Vishal Sharma, Ph.D., Senior Member, IEEE[1], Fellow, IETE[2]

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PROFILE

International technologist and entrepreneur with 20+ years of experience in networking and telecom technologies, who has lead research, industry, labs, and academia; coordinated globally diverse expert teams; technology leader, system & network architect, project & product manager, deep-researcher, and veteran communicator and influencer all rolled into one; 12 US patents granted; 10 IETF RFCs published; 6 IEEE Communications Magazine special issues edited; Associate Professor (3 years): 8 students graduated, 10 courses taught, 32 seminars & course research projects supervised; considerable standards participation & solid understanding of standards processes; Invited speaker/keynote speaker, session chair, panel moderator, & panelist at leading industry conferences; 145+ workshops, talks, seminars, tutorials, panels in the US, Europe, Australia, Asia; Sample clients: Fujitsu, Tellabs, Cariden/Cisco, Mahi Networks, France Telecom, Covad, ETSA/Silk Telecom (Australia), CTS Telecom, Xilinx, Cypress, Wipro, Infosys.

Focus Areas

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

Core Skills

Reverse-engineering of complex systems and networks; translating between network-level operation and system-level implementation; sound understanding of wireline, broadband wireless, and optical networking issues and ability to convert them into architectures for services, networks, systems and chips; grasp customer requirements, interpret and prioritize features/options, translate them into clear product requirements, high-level architectural specifications and detailed system-level/chip-level operational flows/specs; work seamlessly with executive/engineering management, hardware & software engineering and product marketing teams to realize next-generation products/networks/services; rapidly consume, digest, elucidate, and improvise on cutting-edge industry advances; demystify the complex, and create

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[1] The Institution of Electrical and Electronics Engineers, Inc.
[2] The Institution of Electronics and Telecommunications Engineers, India.

technical, but clearly understood, customer- and market-focused documentation/messaging; translate novel ideas into patentable inventions.

Specific Areas of Expertise

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

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

Key Achievements

- **MEF SDN/NFV Certified Professional**, MEF, June 2018, among the first 70-odd industry professionals to have earned this distinction[3].

- "**Intensive Wireless Communications Engineering: Current Practices**," 3-day Intensive IEEE short-course for communications professionals, successfully completed Dec. 4, 2017;

- **Multiple IEEE Communications Society courses on wireless engineering, wireless networking, wireless communications, IoT, optical networking, & satellite networking successfully completed**: *Network Function Virtualization (NFV), Software-Defined Networking (SDN) and the Road to 5G* (January 31, 2018), *Wireless Evolution of the Overall Network Architecture* (February 7, 2018), *LTE Fundamentals: The Essential*s (February 21, 2018), and *Beyond LTE: LTE Advanced, LTE Advanced Pro, and 5G* (February 28, 2018); *IoT and M2M Essentials* (June 6,

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

2018); *Satellite Data Communications and VSAT Networks* (December 6, 2018); *Background Concepts of Optical Communication Systems* (March 27, 2019); *Visible Light Communications* (April 3, 2019); *Optical Communication for 5G Wireless Networks* (May 1, 2019), *High-Throughput Satellites* (June 12, 2019), *Fundamentals of 5G Small Cell Deployments* (Oct. 2 2019), *Next-Generation Multi-Access Service Based 5G Architecture* (Dec. 4, 2019)

- **12 US patents awarded** in: high-speed switch architectures, switch scheduling, optical routing, MPLS recovery, and IP control of SONET/SDH networks;

- **10 IETF RFCs published**; core contributor in the IETF to the development of IP-based signaling and routing standards for packet, TDM and optical networks; early-contributor to the Optical Internetworking Forum (OIF)'s evolving UNI and NNI signaling/routing standards;

- **Furnished first analytical (probabilistic) framework** characterizing limited wavelength translation in WDM optical networks;

- **Guest Editor of 6 Special Issues of the IEEE Communications Mag.** (IEEE's most highly cited publication with a circulation of 50K+ professionals worldwide);

- **Senior Member (2001)**, IEEE, the highest professional grade of the IEEE and a distinction held by less than 8% of the over 423,000+ IEEE members worldwide;

- **Life Fellow (2005)**, Institution of Electronics and Telecommunications Engineers (IETE), India, a distinction held by less than 7% of the approximately 70,000+ IETE members worldwide;

- **Served as an expert witness in federal and PTAB matters**: expert reports and deposition testimony;

- **Group Leader & Moderator, Carrier Ethernet Group**: nurtured and grew the Group on LinkedIn to 12,024+ telecom professionals from 140+ nations, 3,128+ companies, and 6 continents, and made it a venue for discussions of IP/MPLS, packet-optical, wireless/5G, SDN/NFV, cloud networking and Carrier Ethernet systems, architecture, technology, and network deployment issues of contemporary significance;

- **Subject Matter Expert** at the Broadband Forum (2002);

- **Numerous tutorials, conference and journal papers, and book chapters published.**

POSITIONS HELD

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

-- Advise executive and engineering management at system, software, and chip vendors and carriers/operators on devising technology and product/services strategy & roadmaps.

-- Architect next-generation systems/chips/software or network services & networks via deep technical synergy with senior architects, planners, hardware/software design engineers, and/or network architects, network engineers, and operations teams at clients.

-- Analyze and guide clients on subjects at the forefront of contemporary networking. E.g. cloud-based technologies – intra- and inter-data center design: principles, methodologies, technologies, best-practices; public- and private-cloud architectures; hybrid cloud. Virtualization technologies: SDN and NFV – operation, insights, applications, open-issues, deployment trade-offs; E-VPNs, SD-WAN, data center interconnects, service chaining (SFC), and overlay networking.

-- Solve complex system design, architecture and customer issues for clients, from emerging startups to companies in the Fortune 1000 (impacting a $300+M product line), interacting up-and-down the chain of command from engineers to senior architects to executive & engineering leadership.

-- Engage with carriers ranging in size from small local and regional operators to global giants, helping them with technology strategy, knowledge enhancement, best-practices; have earned recognition for our work.

-- Track SDN/NFV standards in the industry, such as those at the ONF, IETF (NVO3, SFC, and BESS WGs), MEF (3.0, LSO), ETSI NFV ISG, and P4 Consortium. Strong participation in the IETF during 1998-2006, which was focused on the development of core Internet protocols & architectures: e.g. in the L2 VPNs, L3 VPNs, MPLS, Diffserv, TE, IP-Optical WGs.

-- Retained by some of the highest ranking law firms in the country (AM Law 100) for deep technology analysis of highly complex telecommunications patent portfolios and litigation assistance, over diverse technologies & concepts, spanning IP/MPLS, Carrier Ethernet, VPNs, DOCSIS, 3G/4G wireless protocols, optical switching and networking, TDM, QoS, resilience, and resource allocation.

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

-- Founded the WiNETS (Wireless Networks) Research Group for research in wireline- and wireless-broadband access technologies, including: metro/access network traffic management and QoS, wireless & sensor network routing and test bed development, wireless network infrastructure security, mobile applications and architecture.

-- Graduated 8 students (with student research published in prestigious international industry- and academic-conferences: SANOG'06, APRICOT'06, IEEE Milcom'07, IEEE Milcom'08, and one winning the Best B. Tech. Project Award in EE), and guided 20+ graduate course research projects (three of which were published nationally and internationally), and over a dozen student seminars.

-- Developed and taught junior- to- graduate-level courses, spanning digital circuits, basic electronics, and labs. to queueing theory, scheduling algorithms, circuit- and-packet-switching, and advanced networking protocols and systems to different class sizes, several exceeding 100+ students and a half-dozen+ teaching assistants.

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

-- Architected & designed an MPLS-based control plane for packet and TDM (SONET/SDH) data for Jasmine's CNS (Converged Network System).

-- Strengthened Jasmine's industry standing by my leadership role in numerous MPLS forums & standards bodies (IETF, OIF).

Research Engineer, Tellabs Research Center (TRC), Cambridge, MA   1998 – 2000

-- Analyzed and designed high-speed switch router architectures:
  • Only member of the Research Center to be part of the Tellabs' Advanced Business Development team for evaluating potential acquisitions in the terabit router space; performed deep-dive architectural evaluations of 10+ switch router startups (including names like Avici, Pluris, Torrent (later Ericsson), Redstone (later Unisphere then Juniper), Ironbridge).
  • Designed an IP flow management algorithm for parallel high-speed switches (patented, US 7123581), and devised path protection schemes for MPLS networks (6 patents; US 7298693, 7315510, 7796504, 7804767, 7881184, 8588058).

-- Supervised a summer project for a Ph.D. student from MIT that produced a novel scheduling algorithm for parallel cross-bar switches (patented, US 7123623).

-- Contributed in the Diffserv, MPLS, Traffic Engineering, L2/L3 VPN WG's of the IETF. Devised an MPLS recovery framework; eventually published as RFC 3469.

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

-- Architected & evaluated all-optical switches and switching schemes for WDM/DWDM networks, based on MEMS technologies.

-- Led to one conference (IEEE MPPOI'98) and one journal (IEEE TON) paper.

EDUCATION

Ph.D., **Electrical & Computer Engineering**, UC Santa Barbara.   1997

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

Research led to six conference- and four journal-papers (IEEE TPDS, IEEE TON, IEEE JLT, & Computer Networks).

M.S. (Computer Engineering), UC Santa Barbara.   1993

Thesis: "Frequency Assignment and Capacity Analysis for Cellular Radio."

Research led to one journal (IEEE Trans. on VT) and one conference (ICC) paper.

M.S. (Signals & Systems), UC Santa Barbara.   1993

Motorola Paul V. Galvin Fellowship (given to only two engineers from India annually).

B.Tech., Electrical Engineering, Indian Institute of Technology, Kanpur.   1991

Winner **Best B. Tech. Project** in Electrical Engineering Award for designing, fabricating, and testing a fully-functional Ethernet repeater.

AWARDS & HONORS (selected)

1. **Network Transformation Awards 2019,** Judge, SDN NFV World Congress, The Hague, Netherlands, 14-17 Oct. 2019.

2. **Startup Elevate[4] – IoT Startup Program (IoT Security, Industrial IoT, and Finals)**, Judge, IoT World, Santa Clara, CA, May 14-16, 2019.

3. "**Today's Network Innovations: Fuel for Tomorrow's Network Transformation?**," Invited Keynote, Network Transformation Congress, San Jose, CA, April 30 – May 1, 2019.

4. "**Digital Forensics: Global IP Challenges**," Chair & Panelist, 45th Global Legal ConfEx and GDPR Expo, San Francisco, CA, Nov. 15, 2018.

5. "**Intellectual Property Ramifications in the Age of IoT**," Invited Chair/Moderator, Eoc-System Center Stage, IoT World, Santa Clara, CA, May 17, 2018.

6. **NFV and Zero Touch Forum**, Session Chair, NFV World Congress, San Jose, CA, April 26, 2018.

7. "**The Evolution of SD-WAN and Implications for the Future**," Chair's Market Highlights, SD-WAN and Business Track, NFV World Congress, San Jose, CA, May 4, 2017.

8. **Invited Attendee**, Open Networking Innovation Forum[5] (ONIF), Open Networking Summit (ONS), April 4, 2017 and March 27, 2018.

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[4] From the Informa Tech/KNect365 website "Startup Elevate, formerly Project Kairos, is an exclusive startup program and community bringing together select investors and some of the most innovative startups disrupting the tech scene!"

9. "**The Impact of SDN on Service Provider Networks: Part 1 and Part 2**", Co-Guest Editor, *IEEE Communications Mag.*, Feature Topic Issues, October 2016, and April 2017, respectively.

10. **Judge, MEF Ethernet Excellence Awards,** MEF 17, November 2017; MEF 16, October 2016; GEN 15, October 2015; and GEN 14, October, 2014.

11. **Invited Speaker** on **Intellectual Property Challenges and IoT**, IoT World, May 12, 2016.

12. "**Virtualization for 5G Network Architecture**" Invited Panel Chair, 5G Forum USA, Palo Alto, CA, April 12, 2016.

13. "**Challenges and Opportunities in Operationalizing NFV**," Chair's Market Highlights, Forum 2 Operations, NFV World Congress, San Jose, CA, April 21, 2016.

14. "**Is NFV an Enabler for 5G and Mobile Edge Computing (MEC)?**," Leader Roundtable, 5G Forum USA, Palo Alto, CA, April 13, 2016

15. "**How Do NFV and MEC Play Together? How Can Advances in NFV Synergistically Help in Advancing MEC?**" Leader, Interactive Roundtable, Mobile Edge Computing (MEC) Focus Day, CNV 2015, Palo Alto, CA, Dec. 3, 2015.

16. "**Status of NFV Transformation Going into 2016**," Panel Chair, Carrier Network Virtualization (CNV 2015), Palo Alto, CA, Dec. 2, 2015.

17. **Chairman, Service Provider Track A, Day Two**, Carrier Network Virtualization (CNV 2015), Palo Alto, CA, Nov. 30 – Dec. 3, 2015.

18. "**Network Functions Disaggregation: Innovations in NFV, SDNs, and Optical Networks**," Invited Moderator, MEF GEN 15, Dallas, TX, November 18, 2015

19. **Chairman, Service Provider Technology Track 2,** MEF GEN 15, Dallas, TX, Nov. 18, 2015.

20. **Group Moderator & Manager**, Carrier Ethernet Group on LinkedIn, Avenue for discussing the technology, strategy, and business of modern packet networking, March 2012 - present. (11,910+ members spanning 140 nations, 3,128 companies, 6 continents)

21. **Sponsorship Chair & Organizing Committee Member**, *IEEE 5G Summit Silicon Valley*, Google Campus, Mountain View, CA, November 16, 2015.

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

22. **"Reliability in the NFV World - How Can 100% Service and Application Availability be Achieved?"** Panel Chair, NFV World Congress, San Jose, CA, May 6, 2015.

23. **"Open Source IoT in the Cloud**,**"** Session Chair, IoT Open-Source Summit at IoT World Summit, San Francisco, CA, May 13, 2015.

24. **"The SDN & NFV Promise to Make the Network Agile and Optimum**,**"** Chair, 5G Forum USA, Palo Alto, CA, April 15, 2015.

25. **SDx Summit**, Chair, Carrier Network Virtualization (CNV 2014), Palo Alto, CA, December 9, 2014.

26. **"Evolution of the Carrier Ethernet Professionals Community**,**"** Invited Moderator, Panelists from PLDT, Telin Singapore, & Sri Lanka Telecom, MEF GEN 14, Washington, D.C., November 17, 2014.

27. **"Making the Intangible Tangible via R&D Innovation**,**"** Invited Talk, 2nd Futurewei Vision Summit, Santa Clara, CA, November 6, 2014.

28. **Co-Chair, Cloud Infrastructure Track**, TiECon 2014, Santa Clara, CA, May 16, 2014.

29. **Member, Scientific Committee,** MPLS & Ethernet World Congress, Paris, France, 2003 – 2013.

30. **Innovation Certificate**, Tellabs Operations, Inc., June 2000.

PUBLICATIONS, WORKSHOPS, PANELS & TALKS (selected)

1. **"TDM, VoIP, Virtualization and the Future of the PSTN**,**"** Invited Panelist, VoIP and the Independent Telecom, Virtual Conference, Sep. 30 – Oct. 4, 2019.

2. V. Sharma, **"5 Fundamental Schedulers for Every System/Network Architect's Toolkit**,**"** LinkedIn Pulse, March 23, 2016.

3. V. Sharma, **"4 Questions Network/System Architects Should Answer about Scheduling**,**"** LinkedIn Pulse, March 21, 2016.

4. V. Sharma and M. Allen, **"Packet-Optical Integration – The Key to Evolving Towards Agile Optical Networks**,**"** Photonic Tech Briefs, January 2011.

5. **"Understanding Military Grade Optical-Ethernet Networks: A Versatile Solution for Achieving DoD's Net-Centric Operations Strategy**,**"** Industry Tutorial, IEEE Milcom'10, San Jose, CA, November 1, 2010. (With S. Davari, Broadcom Corp.)

6. "**A WiMAX Shindig: Discussing Contemporary Technological and Market Issues**," Invited Talk, Forschungszentrum Telekommunikation Wien (FTW), Vienna, Austria, February 4, 2008.

7. "**Elements of Cross-Layer System & Network Design for QoS-Enabled Wi-Max Networks**," Industry Tutorial, IEEE Milcom'07, Orlando, FL, October 29, 2007. (With Prof. A. Karandikar, IIT Bombay.)

8. V. Sharma and N. Vamaney, "**The uniformly-fair deficit round-robin scheduler for IEEE 802.16 WiMax networks**," Proc. IEEE Milcom'07, Orlando, FL, October 2007.

9. K. Barapatre, N. Koshta, V. Sharma and F. Ricciato, "**Case study: Infrastructure security in cellular data networks**," APRICOT'06 (Asia-Pacific Regional Internet Conference on Operating Technologies), Perth, Australia, March 1-2, 2006.

10. V. Bhedaru and V. Sharma, "**Packet classification algorithms for next-generation networks: A perspective**," Proc. IETE Int'l Conf. on Next-Generation Networks (ICNGN'06), Mumbai, India, February 9-11, 2006.

11. "**High-Performance Switch Architectures: Theory & Practice**," Metanoia, Inc. "Next-Generation Networking Technologies" Workshop Series, Bangalore, India, July 19-20, 2005.

12. M. Morrow, V. Sharma, and T. Nadeau, L. Andersson, "**Challenges in enabling IP-service quality in the Internet**," Guest Editorial, IEEE Commun. Mag., vol. 43, no. 6, June 2005, pp. 88-90.

13. "**Inter-Domain Traffic Engineering: Motivation, Key Aspects & Challenges**," Invited Talk, Acreo AB, Stockholm, Sweden, May 27, 2005.

14. V. Sharma, A. Das, and C. Chen, "**On the issues in implementing the Peer Model in integrated optical networks,**" Photonic Network Communications, Special Issue on the IP-Centric Control and Management of WDM Optical Networks, vol. 8, issue 1, June 2004, pp. 7-21.

15. R Hartani and V. Sharma, "**State-of-the-art router design techniques for efficient MPLS network design and traffic engineering**," MPLS World 2004, Paris, France, February, 2004.

16. V. Sharma and E. A. Vavarigos, "**An analysis of limited wavelength translation in regular all-optical WDM networks**," J. of Lightwave Technology, Special Issue on "Optical Networks," vol. 18, no. 12, December 2000, pp. 1606-1619.

17. V. Sharma and E. A. Varvarigos, "**Circuit switching with input queueing: An analysis for the d-dimensional wraparound mesh and the hypercube**," IEEE Trans. on Parallel and Distributed Systems, vol. 8, no. 4, April 1997, pp. 349-356.

18. G. Bernstein, E. Mannie, V. Sharma, "**MPLS-based control of SDH/SONET optical networks**," IEEE Network, Special Issue on "IP-Optical Integration," vol.15, no. 5, July/August 2001, pp. 20-27.

19. T. Kawashima, V. Sharma, and A. Gersho, "**Capacity enhancement of cellular CDMA by traffic-based control of speech bit rate**," IEEE Trans. on Vehicular Technology, vol. 45, no. 3, August 1996, pp. 543-550.

TECHNICAL ONLINE VIDEOS PRODUCED & SEMINARS CONDUCTED (selected)

1. "**SD-WAN Validation Using Network Emulation Tools**", CE Live! ™, Nov. 9, 2017. (With Neal Roche, CEO, Apposite Technologies, and Tom Nadeau, Principal, Lucidvision.)

2. "**The What, Why, and How of Open Networking and a Peek at the Open Networking Summit 2017**", CE Live! ™, March 16, 2017. (With Arpit Joshipura, GM Networking & Orchestration, Linux Foundation.)

3. "**How Do Schedulers in Routers Work? Understanding RR, WRR, WFQ, and DRR Through Simple Examples**," Metanoia, Inc., Network Design & Architecture Series, March 9, 2016.

4. "**Unraveling the MEF's Third Network & LSO Initiatives**," CE Live! ™, June 3, 2015. (With Rami Yaron, Co-Chair MEF Global Marketing Committee & VP of Strategy & Technology, Telco Systems, NJ.)

5. "**How Not To Configure Committed Burst Size (CBS) On Your Network**," Metanoia, Inc., Network Design & Architecture Series, February 11, 2015.

PATENTS GRANTED (US)

1. **Method and Apparatus for Validating a Path Through a Switched Optical Network**, 7,095,956, Issued August 22, 2006.

2. **Method and Apparatus to Switch Data Flows Using Parallel Switch Fabrics**, 7,123,581, Issued October 17, 2006.

3. **High-Speed Parallel Crossbar Switch**, 7,123,623, Issued October 17, 2006.

4. **Reverse Notification Tree for Data Networks**, 7,298,693 B1, Issued November 20, 2007.

5. **Method and Apparatus for Detecting MPLS Network Failures**, 7,315,510 B1 Issued January 1, 2008.

6. **System and Method for Network-Layer Protocol Routing in a Peer-Model Integrated Optical Network**, 7, 457, 277, Issued November 25, 2008.

7. **Method for Establishing an MPLS Data Network Protection Pathway**, 7,796,504, Issued September 14, 2010.

8. **Protection/Restoration of MPLS Networks**, 7,804,767, Issued September 28, 2010.

9. **Reverse Notification Tree for Data Networks**, 7,881,184, Issued February 1, 2011.

10. **Method and Apparatus for Detecting MPLS Network Failures**, 8,130,637 B1 Issued March 6, 2012.

11. **Reverse Notification Tree for Data Networks**, 8,588,058, Issued November 19, 2013.

12. **Method for Establishing an MPLS Data Network Protection Pathway**, 8,737,203, Issued May 27, 2014.

A full Curriculum Vitae (CV) including: a complete list of publications, industry service, standards contributions, research guidance, academic teaching, tutorials and videos produced, seminars conducted, and editorships, may be requested by calling Dr. Sharma's office or cell phone above.