



IEEE Toronto 5G Summit

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Evolution to 5G: An operator's perspective

Dr. Ivo Maljevic

Tellus

Abstract

A new generation of cellular networks is introduced approximately once every 10 years. Extrapolating from the past, the fifth generation of cellular networks is anticipated by 2020. Is this well-established pattern the main reason for the development of 5G? The answer is no; the use cases and service requirements of 2020 will far exceed the capabilities of evolved 4G networks, thus requiring a new generation network. High level use cases and key performance differences between 4G and 5G targets are discussed in this talk. Migration from 4G to 5G will require a number of architectural changes from mobile network operators, and the key impacts to radio access network and core network design are highlighted. 3GPP timelines and TELUS research that leads to 5G are also presented in the talk.

Biography

Dr. Ivo Maljevic is a senior member of TELUS technology strategy team within the Chief Technology Office, where he focuses on defining a long-term vision for the RAN, spectrum strategy and standardization. In terms of broader industry involvement, in the past he has participated in the Canadian Evaluation Group for the IMT-Advanced proposal, and now he is actively involved in NGMNs and ATIS 5G initiatives. He also participates in 3GPP RAN sessions. Additionally, Ivo is an adjunct lecturer at the University of Toronto. Prior to TELUS, he was with Soma Networks, and before that, he worked at Motorola Canada. His areas of expertise include LTE/WiMAX/CDMA wireless systems, software defined radio, signal processing, and digital communications theory.

Realizing the 5G Vision: Current status, and emerging physical layer and management challenges

Prof. Panagiotis Demestichas

University of Piraeus

Abstract

The talk will start from a very brief overview of the drivers and activities regarding the definition, development and standardization of 5G systems. Then, the main focus of the talk will be on the following technical challenges: (a) the motivation, challenges and approaches for a new air interface below 6 GHz; (b) the optimal optimal splitting of functionality between software and hardware technologies; (c) the essential upgrades in the 5G management intelligence (taking into account the diverse services, the proliferation of re-

sources, and the advent of software-networks); (d) the emerging needs for validation through experimentation.

Biography

Prof. Panagiotis Demestichas received the Diploma and the Ph.D. degrees in Electrical Engineering from the National Technical University of Athens (NTUA). He is full Professor (since April 2012) and has been the Chairman (September 2011 – September 2015) of the Department of Digital Systems of the University of Piraeus. In the period from October 2015 to September 2016 he is on Sabbatical, collaborating with the University of Surrey and in particular its 5G Innovation Center. He has over 25 years of experience in R&D in the fields of wireless/mobile broadband networks, fixed-mobile broadband convergence, Internet technologies, network planning and management, smart cities and environment management. Recent interests include 5G aspects, and especially, the exploitation of spectrum beyond 6 GHz, overall spectrum management, 5G architectures, knowledge-based and predictive management, virtualisation technologies based on SDN and NFV. He has several publications in these areas in international journals and refereed conferences. At the European level, he has been actively involved in (and coordinated) a number of international research and development programs. He is also organizing the European Conference on Networks and Communications (EUCNC 2016), which will take place in Athens, Greece in June 2016. He has also been involved in several bilateral collaborations with international and national industrial entities and public-sector organizations. In terms of standardization, he has contributed to various standardization bodies such as ETSI and IEEE. He was also chairing Working Groups of WWRF related to next-generation networking and advanced management technologies. He is a senior member of the IEEE, member of ACM and the Technical Chamber of Greece.

A 5G Paradigm Based on Two-Tier Physical Network Architecture

Prof. Elvino S. Sousa
University of Toronto

Abstract:

This talk will focus on a paradigm for 5G cellular networks centered on the concept of a two-tier network structure. The two-tier network consists of a set of deployed transceiver structures that act as terminals to the base classical stations/access points and relay communications to nearby user terminals based on use-case scenarios. This concept of two-tier can be

looked at from different standpoints including that of classical relays, user transceiver antenna offloading, public/private physical network layering, or primary/secondary base stations. The talk will discuss the concept as a complement to the deployment of small cells to achieve the required future network capacities.

Biography:

Elvino S. Sousa received his B.A.Sc. in engineering science, and the M.A.Sc. in Electrical Engineering from the University of Toronto in 1980 and 1982 respectively, and his Ph.D. in electrical engineering from the University of Southern California in 1985. Since 1986 he has been with the department of Electrical and Computer Engineering at the University of Toronto where he is now a Professor and the Jeff Skoll Professor in Computer Network Architecture. He has performed research in CDMA and wireless systems since 1983. His current interests are in the areas of broadband wireless systems, smart antenna systems, autonomous infrastructure wireless networks, self configurable wireless networks, user deployed networks, two-tier wireless networks, and autonomous spectrum assignment. He was the founder of wireless communications at the University of Toronto and is the director of the wireless lab, which has undertaken research in wireless systems for the past 24 years. He has been invited to give lectures and short courses on spread spectrum, CDMA, and wireless systems in many countries, and is currently an IEEE VTS Distinguished Lecturer. He was the technical program chair for PIMRC 95, vice-technical program chair for Globecom '99, Co-Technical Program Chair for WPMC 2010 and for PIMRC 2011, and has been involved in the technical program committee of numerous international conferences. He is a past chair of the IEEE Technical committee on Personal Communications and winner of the TCPC inaugural awards for contributions to wireless communications. He has spent sabbatical leaves at Qualcomm and Sony CSL/ATL, where he was the holder of the Sony sabbatical chair. He has been awarded the Queen Elizabeth II Golden Jubilee Medal.

A large scale field trial of 5G experimental system: leap forward from 5G concept to reality

Dr. Peiyang Zhu

Huawei

Abstract

5G has been a hot topic in recent few years both in Academia and Industries. There are many discussions and white papers on 5G vision, requirements, usage scenarios and enabling technologies. In this talk, some key enabling

technologies related to new waveform (f-OFDM), multiple access technology (SCMA), new coding (Polar Code) and advanced antenna technology (massive MIMO) will be introduced along with the rationales for the proposed technologies. The remaining of the talk will be focus on the description of the 5G experimental system based on those technologies and the discussion of field trial results.

Biography

Dr. Peiying Zhu is a Huawei Fellow. The focus of her research is advanced wireless access technologies for LTE/LTE-A and beyond. She is currently leading 5G wireless system research in Huawei. Prior to joining Huawei in 2009, Peiying was a Nortel Fellow and Director of Advanced Wireless Access Technology in the Nortel Wireless Technology Lab. She led the team and pioneered research and prototyping on MIMO-OFDM and Multi-hop relay. Many of these technologies developed by the team have been adopted into WiMAX /LTE standards and 4G products. Peiying has more than 150 granted patents in those areas. She was actively involved in IEEE 802 and 3GPP LTE standards development. She is currently a WiFi Alliance Board member and Treasurer.

The 5G mmWave Channel Model Alliance

Prof. Dave Michelson

University of British Columbia

Abstract

Although advances in high frequency system-on-chip technology during the past decade have brought the goal of exploiting the vast amounts of bandwidth available in the millimeter wave bands for personal wireless communications closer than ever before, significant challenges remain. Foremost among them are development of techniques for mitigating the many impairments introduced by the wireless channel across a wide variety of usage scenarios. Traditionally, standardized channel models useful in fair comparison of proposed wireless standards have been developed by channel modeling study groups convened by standards bodies based upon studies conducted previously by independent teams of academic and industry researchers. The technical challenges of conducting such studies and the accelerated pace at which the wireless industry wishes to develop 5G standards for millimeter-wave wireless communications has encouraged NIST to bring together leading research groups to coordinate pre-standardization millimeter-wave channeling modeling research efforts. The 5G mmWave Channel Model Alliance will provide a venue to promote fundamental re-

search into measurement, analysis, identification of physical parameters, and statistical representations of mmWave propagation channels. In addition to making available methodology and best practice data, the Alliance will focus on the development of usage scenarios for Indoor, Outdoor and Emerging environments. In addition, the Alliance has identified the following visionary goals: 1) Refining, improving, and troubleshooting the initial channel models developed by international standards-making bodies, 2) Focusing on unaddressed usage scenarios, parameters, frequencies, and architecture, 3) Providing a source of continuity for stakeholders involved in different stages in the standards development life-cycle, 4) Serving as a liaison to other consortia and international groups, and, 5) Aggregating new and improved channel measurement and modeling methodologies and best practices.

Biography

David G. Michelson received his B.A.Sc., M.A.Sc., and Ph.D. degrees in electrical engineering from the University of British Columbia (UBC), Vancouver, Canada. From 1996 to 2001, he served as a member of a joint team from AT&T Wireless Services, Redmond, WA, and AT&T Labs-Research, Red Bank, NJ, where he contributed to the development of propagation and channel models for next-generation fixed and mobile wireless systems that formed the basis for those later adopted by the WiMAX and LTE communities. Since 2003, he has led the Radio Science Laboratory at UBC, where his research interests focus on antennas and propagation for wireless communications system design in a wide range of environments and scenarios. Since 2013, he has also served as co-director of the AURORA connected, autonomous and electric vehicle testbed at UBC. Prof. Michelson is a member of the Steering Committee and leads the Emerging Scenarios working group of the 5G mmWave Channel Model Alliance sponsored by the National Institute of Standards and Technology, member of the Canadian National Committee of the International Union of Radio Science, and member of the Boards of Governors of the IEEE Communications Society and IEEE Vehicular Technology Society. He is the founding Editor of the Wiley/IEEE Press Series on Vehicular Technology. In 2011, he and his former student Simon Chiu won the R. W. P. King Best Paper Award of the IEEE Antennas and Propagation Society.

Enabling Technologies for Highly Efficient and Cost-Effective 5G Communications

Prof. Xianbin Wang

University of Western Ontario

Abstract

In achieving the anticipated 1,000 times of capacity increase, highly efficient air interface is essential for 5G in enabling the new spatial transmission schemes with extremely high utilization rates of distributed radio resources. At the same time, cost-effective deployment and operation of 5G infrastructure is critical to support the related ICT applications and ecosystem to be created by 5G. The focus of this talk is to analyze the main technical challenges of 5G, identify the essential key enabling technologies for efficient and cost-effective 5G communications, and present the emerging R&D opportunities. The main challenges of 5G will be analyzed based on the discussion of the technical requirements of 5G and the distributed nature of 5G radio resources. Enabling technologies for highly efficient and cost-effective 5G communications, including massive MIMO, NOMA, and SDN enabled spectrum and energy management in heterogeneous networks will be presented. We aim to bridge all stakeholders related to 5G and accelerate the ongoing R&D efforts and standardization processes worldwide.

Biography

Dr. Xianbin Wang (S98-M99-SM06) is a Professor and Canada Research Chair at Western University, Canada. He received his Ph.D. degree in electrical and computer engineering from National University of Singapore in 2001. Prior to joining Western, he was with Communications Research Centre Canada as Research Scientist/Senior Research Scientist between July 2002 and Dec. 2007. From Jan. 2001 to July 2002, he was a system designer at STMicroelectronics, where he was responsible for system design for DSL and Gigabit Ethernet chipsets. His current research interests include adaptive wireless systems, 5G networks, communications security, and distributed ICT systems. Dr. Wang has over 250 peer-reviewed journal and conference papers on various communication system design issues, in addition to 24 granted and pending patents and several standard contributions.

Dr. Wang was the recipient of three IEEE Best Paper Awards. He currently serves as an Associate Editor for IEEE Wireless Communications Letters, IEEE Transactions on Vehicular Technology and IEEE Transactions on Broadcasting. He was also an editor for IEEE Transactions on Wireless Communications between 2007 and 2011. Dr. Wang is a Senior Member of

IEEE and an IEEE Distinguished Lecturer. He was involved in a number of IEEE conferences including GLOBECOM, ICC, WCNC, VTC, ICME and CWIT, in different roles such as symposium chair, tutorial instructor, session chair, track chair, and TPC chair.

Journey to 5G with Virtualized RAN

Kasper Reinink

Alcatel-Lucent

Abstract

This talk describes the role of virtualization and NFV in effecting the transition from VRAN 4G LTE to 5G; 5G will bring a broad range of new services at various capability, price, cost and performance points with a focus on end-to-end services and flexible personalization. New technologies such as virtualization, life-cycle management automation and orchestration, already being implemented in VRAN 4G LTE, will lay the foundation for the transition to 5G end-to-end services; the proposed service management architecture to deliver such services is presented.

Biography

Kasper Reinink is a principal architect at Alcatel-Lucent in the Wireless CTO team, currently focusing on wireless architecture strategy in the area of network function virtualisation; he has more than 25 years R&D experience in the telecom field in the areas of wireless, transport networking and packet switching involving multiple product lines; he has several patents in wireless and networking, is a Distinguished Member of Technical Staff at Alcatel-Lucent; senior member IEEE and Professional Engineer Ontario; he holds BSc(Eng) and MSc(Eng) degrees in electrical engineering from Witwatersrand University, Johannesburg.

Empowering User Experience in The Next Decade

Javan Erfanian

Bell Canada

Abstract

In this talk, Javan outlines a vision of 2020 and beyond, potential user scenarios, both growing and new demands, and the need for foundational shifts to enable and empower this. The technology trends, in the Road to 5G, will be outlined, with a perspective on characterization of 5G. Finally global initiatives, particularly NGMN 5G initiative will be briefly introduced.

Biography

As Distinguished Member of Technology, at Bell Mobility, Canada, Javan is prime for the wireless technology strategic direction and industry initiatives. In this role, Javan has worked with the industry and standards forums and also the research community. In particular, he has been actively contributing to the work program at NGMN over the years. For the NGMN 5G global initiative, Javan has been the Co-Lead and Chief Editor. He has taught many academic and industry courses and programs, and has been an IEEE Communications Society Distinguished Lecturer for many years. Javan grew up in Iran and completed his education at the University of Calgary and the University of Toronto, with research publications and many citations.

Computer Architecture and SDR

Dr. Nebu John Mathai

Cognitive Systems

Abstract

Communications, control and computation: three pillars that support the bulk of the edifice of electrical engineering. The contribution of radio engineering to control and communications is, of course, without question. Preliminary work in novel forms of quantum computation seem to also require the use of advanced RF and microwave technology to be practical and effective. Software-defined radio (SDR) has long been recognized as a major enabler of making radio personal, thereby opening the field to a variety of novel application areas by the wider community. Given (a) the wide array of wireless communications standards used globally, (b) the adaptive nature of next-generation cognitive radio schemes, and (c) the diversity of unconventional uses of radio that are on the horizon, a malleable and high-performance substrate for radio systems is vital. This talk will provide a brief overview of one aspect of SDR that is vital to ensuring such malleability and performance: embedded computation.

Biography

Nebu John Mathai is Director of Engineering and Architecture at Cognitive Systems Corp. A prolific designer of digital hardware and processing architectures for a variety of application spaces throughout his career, he currently leads a group engaged in an array of research and development activities. Special recent focus has pertained to the design and verification of digital SDR hardware, novel processor architectures for high performance embedded computing, and the development of large-scale supercomputing hardware and software systems. From the University of Toronto, he received the B.A.Sc. in Engineering Science (2000) and the M.Eng. in Electrical En-

gineering (2004). He received the Ph.D. in Electrical Engineering from Texas A&M University (2008) .

Big-data analytics applications for agile networks

Dr. Petar Djukic

Ciena

Abstract

Currently proposed 5G technologies are characterized with very high rate requirements and high degree of network agility providing those rates when and where required. This talk focuses on the impact of these technologies on the wireless backhaul networks. Our thesis is that future backhaul networks will have to take advantage of web-scale technologies, which are currently dominant in large data centres. These web-scale network technologies are characterized by their cost effectiveness and their ability to provide high capacity and agility with virtualization, automation and openness. We show that with web-scale technologies it is possible to take advantage of big-data available in the network and build an intelligent decision plane that can increase network operators revenue and decrease their costs. We show how these results can be achieved with smarter admission control based on the principles of connection overbooking and network revenue management.

Biography

Dr. Petar Djukic (Ciena, Canada) received B.A.Sc., M.A.Sc., and Ph.D. degrees from the University of Toronto in 1999, 2002 and 2007, respectively. From 2007 to 2008 he was a postdoctoral researcher at the Department of Computer Science, University of California, Davis. From 2008 to 2010 he was a postdoctoral researcher at the Department of Systems and Computer Engineering, Carleton University, Ottawa. In 2010 he founded MeshIntelligence Inc., a provider of virtualized TDMA solutions for 802.11-based wireless networks. From 2011 to 2012 he was a research scientist with the Communications Research Centre Canada, working on MAC protocol design for underwater networks. From 2011 to 2012 he was with Huawei Canada researching 5G technologies. Since 2014 he was with Ciena solving software-defined networking problems in converged packet-optical networks. His research interests are in big-data analytics for networks, network management protocols for wireless and converged packet-optical networks, data and control plane protocols for network function virtualization, and MAC protocol design. He has over 30 referred publications and over 20 patent applications and patents

in 5G wireless networking and software-defined networks.

Sustainable Smart Cities: Leveraging Internet of Things and 5G

Dr. Yves Lostanlen
Siradel, North America

Abstract

Dr Yves Lostanlen's talk will present the emerging technologies and future application trends in the Sustainable Smart City viewed by the prism of wireless technology evolutions.

The outline of the talk will touch upon the following items: Sustainable Smart cities Focus on Connectivity Wireless Industry trends: Breadth of applications with different needs in terms of network services. Wireless applications in the cities of the Future: Connected and Sustainable cities at the crossroad of several industries. Technical challenges to overcome: diversity of applications, capacity, billions of connected devices, radio spectrum Possible impacts on standards and 5G network architectures. Requirements for future tools to design and optimize the equipment, the network and the citizen experience management.

Biography

Dr. Yves Lostanlen is currently CEO of SIRADEL North America operating from Toronto, Canada, and Wireless CTO of SIRADEL Group. Yves Lostanlen has entrepreneurial experience and has provided product and consulting services on connectivity (wireless, fiber) to many top-tier companies in the ICT, energy, and media Industries, as well as to governments, municipalities, policy makers, regulators, wireless operators and technology manufacturers. A renowned expert in the wireless industry, Dr Lostanlen has built and actively contributed to more than 30 collaborative research projects (multi-million Euros/CAD) and to several standardization bodies (3GPP, IEEE, ETSI) and EU COST actions. Dr. Lostanlen is also an Adjunct Research Professor at University of Toronto and has a personal interest in technologies (ICT4D) that support global economic growth, sustainability and social development. A senior member of IEEE, Prof Lostanlen is in the Education and training board of the IEEE ComSoc. He has been technical chairman, panel chair, keynote speaker, and reviewer for many international IEEE conferences. He has written more than 100+ scientific articles and book chapters for IEEE transaction journals, Wiley, ACM and the French Academy of Science. He is an international reviewer and advisor for the European Research Council and national research agencies. Born and raised in France, Dr. Yves Lostanlen holds an Habilitation (eq. Doctorate of Science) in Physics, a PhD and an MSc in Electrical and Computer Engineering, and

an MBA from MIT Sloan School of Management (USA).

NECs Vision and R&D activities towards 5G

Dr. Xavier Costa

NEC Lab

Abstract

Mobile networks are a key element of today's society enabling communication, access and information sharing. Mobile traffic forecasts agree in predicting that the demand for capacity will grow exponentially over the next years, mainly due to video services. In addition, services in high priority areas for our society such as education, health, government, public safety and transportation are increasingly expected to rely on a mobile infrastructure. Fifth generation mobile networks (5G) aim at addressing the demands and business contexts of networks for 2020 and beyond. This talk will provide an overview of NEC's 5G vision towards mobile networks by 2020 and describe some of the R&D activities conducted in Europe focusing on specific challenges in the mobile RAN, Transport and Core areas.

Biography

Xavier Costa-Prez is Head of 5G Networks R&D at NEC Laboratories Europe, where he manages several projects focused on 5G mobile core, backhaul/fronthaul and access networks. He is a 5GPPP Technology Board member and the Technical Manager of the Xhaul project. His team contributes to NEC projects for products roadmap evolution as well as to European Commission R&D collaborative projects and has received several NECs R&D Awards for successful technology transfers. In addition, the 5G team contributes to related standardization bodies: 3GPP, BBF, ETSI NFV, ETSI MEC and IETF. Xavier has served on the Program Committees of several conferences (including IEEE Greencom, WCNC, and INFOCOM), published at top research venues and holds over 20 patents. He received both his M.Sc. and Ph.D. degrees in Telecommunications from the Polytechnic University of Catalonia (UPC) and was the recipient of a national award for his Ph.D. thesis.

Enabling 5G: mmWave Silicon Integration and Packaging

Dr. Bodhisatwa Sadhu

IBM Research

Abstract

mmWave technology is rising as a crucial component for 5G and other emerging ancillary wireless networks including Gb/s device-to-device (D2D) com-

munication and mobile backhaul. Some of the key challenges for the commercial scale deployment of mmWave technology in 5G are: 1) integration of complex circuits in silicon technologies, 2) IC, package, antenna and board co-design and integration, and 3) cost effective calibration and test. Through various examples of mmWave transceivers demonstrated in hardware, this talk illustrates how these challenges can be addressed for a variety of potential 5G usage scenarios, from PAN to backhaul.

Biography

Bodhisatwa Sadhu is currently a Research Staff Member in the RF/mm-wave Communication Circuits and Systems group at IBM T.J. Watson Research Center, NY. He received the Ph.D. degree in Electrical Engineering from University of Minnesota, Minneapolis, in 2012. For his Ph.D., he worked on an analog-signal processing front-end for software defined radio applications. Since 2012, Dr. Sadhu has been working on mm-wave transceivers for imaging, backhaul and wireless PAN applications at IBM Watson. He has led the demonstration of a low noise, self-healing frequency synthesizer, and collaborated on the design of advanced frequency synthesizers for wireline and wireless applications. At present, he is focused on silicon based mm-wave phased array systems for 5G communications. Dr. Sadhu currently serves on the Technical Program Committee of the Compound Semiconductor Integrated Circuits Symposium, and is Vice Chair of the IEEE New York Section EDS/SSCS chapter. He has authored and co-authored more than 35 papers, has authored the book, Cognitive Radio Receiver Front-Ends - RF/Analog Circuit Techniques(Springer, 2014), is a chapter author of Wireless Transceiver Circuits,(CRC Press, 2015) and holds 10 issued US patents with 10+ pending. Dr. Sadhu is the recipient of the University of Minnesota Graduate School Fellowship, 2007, 3M Science and Technology Fellowship, 2009 and the University of Minnesota Doctoral Dissertation Fellowship, 2011.

Enabling 5G over PON with Radio over Fiber

Prof. Leslie A. Rusch
Universite Laval Quebec

Abstract

Fiber to the home deployment provides a low capital expenditure solution for femto cell roll-out and provisioning. The universal coverage and extremely high bit rates promised by 5G can be achieved by exploiting the passive optical network (PON) infrastructure providing fiber connections to private residences. Radio over fiber piggy-backs wireless signals on the digital data traveling on the PON fibers. Radios at PON termination points capture 5G signals, convert them to the optical domain and route them to a remote

access node (the smart edge) for electronic triage. Customer premises equipment must be colorless, low-cost and scalable to ever increasing data rate requirements. We examine new system architectures for 5G radio over fiber on a PON infrastructure.

Biography

Leslie A. Rusch received the B.S.E.E. degree (with honors) from the California Institute of Technology, Pasadena, in 1980 and the M.A. and Ph.D. degrees in electrical engineering from Princeton University, Princeton, NJ, in 1992 and 1994, respectively. She currently holds a Canada Research Chair in Communications Systems Enabling the Cloud in the Department of Electrical and Computer Engineering at Universit Laval, QC, Canada. She is an IEEE Fellow and a member of the Centre for Optics, Photonics and Lasers at UL. Dr. Rusch has experience in defense, industrial and academic communications research. She was a communications project engineer for the Department of Defense from 1980-1990. While on leave from Universit Laval, she spent two years (2001-2002) at Intel Corporation creating and managing a group researching new wireless technologies. Prof. Rusch's research interests include digital signal processing for coherent detection in optical communications, spatial multiplexing using orbital angular momentum modes in fiber, radio over fiber and OFDM for passive optical networks; and in wireless communications, radio over fiber for passive optical networks, optimization of the optical/wireless interface in emerging cloud based computing networks, and implantable medical sensors with high bit rate UWB telemetry. She is recipient of the IEEE Canada J. M. Ham Award for Graduate Supervision. Prof. Rusch has published over 120 journal articles in international journals (90% IEEE/OSA) with wide readership, and contributed to over 150 conferences. Her articles have been cited over 4000 times per Google Scholar.

Multitier Cloud Computing and 5G Networks

Prof. Alberto Leon-Garcia

University of Toronto

Abstract

In this talk we present the multitier cloud computing architecture introduced by the NSERC SAVI Network (Smart Applications on Virtual Infrastructure) and implemented in its national testbed. In addition to massive core data centers, the multitier cloud includes a smart edge that offers heterogeneous resources, and an outer edge of sensors and low-power devices. We explain how applications can be orchestrated end-to-end in this multitier cloud. We then focus on the central role of measurement and monitoring systems and

analytics services in enabling smart applications. We present three examples and demos: 1. The MonArch system for multilayer monitoring of SAVIs infrastructure; 2. Monitoring in a smart building using sensor networks; and 3. The CVST application platform for smart transportation and its deployment in the Greater Toronto Area.

Biography

Professor Alberto Leon-Garcia is Distinguished Professor in Electrical and Computer Engineering at the University of Toronto. He is a Fellow of the Institute of Electronics and Electrical Engineering "For contributions to multiplexing and switching of integrated services traffic". He is also a Fellow of the Engineering Institute of Canada and the American Association for the Advancement of Science. He has received the 2006 Thomas Eadie Medal from the Royal Society of Canada and the 2010 IEEE Canada A. G. L. McNaughton Gold Medal for his contributions to the area of communications. Professor Leon-Garcia is author of the leading textbooks: Probability and Random Processes for Electrical Engineering, and Communication Networks: Fundamental Concepts and Key Architecture. He is currently Scientific Director of the NSERC Strategic Network for Smart Applications on Virtual Infrastructures.

Panel: The Journey to 5G Market, Standardization and Adoption

Prof. Raviraj S. Adve, Dr. Shalini Periyalwar

University of Toronto, WWRF

Biography

Raviraj S. Adve (S'88-M'97-SM'06) was born in Bombay, India. He received his B. Tech. in Electrical Engineering from IIT, Bombay, in 1990 and his Ph.D. from Syracuse University in 1996. He received the 1996 Syracuse University Outstanding Dissertation Award. Between 1997 and August 2000, he worked for Research Associates for Defense Conversion Inc. on contract with the Air Force Research Laboratory at Rome, NY. He joined the faculty at the University of Toronto in August 2000 where he is currently a Professor. Dr. Adve's research interests include analysis and design techniques for heterogeneous networks, energy harvesting networks and in signal processing techniques for radar and sonar systems. He received the 2009 Fred Nathanson Young Radar Engineer of the Year award and the 2014 International Conference on Comm (ICC) Backnets Workshop best paper award.

Shalini Periyalwar is a Consultant in wireless technologies and is also an Adjunct Research Professor at Carleton University in Department of Systems & Computer Engineering. During a career spanning over two decades in the wireless industry, Shalini has held various research positions. She was

a Research Advisor in the Advanced Technology group at Blackberry, where she was responsible for research in next-generation wireless systems. Prior to this she spent over a decade at Nortel, leading teams delivering innovation in wireless system architecture and protocols for new wireless technologies and for product evolution. Shalini has over 70 issued U.S. Patents and 50 refereed papers. Her research interests are in next-generation wireless solutions, including system design, wireless network protocols, and resource management algorithms. She is a Senior Member of the IEEE.

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