDMA / Random-Access Scheme for Multiple-Access Communication Networks," Computer & Electrical Engineering Journal, 1983.

Rubin, I. "Synchronous and Channel-Sense Asynchronous Dynamic Group-Random-Access Schemes for Multiple-Access Communications," IEEE Transactions on Communications, Vol. 31-9, pp 1063-1077, September 1983.

Rubin, I., DeMoraes, L.F.M. "Message Delay Analysis for Polling and Token Multiple-Access Schemes for Local Communication Networks," IEEE Journal on Selected Areas in Communications, Vol. 1-5, pp 935-947, November 1983.

DeMoraes, L.F.M., Rubin, I. "Message Delays for a TDMA Scheme under a Non-Preemptive Priority Discipline," IEEE Transactions on Communications, Vol. 32-5, pp 583-588, May 1984.

Rubin, I., Baker, J.E. "Performance Analysis for a Terminal Priority Contentionless Access Algorithm for Multiple-Access Communications," IEEE Transactions on Communications, Vol. 34-6, pp 569-575, June 1986.

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Rubin, I. "Data Compression for Communications Networks: The Delay-Distortion Function," IEEE Transactions on Information Theory, Vol. 22-6, pp 655-665, November 1976.

Baker, J.E., Rubin, I., "Polling with General Service Order Table," IEEE Transactions on Communications, Vol. 35-3, pp 283-288, March 1987.

Clare, L.P., Rubin, I. "Performance Boundaries for Prioritized Multiplexing Systems," IEEE Transactions on Information Theory, Vol. 33-3, pp 329-340, May 1987.

Zukerman, M., Rubin, I. "Queueing Performance of a Multi-Channel System under Bursty Traffic Conditions and State Dependent Service Rates," Australian Telecommunications Research Journal, Vol. 21-2, pp 3-15, November 1987.

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He is the author of the book: Izhak Rubin, “Principles of Data Transfer Through Communications Networks, Internets, and Autonomous Mobiles,” 22 chapters, 746 pages, published by Wiley – IEEE-Press, ISBN 978-1394267750, 2025.

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Sample of Short Course Notes

1. IP networking:
May 12-25, 2001, Engineering 881.193 /
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2001

2. IP networking:
May 22-26, 2000, Engineering 881.193 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 2000
3. Asynchronous transfer mode (ATM) communications networking:
November 16-19, 1999, Engineering 840.39 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1999
4. Communications networkings: local, metropolitan, and wide-area networks: May 24-28, 1999,
Engineering 840.38 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1999
5. Telecommunication networking: local, metropolitan, wide-area networks: August 27, 28-September 3, 10-11, 1998, Hughes Communications, Engineering 840.38 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1998
6. Asynchronous transfer mode (ATM) communications networking: December 8-11, 1998, Engineering 840.39 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1998
7. Telecommunications networking:
local, metropolitan, and wide-area networks:
May 18-22, 1998, Engineering 840.38 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1998
8. Telecommunications networking:
local, metropolitan, and wide area networks:
May 19-23, 1997, Engineering 840.38 /
University of California, Los Angeles, University Extension, Dept. of Engineering, Information Systems, and Technical Management, Short Course Program, 1997

9. Wired and wireless telecommunications networking:
May 20-24, 1996, Engineering 840.38 /
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems, and Technical Management, Short Course
Program, 1996
10. Integrated services telecommunications networking:
high-speed local, metropolitan, and wide-area networks:
May 18-21, 1992, Engineering 840.33 : lecture notes /
University of California, Los Angeles, University Extension, Dept. of Business,
Engineering & Management, Short Course Program, 1992
11. IP and Ad Hoc Networking:
May 27-June 11, and August 5-28, 2004, training course to staff engineers and
scientists at Boeing, Inc., Anaheim, CA, 2004.
12. IP and Ad Hoc Networking:
May 24-28, 2004, Engineering 881.193 /
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2004.
13. IP and Ad Hoc Networking:
May 9-13, 2005, Engineering 881.193 /
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2005.
14. IP Networking Fundamentals:
May 21-22, 2007, Engineering 881.243
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2007.
15. IP and Ad Hoc Networking:
May 23-25, 2007, Engineering 881.245
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2007.
16. IP Networking Fundamentals:
May 19-20, 2008, Engineering 881.243
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2008.

17. IP and Ad Hoc Networking:
May 21-23, 2008, Engineering 881.245
University of California, Los Angeles, University Extension, Dept. of
Engineering, Information Systems & Technical Management, Short Course
Program, 2008.