

★ THE GREAT STATE OF COMMUNICATIONS ★

IEEE  
**GLOBECOM**<sup>2014</sup>  
GLOBAL COMMUNICATIONS CONFERENCE,  
EXHIBITION & INDUSTRY FORUM

AUSTIN, TX, USA  
★ 8-12 DECEMBER 2014 ★  
ADVANCE PROGRAM



FOR CONFERENCE UPDATES, VISIT  
[WWW.IEEE-GLOBECOM.ORG/2014](http://WWW.IEEE-GLOBECOM.ORG/2014)



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**PROGRAM AT A GLANCE**

Start Times	MONDAY	TUESDAY		WEDNESDAY		THURSDAY		FRIDAY
	8-DECEMBER	9-DECEMBER		10-DECEMBER		11-DECEMBER		12-DECEMBER
07:30	Breakfast							Breakfast
08:30	Tutorials & Workshops	Keynotes		Keynotes		Keynotes		Tutorials & Workshops
09:30								
10:00	Coffee	Coffee		Coffee		Coffee		Coffee
10:15								
10:30	Tutorials & Workshops	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Tutorials & Workshops
10:45								
12:15	Lunch	Awards Luncheon		Lunch		Lunch		Lunch
12:30								
13:30	Tutorials & Workshops	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Tutorials & Workshops
14:00								
15:15	Coffee	Coffee		Coffee		Coffee		Coffee
15:30								
15:45	Tutorials & Workshops	Coffee		Coffee		Coffee		Tutorials & Workshops
16:00								
16:15	Tutorials & Workshops	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Technical Sessions	Industry Sessions	Tutorials & Workshops
17:30								
18:00	Best of GC 14 Poster Session	Young Professionals				OPEN		
19:00	Welcome Reception	Dialogue W/Industry Industry Executives		Banquet				
20:00								
21:30								

# WELCOME TO THE IEEE GLOBAL COMMUNICATIONS CONFERENCE IN AUSTIN, TX, USA!



As Senior Executive Vice President – Technology and Network Operations for AT&T, it's with great pleasure that I, also as the General Chair for our IEEE GLOBECOM 2014 Conference, welcome you to the great state of Texas and its capital city of Austin. The theme for this year's conference is "***The Great State of Communications,***" and I can think of no more appropriate theme given who we are and where we are.

Well-known for live music, entertainment and technology, Austin has become a center of focus in the technology world. Austin is home to both technology bellwethers and start-ups. Innovation, like music, is part of the city's rhythm. AT&T has served this great state for 138 years and employs more than 35,000 Texans. As a leading technology innovator, we were pleased to debut our U-verse with AT&T

GigaPower service in Austin earlier this year, with speeds up to 1 gigabit/sec for both uploads and downloads. These are exciting times for technology in the U.S. and the world, and Austin is a prime example of what's possible in a hotbed of innovation, talent and technology.

The Great State of Communications theme at this year's conference will allow us to focus on the hottest topics facing our industry today and well into the future. Topics include:

- Beyond 5G, IoT
- Big Data Analytics
- Cloud Computing
- Cross-Disciplinary Applications
- Emerging Technologies
- Business, Government and Policy
- Engineering Management

I look forward to the lively discussions sure to take place this year's event. Thanks for your efforts and energy in making this year's show a great one. Let's kick the tires a bit and see what we come up with.

**John Donovan**  
General Chair

## LOOK FORWARD TO SEEING YOU IN AUSTIN!

# WELCOME TO IEEE GLOBECOM 2014 IN AUSTIN!

On behalf of the Organizing Committee and all of the volunteers who have worked so diligently over the past several years to make this conference a success, we enthusiastically welcome you to IEEE GLOBECOM 2014 and to Austin, Texas! Our theme, "***The Great State of Communications***," was chosen to highlight our unique location in the Capital City of Texas -- Austin -- and the large number of high technology companies in the Central Texas region, collectively known as Silicon Hills.

Our program this year has been specially developed to provide the best value for both our academic/researcher attendees, as well as our communications engineer practitioner attendees. You will find IEEE GLOBECOM 2014 to be packed with an exciting technical program, along with great networking opportunities and social events. Our downtown venue also offers a vast number of entertainment opportunities, all within walking distance, during your stay in Austin.

We believe that you will find the technical program, managed by Professors Jeffrey Andrews and Robert Heath of the University of Texas at Austin, and our industry program, managed by James Kimery and Ian Wong from National Instruments, to be first class and not to-be-missed.

We are especially pleased to have AT&T as our Diamond Level Patron. Representing AT&T is John Donovan, the General Chair of IEEE GLOBECOM 2014. Mr. Donovan is the Senior Executive Vice President, AT&T Technology and Network Operations, and oversees AT&T's technology and global network, including the company's best-in-class mobile broadband network. Additionally, all of our other patrons have given a very high level of financial support, thus assuring the success of IEEE GLOBECOM 2014. We are grateful for the strong support of AT&T, as well as our other IEEE GLOBECOM 2014 patrons: Cisco, Huawei, National Instruments, Samsung, Alcatel-Lucent, Ericsson, Intel, Nokia, Qualcomm, Fujitsu Networks, Corning and Technology Crossover Ventures.

We have worked hard to make the first-ever IEEE GLOBECOM conference in Austin, Texas both exciting and affordable as you advance your knowledge and career. Each ComSoc flagship conference (GLOBECOM and ICC, both held annually) is a life experience you should not miss.

Our conference provides you with an outstanding program through leading edge technical paper presentations, hot topic tutorials, new technology workshops, visionary keynotes, and the newly expanded Industry Program and the "Best of IEEE GLOBECOM" poster session. We look forward to hosting you in Austin, and are glad you are here!



**T. Scott Atkinson**  
Executive  
Chair



**Doug Zuckerman**  
Executive  
Vice Chair



**Ted Rappaport**  
Program  
Executive



**David Wolter**  
Industry  
Executive



**Keith Cambron**  
Industry  
Executive

**ON BEHALF OF THE ENTIRE TECHNICAL PROGRAM COMMITTEE,  
WE ARE DELIGHTED TO WELCOME YOU ALL TO OUR  
FAVORITE CITY AND HOME FOR IEEE GLOBECOM 2014.**

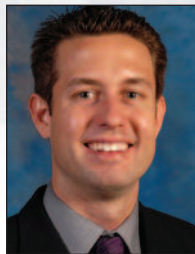
We attended our first IEEE GLOBECOM more than a decade ago (2000 for Jeff and 2002 for Robert). At that time, we never imagined that we would be writing this letter to you now. We are excited to present to you an outstanding technical program assembled by a handpicked team of symposia chairs and more than 4300 reviewers.

In organizing this conference, we've learned firsthand how much planning and work goes into every IEEE GLOBECOM and IEEE ICC. We hope you find the small portion of the technical program that you are able to attend rewarding and educational.

In part because of the enormity of the technical program – in particular the technical symposia – a new feature of IEEE GLOBECOM 2014 is a “Best of IEEE GLOBECOM” poster session, which will be held starting an hour before the Welcome Reception and continue until the reception is in full swing. This poster session features some of the best and most interesting papers submitted to the conference. 100 papers were nominated by the symposia and track chairs, which the Awards committee (chaired by Z. Xiong) whittled down to 50. Best Paper Awards will also be selected from these 50 presentations. One goal of this new poster session is to allow attendees to obtain broader and deeper insight into the innovative research in the many corners of ComSoc. We hope that you take full advantage of this unique opportunity.

We expect you will enjoy the intimate atmosphere afforded by the Hilton's compact layout, which is where all formal technical exchanges will take place. This did require, however, a slightly smaller and even more selective technical program than is typical. For example, we have 12 Tutorials (out of 32 submissions) and 15 Workshops (out of 48 submissions), while the technical program features 859 papers selected out 2171 submissions, for an overall acceptance rate of just over 39%. We are grateful to the Workshop Chairs (S. Rangan, C. Papadias and L. C. Wang), the Tutorial Chairs (M. Dohler and L. Cimini) and the Symposia Chairs (S. Cui and S. Aissa) for their dedicated efforts over the last 2 years.

Finally, we hope you are able to spend some time exploring and taking in the unique vibe and culture of central Austin, including Lady Bird Lake (which offers outstanding running, walking, and biking on the Hike & Bike trail), swimming in the cool and natural waters of Barton Springs, strolling South Congress, eating your way through the Whole Foods flagship store, and the many vibrant nightlife corridors in downtown, whose live music is world renown. Also be sure to check out The University of Texas at Austin campus, only 15 blocks from the Hilton, and just past the State Capitol. Austin's charms are subtle but numerous, leading it to be the United States' fastest growing city since 2000 and a magnet for techies, bohemian hipsters, aspiring musicians, and everything in between.



**Jeff Andrews**  
TPC Co-Chair



**Robert Heath**  
TPC Co-Chair

**WE WISH YOU A  
WONDERFUL STAY IN AUSTIN!**

## KEYNOTE SESSION

Tuesday, 9 December 2014 • 08:30 – 10:00

Chair: Mahmoud Daneshmand, Stevens Institute of Technology



**EDWARD G. AMOROSO**  
Chief Security Officer  
AT&T Inc.

### Recent Advances in Cloud Security

As individuals and organizations continue to accelerate their use of cloud infrastructure, services, and applications, security concerns will also continue to accelerate. A range of security solutions for cloud is presented here, including private clouds behind perimeters, public cloud with dedicated perimeters, encrypted content embedded in cloud, containerized session access to cloud, and run-time virtualization of cloud objects. Examples are provided using commercially available cloud security products and services.

**Biography:** Dr. Edward G. Amoroso currently serves as Senior Vice President and Chief Security Officer at AT&T, where his primary responsibilities lie in the real-time protection of AT&T's vast enterprise, network, and computing infrastructure, including its emerging LTE mobile network. Ed's team is presently focused on creating innovative means for reducing the risk of advanced

persistent threat (APT), distributed denial of service (DDOS), mobile malware, and cloud infrastructure attacks targeting AT&T and its customers.

During his twenty-nine year career with AT&T, beginning at Bell Labs, Ed has focused exclusively on cyber security, working on projects ranging from Unix operating system security to critical infrastructure protection design. Ed is the author of dozens of technical papers and reports, as well as five published books on the topic of cyber security. For the past twenty-three years, he has also served as adjunct professor of computer science at the Stevens Institute of Technology, where he has introduced roughly 2,500 graduate students to the topic of computer security.

Ed holds the BS degree in physics from Dickinson College, and the MS and PhD degrees in computer science from the Stevens Institute of Technology. Ed is also a graduate of the Columbia Business School. In 2000, Ed was awarded the AT&T Labs Technology Medal and was elected an AT&T Fellow in 2009. Ed's work has been featured in major news media such as the Wall Street Journal, the New York Times, and CNN. He recently completed, with his seventeen-year-old son Matthew, a high school textbook on computer science entitled "From Gates to Apps," available from Silicon Press.



**JAMES TRUCHARD**  
President, CEO, and Cofounder  
National Instruments

### Next-Generation Tools for Next-Generation Wireless Research

With the widespread adoption of smart devices, wireless consumers' demand for data has increased exponentially and forced service providers to invest in new and faster technologies to keep up with the demand. Even with the planned 4G rollouts, industry experts agree that a fifth generation or 5G is inevitable. 5G holds the promise of everything and nothing because it has yet to be defined. It is needed to increase network capacity; however, many researchers view 5G as an inflection point—an opportunity to expand the capabilities of our wireless networks and perhaps redefine the term "network."

Today's cellular networks are plagued by inherent long and unpredictable latencies, and the use of a single-data-pipe, one-size-fits-all approach to connected devices virtually eliminates the possibility of a heterogeneous network that could potentially serve a broader class of applications beyond Internet data. A multidata-plane, low-latency network could not only impact the world economy but surely improve all of our lives. Against this backdrop, wireless researchers have a blank sheet of paper for designing 5G, so the potential of 5G lies with them and their ability to manage the system complexities created by advancements in communication, computation, and control technologies. Applying traditional "siloeed" design approaches to solve the 5G puzzle could in fact be the bottleneck preventing a new network vision because these approaches tend to "reinvent the wheel." Innovative technologies that can be created, designed, simulated, and prototyped faster lead to faster deployment.

At this session, Dr. James Truchard, CEO, Cofounder and President of National Instruments, explores the evolution of system design as a discipline and discusses how new graphical approaches can be applied to the complex system challenges of 5G.

**Biography:** Named an Innovation Agent by Fast Company, James Truchard, president and CEO, cofounded National Instruments in 1976 and has pioneered the way scientists and engineers solve the world's grand engineering challenges.

As one of Forbes' America's Favorite Bosses, Dr. James Truchard, commonly known around NI as Dr. T, has led the company from a three-man team to a multinational organization recognized as a Fortune 100 Best Places to Work and one of the top 25 "World's Best Multinational Workplaces" by the Great Places to Work Institute.

Under Truchard's leadership, the company's long-term vision, known as the 100 year plan, and focus on improving the world by providing tools that accelerate productivity, innovation, and discovery, has led to strong, consistent company growth and success of its broad base of customers, employees, suppliers, and shareholders. Learn more about the NI company story at [ni.com/company](http://ni.com/company).

Additionally, Truchard has been recognized with the Woodrow Wilson Award for Corporate Citizenship for his community involvement with organizations including: the Engineering Foundation Advisory Council, The University of Texas at Austin Chancellor's Council, Austin Software Council, and FIRST Robotics.

Truchard holds a doctorate in electrical engineering, as well as a master's degree and bachelor's degree in physics, all from the University of Texas at Austin. Truchard earned his master's and doctorate degrees while working full-time as the managing director of the acoustical measurements division at the UT Applied Research Laboratories.

## KEYNOTE SESSION

Wednesday, 10 December 2014 • 08:30 – 10:00

Chair: Mahmoud Daneshmand, Stevens Institute of Technology



### PANKAJ PATEL

Executive Vice President & Chief Development Officer  
Cisco

#### Are you ready for the Internet of Everything?

The Internet fundamentally transformed the world...The Internet of Everything will be responsible for creating the trillions of dollars of value that is the Internet of

Everything's potential. The people and the companies who come up with the best ideas, who discover the most effective and efficient ways to use the Internet of Everything will be the ones who succeed in the future. Join Pankaj Patel, Cisco's Executive Vice President and Chief Development Officer as he discusses how Cisco is committed to innovation, simplicity, building winning teams and helping customers exceed their goals.

**Biography:** Pankaj Patel is Executive Vice President and Chief Development Officer at Cisco. He is responsible for leading the development and execution of Cisco's \$36.3 billion technology portfolio across a global team of more than 28,000 employees. He drives Cisco's technology innovation strategy to transform how people connect, communicate and collaborate through integrated hardware and software platforms and architectures from Cisco's routing, switching, security, mobility, video, collaboration, data center and cloud offerings.

Patel holds a bachelor's degree in engineering from the Birla Institute of Technology and Science in Pilani, India, and a master's degree in electrical engineering from the University of Wisconsin-Madison. In 2003, he was awarded a patent in the area of multi-service architecture.



### WEN TONG

IEEE & Huawei Fellow  
Head of Wireless Research  
Head of Communications Technologies Laboratories, Huawei 2012 LAB

#### 5G Wireless Goes Beyond Smartphones

The 5G wireless will bring a dramatic improvement of end user experience than that of today, 5G is a tool for telecom operators to explore new revenue streams from verticals by transforming the industries to improve efficiency and enable a vast range of innovations, such a transformation is emerging and 5G will make it pervasive. This talk will also present a set of key enabling technologies for 5G and to discuss the challenges and impacts in the context to meet much more diversified requirements than the previous generations, a much more extensive joint effort across variety of industries becomes essential to make 5G a success.

**Biography:** Wen Tong is the IEEE Fellow and Huawei Fellow; the Head of Wireless Research, and the Head of Communications Technologies Laboratories, Huawei 2012 LAB

Prior to joining Huawei in March 2009, Dr. Wen Tong was the Nortel Fellow and global Head of the Network Technology Labs at Nortel. He received the M.Sc. and Ph.D degrees in Electrical Engineering in 1986 and 1993 and joined the Wireless Technology Labs at Bell Northern Research in 1995 in Canada. He has pioneered fundamental technologies in wireless with 180 granted US patents. Dr. Tong was Nortel's Most Prolific Inventor.

Dr. Tong has conducted the advanced research work spanning from 1G to 4G wireless at Nortel. He had been the director of Wireless Technology Labs from 2005 to 2007. From 2007 to 2009, Dr. Tong was the head of Network Technology Labs, responsible for Nortel's global strategic technologies research and development. In 2007, Dr. Tong was inducted as Nortel Fellow.

Since 2010, Dr. Tong is the vice president and head of Huawei wireless research leading one of the largest wireless research organizations in the industry with more than 700 research experts. In 2011, Dr. Tong is appointed the Head of Communications Technologies Labs of Huawei 2012 LAB, a corporate centralized next generation research initiative. In 2011, Dr. Tong was elected as Huawei Fellow.

## KEYNOTE SESSION

Thursday, 11 December 2014 • 08:30 – 10:00

Chair: Mahmoud Daneshmand, Stevens Institute of Technology



### ALICIA ABELLA

Assistant Vice President (AVP)  
AT&T Labs

#### Cloud Computing: A New Strategic Infrastructure

Since the term was first uttered publicly in 2006, cloud computing has acquired many definitions, been embraced by some and

feared by others, been called disruptive, and reached a point where it's no longer an "if" for many businesses but a must.

The term "cloud computing" in the aforementioned sentence could easily be replaced by other terms taken from our modern technological history, and it would still be accurate. This talk will draw parallels between cloud computing and historically disruptive technologies that were strategic to the national and global economy. For example, when viewed as an infrastructure, cloud computing can be thought of as strategic to the economy as the highway infrastructure was in the 20th century. When considering commoditization and standardization, they may prove as vital to the proliferation of cloud computing as the standardization of intermodal containers was to the shipping industry. When looking at the cloud ecosystem, companies, both big and small, are competing to provide cloud technologies and services, in some cases even diverting from their main line of business, just as shipping companies emerged as a result of the shipping needs of the 20th century. Cloud computing

as a global infrastructure, standardization of cloud technology components, and the formation of an industry solely devoted to cloud computing are some of the compelling trends and drivers that we will explore in this talk.

**Biography:** As AVP of Cloud Technologies and Services Research Organization, Dr. Abella has held positions that allow her to demonstrate her skills in a broad research spectrum which have unfolded into her organization's current responsibilities which include research in cloud computing, distributed storage, human-computer interaction, mobile services, SIP/VoIP technology, ubiquitous computing, and emerging devices.

In 2013, Dr. Abella received Columbia University's Medal of Excellence, an award given each year to an alumnus or alumna, under 45 years of age, whose record in scholarship, public service, or professional life is outstanding. This is the first time since 1929, when the award was first given, that Columbia has awarded the medal to an engineer. In 2011, she was selected by President Obama to be on his Presidential Advisory Commission for Educational Excellence for Hispanics. Also in 2011, she was inducted into the prestigious WITI (Women in Technology International) Hall of Fame. In 2010, she was honored as one of the Top Five Women of the Year by Hispanic Business Magazine. She is also a member of the elite group of AT&T Science and Technology Medal award winners and recipient of the Hispanic Engineers National Achievement Award for Outstanding Technical Achievement.



### RAJESH PANKAJ

Senior Vice President, Engineering  
Qualcomm Research

#### Future of Wireless

Rajesh Pankaj, Senior VP Engineering, Qualcomm Technologies, Inc. will discuss the future of Wireless and the latest technology advancements Qualcomm is working on, including 5G, LTE-unlicensed

and small cells, in an effort to solve the 1000x mobile data challenge and improve network efficiencies and the user experience.

Qualcomm aims to be a leading force in bringing 5G to life. Rajesh will speak on the latest developments with 5G and how it is about enabling new services and devices, connecting new industries, and empowering new user experiences. He will delve into how broader dimensions of improvements will drive new 5G services and how a unified 5G design is scalable and adaptable across extreme variations of use cases.

The number of consumers utilizing mobile devices such as smartphones and tablets on a daily basis has grown significantly and is predicted to continue to grow 1000 times over the next decade or so. This growing trend results in a dramatic increase in data usage which puts pressure on networks and ultimately affects network performance and the user experience. Network operators have to address this issue in order to meet the needs of their customers and

this growing demand. Qualcomm is working on solutions to cost-effectively meet the 1000x mobile data challenge. Join Rajesh as he shares information on the different technologies Qualcomm is developing to help address the 1000x mobile data challenge. This will include information on making use of all spectrum types, including LTE in unlicensed spectrum, and how network densification through the use of hyper-dense small cells will provide greater efficiencies in spectrum and the user experience.

**Biography:** Rajesh Pankaj is a senior vice president of engineering at Qualcomm Research. He currently oversees Qualcomm Research's Systems Engineering and Systems Integration and Test departments in San Diego, California. He also directs Qualcomm Research's international offices in Austria, China, Germany, India, and Korea. In this role, he leads the operational efforts for a broad portfolio of research projects with topics ranging from next generation wireless networks to innovative technologies such as 3G HetNets, LTE, and small cells. Another project under Pankaj's purview is pervasive computing, commonly known as context awareness. Engineers on this project explore sensor capabilities on mobile phones, making devices more aware of a user's context.

Pankaj holds a PhD and Master of Science in electrical engineering and computer science from the Massachusetts Institute of Technology and a Bachelor of Science in electrical engineering from the Indian Institute of Technology, Kanpur, India. Pankaj holds more than 15 patents and is a member of IEEE.



Tuesday, 9 December 2014  
18:30 – 20:00

## DIALOGUE WITH INDUSTRY LEADERS: THE ROADMAP TO 2025

The communications industry has experienced a thirty-year explosion in growth that connected much of the world with the Internet. The past ten years alone saw the advent and seemingly overnight spread of the smartphone, as well as new wireless standards that provide us with a faster connection in our pockets than we used to have in our houses. In this special session, we ask a panel of industry leaders, "What might the next ten years show us?" and "What can we learn from the previous decade to position ourselves for maximum contribution in the coming decade?" This dialogue will feature audience interaction with our distinguished panel, and is open to both technical and industry program participants.

### MODERATOR



**David Lu**  
Vice President, AT&T



**Tareq Bustami**  
VP, Product  
Management, Freescale



**Farooq Khan**  
President, Samsung  
Research America



**Glenn Laxdal**  
VP, Advanced  
Technology Solutions,  
Ericsson



**Mike Murphy**  
CTO, Networks,  
North America, Nokia



**Rod Naphan**  
CTO & Senior VP,  
Fujitsu Network  
Communications

### PANELISTS



Tuesday, 9 December 2014 • 10:30 – 12:15

## EF-1: Network Transformation

**Moderator:** Paritosh Bajpay, VP, Domain 2.0 Services Design, AT&T Labs

**Panelists:** Don Fendrick, VP & CTO, Alcatel-Lucent  
Kireeti Kompella, Senior VP & CTO, Juniper Networks  
John Lazar, CEO, MetaSwitch  
Rod Naphan, CTO & Senior VP, Fujitsu Network Communications  
Doug Wolff, VP & CTO, Ericsson

The User-Defined Network Cloud (UDNC) is a network transformation vision for the network of the future. The goal is to build a smart, cloud-like network that can address business changes, customer needs and deliver new and unique services to customers quicker than before. The UDNC being built is a global first at this scale.

Software-Defined Networks (SDNs) and Network Function Virtualization (NFV) are two key technologies used in UDNC. SDN shifts control of the network from hardware to software, removing pre-defined physical limits. This creates an “intelligent” network that is more flexible, efficient and aware of applications. NFV moves network functions from hardware-based appliances into software platforms inside virtual computing machines. This means we can update network functions from almost anywhere and do it quickly without having to redeploy new hardware. We can dynamically reroute traffic, add capacity and introduce new features through programmable, policy-based controllers.

UDNC helps operators meeting the growing demand and evolving nature of communications. It also allows operators to work with new suppliers and take advantage of new innovations more quickly and efficiently. The supplier base is expanded with the inclusion of small and nimble companies for their innovative capabilities, as well as larger, more experienced companies to tap into economies of scale.

The executives of this forum will highlight the UDNC network architecture, management functions and suppliers’ innovations towards the vision.

Wednesday, 10 December 2014 • 10:30 – 12:15

## EF-2: 5G Vision: Requirements and Key Technologies

**Moderator:** Wonil Roh, VP, Wireless, Samsung

**Panelists:** Chih Lin I, China Mobile Research Institute  
Yoshihisa Kishiyama, NTT DoCoMo, Inc.  
Eric Dahlman, Ericsson Research  
Peiyong Zhu, Huawei Technologies Canada Co., Ltd.  
John Smee, Qualcomm Incorporated  
Rakesh Taori, Samsung Electronics Co., Ltd.

The race to search for innovative solutions to enable the Next Generation Mobile Communications (5G era) has recently begun worldwide. In early 2013, the European Commission announced that it would invest €50 million in 2013 for 5G research in multiple projects such as METIS, quickly followed by the formation of the Chinese Government-led IMT-2020 Promotion Group in February 2013, the initiation of the Korean Government-led 5G Forum in May 2013, and the formation of 2020 and Beyond Ad-hoc within ARIB (Association of Radio Industries and Businesses), Japan, in October, 2013. While the standardization of 5G specifications in standards bodies such as the Third Generation Partnership Project (3GPP) and the formal ratification of 5G standards by the International Telecommunication Union

(ITU) are still several years away, many share the vision of targeting 2020 for the initial commercialization of 5G cellular with drastically enhanced user experiences in several aspects including Gbps data rate support.

This session aims to bring together the experts from the mobile communications industry worldwide for presentations and discussion on the 5G vision and technologies, ranging from components, algorithms, modem, and network design to services along with the recent 5G global activities and progresses.

Thursday, 11 December 2014 • 10:30 – 12:15

## EF-3: Internet of Things: From Standardization to Deployment and Commercialization

**Moderators:** Rasmus Nielsen, Cisco Systems  
Neeli Prasad, SAI Technologies

**Panelists:** Sean Parham, VP, Cisco Systems  
Dilip Krishnaswamy, IBM  
Rob Chandhok, Senior VP, Qualcomm  
Liam Quinn, Senior Fellow, Dell  
David Fuller, VP, National Instruments

By 2020, the Internet of Things is expected to drive the deployment of 50 billion connected devices and a value-at-stake of \$19 trillion. What started as a concept for providing universal identities in the form of RFIDs has evolved into a domain encompassing numerous technologies from low-power sensor networks to cloud applications as well as a whole new breed of business models. From being a concept attracting plenty of research, the domain has been adopted by multiple standardization bodies consolidating the many industrial best practices across numerous verticals and industrial players from Machine-to-Machine approaches of service providers to the improvement of operational excellence by both larger and smaller enterprises.

The state of the Internet of Things has reached a breaking point with a large number of pure players providing offerings across the whole range of different services from low powered devices focusing on the ease-of-use to device management platforms including connectivity management. On the application side a number of platforms are available providing different sets of capabilities including support for application development to targeted platform where enterprises can develop their own vertical-targeted applications.

The focus of this forum is to hear from executives of major companies to provide a unified view of the state of the Internet of Things from their aspiration into the Internet of Things.

Tuesday, 9 December 2014 • 14:00 – 15:45

## **IF-1: Emerging Technologies for Next Generation Wi-Fi: What's Beyond IEEE 802.11ac?**

**Organizer:** Monisha Ghosh, InterDigital

**Panelists:** Robert Stacey, Principal Engineer, Intel  
Ron Porat, Senior Principal Engineer, Broadcom  
Sachin Katti, Chief Scientist, Kumu Networks  
Hemanth Sampath, Principal Engineer, Qualcomm

The demand for mobile data is increasing at a rapid pace, with the increasing use of smartphones and video applications. Wi-Fi is increasingly seen as an important piece of this market, with projections of more than half of all mobile data being off-loaded to Wi-Fi by 2018.

The IEEE 802.11 standardization group recently ratified 802.11ac as the newest member of the 802.11 family of Wi-Fi standards. While 802.11ac specified a number of improvements over 802.11n such as: (i) up to 8 spatial streams (ii) mandatory support of bandwidths up to 80 MHz and (iii) multi-user MIMO on the downlink, these improvements mainly improve the per-link throughput on the downlink. In order to satisfy the requirements of future high density deployments of Wi-Fi, it is important to consider other metrics for system performance, such as area-throughput, which are more relevant in use cases where there are dense deployments of access points and stations. Recently, 802.11 started a new task group, 802.11ax, to develop the next generation of Wi-Fi physical (PHY) and medium access control (MAC) protocols that would satisfy these requirements.

In this panel, we would like to discuss new technologies that would need to be incorporated in 802.11ax in order to meet the stated goal of improving the average throughput per station by at least a factor of four, in dense deployments. A partial list of these technologies includes:

- a. Uplink multi-user MIMO
- b. Full-duplex wireless
- c. Scheduled MAC
- d. Inter-AP coordination
- e. OFDMA

Tuesday, 9 December 2014 • 14:00 – 15:45

## **IF-3: Programmable Carrier Infrastructure: Implications of NFV and SDN**

**Organizers:** Steven Wright, Robert Doverspike, R. Schlichting, T. Anshultz, AT&T

**Panelists:** Robert Doverspike, AT&T Research  
Tetsuya Nakamura, NTT DOCOMO  
Christopher Liljenstolpe, Metaswitch  
Dilip Krishnaswamy, IBM Research

Carriers are deploying technologies like Network Function Virtualization and Software Defined Networks promise to reshape today's network infrastructure into a globally-distributed, heterogenous computing platform. NFV and SDN propose a variety of software components that are aware, at some level of abstraction, of the network's capabilities. These technologies effectively re-envision the network infrastructure with a layered software perspective in contrast to the traditional siloed view of independent infrastructures organized by proprietary physical elements dedicated to a specific type of service. NFV and SDN are increasingly based on open source components in addition to proprietary developments. These approaches envisage a change in the lifecycles of network elements into independent lifecycles for hardware and software components. Operating multiple services on a common infrastructure through virtualization promises savings in capital costs, but implies potential operational changes. Developments of new capabilities on and in this programmable infrastructure are increasingly done through Proof of Concept mash-ups rather than formal standardization programs. The panelists will provide their perspectives on recent developments of NFV and SDN technologies in carrier networks.

Tuesday, 9 December 2014 • 14:00 – 15:45

## **IF-5: The Smart Grid as an Application Deployment Platform**

**Organizer:** Stan McClellan, Texas State University

**Panelists:** George Koutitas, Gridmates  
Karl Popham, Austin Energy  
Bill Krakar, Freescale Semiconductor  
Bill Muston, OnCor Energy Delivery  
Ed Davalos, AT&T Business Solutions

Many "Smart Grid" implementations have achieved real-time data and command flow to support optimization and energy management. This foundation is primed for the deployment of novel business models and application-layer technologies which enable a new marketplace for energy services.

Following the paradigm of the telecommunication sector, the next generation energy service market will include development of applications which use the Smart Grid as a base-platform to provide advanced, next-generation services to the customers of the power grid.

This panel session will explore the use of Smart Grid deployments as an application development platform. The panel will capture current trends as well as future aspects, including energy management, energy analytics, Internet of Things, Machine to Machine communications, personalized applications and peer-to-peer energy exchange. The panelists will present viewpoints which stem from real-world deployment of Smart Grid systems, advanced applications, and challenges related to technology and business aspects of the Smart Grid.

Tuesday, 9 December 2014 • 14:00 – 15:45

## **IF-7: 100G and the Metro Optical Migration**

**Organizer:** Michael Sabelhaus, Fujitsu

**Panelists:** Alan Gibbemeyer, Acacia  
Michael Freiberger, Verizon  
Ron Kline, Ovum

With a tremendous proliferation of bandwidth-thirsty applications, ranging from online learning, mobility, to university research, and cloud computing, Carriers more than ever, are reevaluating their transport networks. We are seeing a migration to 100G in both the Metro and Regional networks based on pressure to continually lower costs, improve service velocity and provide higher bandwidth services. While 10G has been a dominate Metro transport rate and is still showing signs of longevity, we will consider drivers for metro 100G, key applications, upcoming 100G technology evolutions, and look at migration to even larger rates.

Tuesday, 9 December 2014 • 14:00 – 15:45

## **IF-9: Federal Communications Policies Impacting the US Telecom Sector: Looking Back at 2014 and into the Future**

**Organizer:** Lawrence Movshin, Wilkinson Barker Knauer, LLP

**Panelists:** Bryan Tramont, Wilkinson Barker Knauer, LLP  
Michael Ha, FCC  
Reza Arefi, Intel Corporation  
John Godfrey, Samsung Electronics, North America

This is a panel reviewing significant policy initiatives adopted by, or under consideration in, Congress, the White House and the Federal Communications Commission, and discuss how these policies have shaped, or will impact, the nation's role as a technology leader. Issues to be addressed will focus on recently held or planned spectrum auctions;

the FCC's policies governing the availability of spectrum for, and use of, unlicensed devices; policies regulating receiver susceptibility and new initiatives to adopt "harm" or "interference" thresholds, and the United States nascent policies at the upcoming World Radio Administrative Conferences. I would expect to include representatives of the wireless telecommunications carriers, broadcaster/cable providers and (hopefully) one or more members of the FCC's key staffers on spectrum and technology.

Tuesday, 9 December 2014 • 16:15 – 18:00

## **IF-2: 5G mmWave Small Cell Networks: Are we ready for multi Gb/s 5G wireless system design and test?**

**Organizers:** Eckhard Ohlmer and Vincent Kotzsch, National Instruments  
**Chair:** Robert Heath, University of Texas, Austin

**Panelists:** Emilio Calvanese Strinati, CEA-LETI  
Thorsten Draeger, National Instruments Dresden  
Amitava Ghosh, Nokia  
Sampath Rangarajan, NEC Laboratories America  
Geng Wu, Intel

Small cells, exploiting large chunks of spectrum in mmWave bands, may become key to meeting the multi-Gb/s access and backhaul data rate demand of cellular networks in 2020. Recent research has led to an understanding of fundamental mmWave topics, for example, propagation characteristics, beamforming principles and antenna technology. Yet, integrating this exciting technique seamlessly into a practical wireless communications system requires rethinking all aspects of the system as a whole. Various system related aspects, such as

- reconfigurable and re-routable multi-hop mmWave backhaul,
- unified mmWave backhaul and access link,
- mobility on the mmWave access link,
- multi user mmWave access protocols,
- the possibility to split the wireless system into high rate mmWave data plane and coverage oriented control plane,
- how to prototype and test mmWave-enhanced communications systems require solutions and more topics are being identified as research and the understanding of mmWave systems advance.

Tuesday, 9 December 2014 • 16:15 – 18:00

## **IF-4: Security Challenges in Network Function Virtualization (NFV)**

**Organizers:** Ashutosh Dutta, AT&T  
Subir Das, Applied Communication Sciences

**Panelists:** Francois Cosquer, Alcatel-Lucent  
Kapil Sood, Intel  
Dennis Cox, IXIA  
Stephen Chasko, Landis+Gyr  
Rita Marty, AT&T

Network Function virtualization (NFV) is becoming the key pillar of future network components that telecom operators and service providers can leverage in order to provide flexible and cost effective service without compromising the end user quality of service. The goal is to remove the dependencies of custom made hardware by abstracting the underlining networking components into software applications that can run on common of the shelf (COTS) hardware computing platform. The advantages are manifold: operators can save their equipment costs, power consumption, specialized maintenance costs and enable network services quicker which are mainly controlled by programmable software. Industry-wide effort has already started, with many standards organizations developing and ratifying standards for interoperability and ease of deployment for network virtualization. For example, , ETSI NFV, ONF, Open Flow, and Open Day Light

are actively working in close collaborations with 3GPP, IETF, DMTF, IEEE to enable the rapid deployment of virtualized solutions in the operator's networks.

While network function virtualization opens up the door for flexible service creation and rapid deployment, it also adds additional security challenges attributed by the cloud computing, virtualization and software defined network aspects of the network. The panel will consist of operators, vendors and security experts who are actively involved in research, standards and trial deployment. The audience will benefit from knowing the technology and industry trends, security threats and possible mitigation techniques along with the opportunity to interact with the industry experts.

Tuesday, 9 December 2014 • 16:15 – 18:00

## **IF-6: Low Power Solutions for IoT**

**Organizer:** Shahriar Emami, Samsung

**Panelists:** Massoud Pedram, University of Southern California  
John Chong, VP, Product and Business Development, Kionix  
John Min, Director, Solution Engineering, Imagination Technologies  
Frederik Beer, Universität Erlangen-Nürnberg  
Hendricus De Ruijter, Standards Architect

Internet of things also known as "the next internet revolution" is expected usher in a new age in wireless connectivity for all objects resulting in billions of new connections. The new networks will support innovative services and culminate in substantial economic benefits. The IoT nodes must be able to operate for years without requiring battery replacement. The mere scale of deployment constrains us to low power radio paradigm. This forum, consisting of technologists and academicians, examines the motivation, history as well as advances in low power approaches to IoT. The emerging standards and their merits will also be addressed. The panelists will then discuss the remaining challenges and conclude with some potential solutions.

Tuesday, 9 December 2014 • 16:15 – 18:00

## **IF-8: Digital Predistortion for Power Amplifier Linearization: Trends and Challenges for Future of Communication Systems**

**Organizer:** Takao Inoue, National Instruments

Linearity of power amplifiers (PA) has been and will increasingly become an important system performance metric to support high throughput and reliability wireless communication systems. PA linearity is known to influence bit error rate, spectral leakage, and power efficiency: all of which are crucial system performance metrics.

Traditional linearization techniques have relied on insertion of nonlinear analog components that made the design, implementation, and quality assurance a challenging task. More recently, digital predistortion technique (DPD) has been shown to be particularly suitable for modern wireless communication systems using digital modulation and baseband techniques. Over the years, significant advances have been made in terms of amplifier nonlinearity modeling, characterization, signal processing techniques to combat the nonlinearity and memory effects in the amplifier, and implementation architectures. The PA linearization problem remains to be unique in that it is a mix of RF circuits and digital signal processing problems.

In this panel, we will hear from the leading industry panelists on their views of state of the art techniques, challenges, and outlook for future trends.

Tuesday, 9 December 2014 • 16:15 – 18:00

## **IF-10: Building, Monetizing and Litigating a Patent Portfolio**

**Organizer:** Michael D. Specht, Sterne, Kessler, Goldstein & Fox P.L.L.C.

**Panelists:** Christian Dubuc, Vice President, Acacia Research  
Parham Momtahan, Senior Advisor, Wavefront  
Leonard Forsys, President, Forsys Consulting Group  
Margie To Pearce, Associate General Counsel, Practice Fusion, Inc.

A strong patent portfolio can add tremendous value to businesses at any stage of development. Businesses can use a patent portfolio to protect their core ideas while adding appeal to potential investors or buyers. Strategic use of patents can restrict competition to the benefit of the patent owner. More controversially, some businesses leverage a strong patent portfolio as a primary source of revenue.

The monetization of patent portfolios, however, might look much different in five years than it does today. With the smartphone patent wars, backlash against non-practicing entities, and groundbreaking Supreme Court decisions, the business of patent portfolios has gained considerable public attention in the past few years. Add to the public attention the new patent application laws that went into effect in 2012, combined with legislation on patent litigation currently being considered in Congress, and it is clear the recipe for business success with patents is changing even if the ingredients remain the same.

Wednesday, 10 December 2014 • 14:00 – 15:45

## **IF-11: The Challenge Ahead: Identification and Selection of Candidate Technologies and Architectures for 5G Wireless Access**

**Organizers:** David Michelson, UBC  
Yi Wang, Huawei

**Panelists:** Peiying Zhu, Huawei Technologies  
Chih-Lin I, China Mobile Research Institute  
Amitabha Ghosh, Nokia  
Takehiro Nakamura, NTT Laboratories  
Stefan Parkvall, Ericsson Research  
Tomohiko Taniguchi, Fujitsu Laboratories Limited

Such is the demand for better, faster, cheaper wireless access that the quest to develop 5G wireless technology has begun even before any particular specification has been published in any official document by any telecommunication standardization body. The performance goals that have been proposed for 5G by an increasing number of informal research groups and collaboration bodies are both challenging and audacious. There is a growing consensus that meeting these goals will require adoption of wireless access technologies that represent a radical break from the past. As challenging as development and assessment of alternative technologies will be, some of the greatest challenges will be political. This session will begin with summaries of the leading candidate technologies and architectures for 5G wireless access then focus on the need for, opportunities for, and challenges associated with cooperation and collaboration as the wireless industry seeks to develop, standardize and commercialize them. Multiple perspectives, including spectrum allocation, use case definition, technology development, standardization and commercialization, and multiple roles including government, industry and academic that will be necessary to achieve these goals will be considered.

Wednesday, 10 December 2014 • 14:00 – 15:45

## **IF-13: Update on Wired Broadband xDSL/IPTV Systems, including the New G.fast Standard**

**Organizer:** Russ Gundrum, University of Houston

**Panelists:** Vernon Reed, Lead Member, Technical Staff, AT&T Labs  
Jochen Maes, Alcatel-Lucent Bell Labs  
George Ginis, ASSIA, Inc.  
Dhadesugoor R. Vaman, Digital Compression Technology LLC  
Andrew Long, EXFO

Austin has been deemed as one of the battleground cities between Google Fiber and AT&T's recently announced GigaPower U-verse service. The San Antonio/Austin area was the first in AT&T's footprint to receive IPTV (U-verse) service back in 2005, so this is an ideal place and forum to provide this update.

Wednesday, 10 December 2014 • 14:00 – 15:45

## **IF-15: IEEE 802.11ah: Wi Fi Technology Tuned for Internet of Things (IoT)**

**Organizer:** Amal Ekbal, National Instruments

**Panelists:** Hemanth Sampath, Qualcomm  
Hongyuan Zhang, Marvell Semiconductor  
Sai Shankar Nandagopalan, Adeptence/Tensorcom  
Guodong Zhang, InterDigital

The growth of the Internet made everyone realize the huge disruptive potential of not only identifying the things around us, but also communicating with them. Now, with the availability of low-cost, low-power and scalable wireless communication technologies, this grand vision of IoT has the chance of becoming a reality.

In this context, IEEE 802.11 is in the process of creating a new amendment called 802.11ah to specifically create a version of the standard suitable for IoT use cases. In this panel, we will review the challenges faced by the current 802.11 physical (PHY) and medium access control (MAC) layers in IoT scenarios. Then, we will discuss various ideas that could improve these capabilities, with a focus on the solutions chosen by the 802.11ah task group and the reasons behind those choices. In particular, 802.11ah PHY layer uses Sub-GHz spectrum and lower bandwidth channels (1MHz, 2MHz, etc.). The MAC layer incorporates significant changes that increase scalability (via a hierarchical grouping of nodes), improve power save modes, extend range and reduce overhead for small data packet transmissions. Then, we will discuss what further ideas could be incorporated in the next generation of 802.11ah.

In addition to 802.11ah, there are several other wireless access technologies targeting IoT space such as Bluetooth low energy, Zigbee, LTE machine type communications (MTC), Z-Wave etc. We will discuss the relative strengths and weaknesses of these technologies and explore how these technologies may even coexist and satisfy complementary roles in the macro-level IoT architecture.

Wednesday, 10 December 2014 • 14:00 – 15:45

## IF-17: Big Data Cloud Networking

**Organizer:** Mark Karol, IEEE Cloud Computing Initiative

**Panelists:** Geng Lin, Google

Mahmoud Daneshmand, Stevens Institute of Technology

Wu Chou, Huawei

Michael Enescu, Cisco

Mark Davis, Dell

Third IEEE North America Cloud Computing Congress: Cloud Computing already has widespread impact across how we access today's applications, resources, and data. The IEEE Cloud Computing Initiative (CCI) intends to help accelerate the development and use of cloud computing technologies and help advance the understanding and use of the cloud computing paradigm by coordinating IEEE cloud computing conferences, publications, standards, educational, and regional activities.

This forum features key industry panelists presenting their views on "big data cloud networking." In recent years there have been great improvements in processing capabilities and storage capacity along with the ability to create networks that interconnect billions of smart terminals and trillions of devices. The panelists will discuss the issues and challenges associated with cloud network architectures, the exponential increase in the number of network-connected devices, and the support of big data services and applications.

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Wednesday, 10 December 2014 • 14:00 – 15:45

## IF-19: Standardization:

### An Excellent Career Path for Senior Engineers

**Organizer:** Ken Krechmer, IEEE Senior Member

**Panelists:** Donggeiun Choi, Korean Standards Association

Periklis Chatzimisios, Alexander TEI of Thessaloniki

Alexander D. Gelman, NETovations

Karen Pieper, Tabula

Too many good, mid-career engineers are un- or underemployed. One way to address this is to help engineers recognize standardization as a very desirable mid-career path.

Technical education, especially in the US, does not address the importance of standardization, the technical challenges and standardization career possibilities. Perhaps as a result, many working engineers look down on standardization, seeing only a time-consuming political process. With this background it is not surprising that most senior engineers don't recognize standardization as an intellectually and financially rewarding career. This is unfortunate, as native English speaking senior engineers have the best background to be successful standardization engineers.

This session addresses standardization as a mid-career choice in three parts:

- The large and rapidly growing need for communications standardization engineers is created by the thousands of different communications standardization committees and sub-committees worldwide. A panel of five communications standardization experts, each familiar with different areas of communications standardization, explain how the need for world-wide coordination of communications systems is creating new employment opportunities.
- Why communications standardization is technically challenging. Presented by Ken Krechmer. An overview of isology (the science of standards) focusing on the more rigorous aspects of the field.
- What a standardization engineer does and potential employers. Each panelist presents their experience in standardization and takes questions.

Wednesday, 10 December 2014 • 16:15 – 18:00

## IF-12: SDN, NFV, Autonomic Management & Control (AMC) of Networks and Services, and IPv6, as Complementary Enablers for 5G

**Organizers:** Ranganai Chaparadza, IPv6 Forum & ETSI AFI  
Tayeb Ben Meriem, Orange, ETSI AFI, TMF, NGMN

**Panelists:** Ranganai Chaparadza, IPv6 Forum & ETSI AFI

Tayeb Ben Meriem, Orange, ETSI AFI, TMF, NGMN

John Strassner, Huawei, TMF ZOOM

Kenneth Dilbeck, TeleManagement Forum

Klaus Martiny, Deutsche Telekom, NGMN

George Dobrowski, Huawei, BBF

Steven Wright, AT&T Services Inc, ETSI NFV

Francisco-Javier Ramón Salguero, Telefonica, ETSI NFV

Manish Patil, Dell, OMG SDN WG

Mehmet Ulema, Manhattan College: IEEE NGSON

Takashi Egawa, NEC, ITU-T SG13

Research communities need to adopt the architectural frameworks for SDN (Software-Driven/Defined Networking), NFV (Network Functions Virtualization) and AMC (Autonomic Management & Control of Networks and Services), being unified and standardized for a holistic combined view of the three paradigms, and use them in their research as frameworks commonly shared with the industry.

The three technologies must now be considered through a "combined" approach, from standardization perspective, in order to holistically guide the industry. SDOs/Fora harmonization efforts are intensifying in pursuit of synergy-building and harmonization/unification of standardized-architectural-frameworks for SDN, NFV, AMC, and Converged Management of Fixed/Mobile Networks.

This panel session presents a joint White-Paper by the collaborating SDOs/Fora: Industry Harmonization for Unified Standards on Autonomic Management & Control (AMC) of Networks and Services, SDN and NFV, as three complementary emerging paradigms, and on Converged Management of Fixed/Mobile Networks: From silo approach to cross-SDO combined approach. NGMN (an alliance of telecom operators) is working on requirements for 5G. According to perspectives from other various SDOs/Fora and research communities working on 5G as well, various aspects of 5G (e.g. enabling technologies such as AMC, SDN, NFV, IPv6, etc) are being discussed. From AMC point of view, 5G is calling for intelligent/autonomic network capabilities in End-to-End system architectures, including the need for intelligent 5G core networks with embedded Autonomic-Functions (Decision-making-Engines) that optimally and adaptively provision resources and control traffic engineering and QoS mechanisms in such a way as to handle the anticipated huge traffic volumes of diversified traffic flows expected.

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Wednesday, 10 December 2014 • 16:15 – 18:00

## IF-14: Cable Industry Access Technologies

**Organizer:** Mehmet Toy, Comcast

**Panelists:** Mehmet Toy, Comcast

Edwin J. Mallette, Bright House Networks

Jorge Salinger, Comcast

Belal Hamzeh, CableLabs

Cable Industry has new initiatives to support growing user demands in data, voice and video services. DOCSIS 3.1, DOCSIS Provisioning of EPON (DPoE), Converged Multiservice Access Platform (CMAP) and XPON are among them. This forum will discuss pros and cons of these technologies.

Wednesday, 10 December 2014 • 16:15 – 18:00

## IF-16: IPv6 and IoT Challenges

**Organizer:** Latif Ladid, President UL/IPv6 Forum, Chair IEEE ComSoc IoT Subcommittee

**Panelists:** Jorge Pereira, Principal Scientific Officer, DG CONNECT, European Commission: *The Critical Role of IoT Experimentation*  
Sebastian Ziegler, Mandat International Vice-Chair, IEEE ComSoc IoT SubC and IoT Forum: *IoT6 Project Success Story*  
Srdjan Krco, Co-founder & CEO, DunavNET: *IoT Architecture Approaches in EU*  
Antonio Jara, Assistant Professor, Post Doc, HES-SO University, HOP Ubiquitous, Vice-Chair IEEE ComSoc Internet of Things (IoT): *The IPv6-based IoT Opportunities and Challenges*  
Pascal Thubert, Chair, IETF 6TiSCH WG, Cisco Systems: *The Fringe Internet*

The public IPv4 address space managed by IANA (<http://www.iana.org>) has been completely depleted by 1 February 2011. This creates by itself an interesting challenge when adding new things and enabling new services on the Internet. Without public IP addresses, the Internet of Things capabilities would be greatly reduced. Most discussions about IoT have been based on the illusionary assumption that the IP address space is an unlimited resource or it's even taken for granted that IP is like oxygen produced for free by nature. Hopefully, the next generation of Internet Protocol, also known as IPv6 brings a solution.

The introduction of IPv6 provide enhanced features that were not tightly designed or scalable in IPv4 like IP mobility, ad hoc services; etc catering for the extreme scenario where IP becomes a commodity service enabling lowest cost networking deployment of large scale sensor networks, RFID, IP in the car, to any imaginable scenario where networking adds value to commodity.

This session will be devoted to analyze the transformative impact of IPv6 on IoT and its advances feature, presenting the challenges and solutions being considered in the context of several EU and Korean research projects.

Wednesday, 10 December 2014 • 16:15 – 18:00

## IF-18: Programmable Cloud Networking

**Organizer:** Mark Karol, IEEE Cloud Computing Initiative

**Panelists:** Steve Diamond, EMC  
Hans-Martin Foisel, Deutsche Telekom  
Rajeev Agrawal, Nokia  
Geng Lin, Google  
Chung-sheng Li, IBM  
Masum Hasan, Cisco

Third IEEE North America Cloud Computing Congress: Cloud Computing already has widespread impact across how we access today's applications, resources, and data. The IEEE Cloud Computing Initiative (CCI) intends to help accelerate the development and use of cloud computing technologies and help advance the understanding and use of the cloud computing paradigm by coordinating IEEE cloud computing conferences, publications, standards, educational, and regional activities.

In this session, expert panelists will present their views on "Programmable Cloud Networking." There are on the many challenges in designing a cloud computing system that can meet various requirements and support a diverse set of cloud applications and services. Many issues need to be addressed, including, but not limited to, security, reliability, architecture, standardization, and economics. Further issues arise when cloud architectures are applied to providing the network functions for mobile

broadband networks. The objective is to allocate resources where and when they are needed to help deliver any service or application when the user demands it. The panelists will discuss the issues and challenges and present some potential solutions based on programmable, Software Defined Networking (SDN), and Network Functions Virtualization (NFV).

Wednesday, 10 December 2014 • 16:15 – 18:00

## IF-20: Reduce the Overhead Workload of Engineering Management

**Organizer:** Zhen Zhao, Comcast

**Panelists:** Zhen Zhao, Comcast  
Mehmet Toy, Chair, Programmability Technical Committee; Chair, Cable Networks and Services Committee  
Jorge Salinger, VP, Access Architecture, Comcast  
Belal Hamzeh, Director, Principal Architecture, Cablelabs

Currently, there are many software management tools and at Comcast we are using several of them, such as Sonar, ALM, Rally, Splunk, Omniture, SevOne, JIRA and etc. Each tool give out a lot of data to engineering managers. Managers use these data to monitor the process of software development. The problem is there are too much data. Managers have to analyze all these data manually. This brings a lot of overhead to engineering management. It is also possible that some hidden relationships that help with disclosing management problems or improving team work may be undermined by tons of other data.

This panel explores the current and future potential solutions of engineering management problems faced by different size companies. This panel presents the latest breakthroughs in engineering management, as well as some of the exciting opportunities and challenges for this regime. Experts from leading computer engineering companies provide their vision and experience, and will highlight their management solutions.

As a seed of this topic discussion, we propose using parallel coordinate in engineering management at Comcast. Different from those existing engineering management tools that focus on supporting more data to managers, this proposal focuses on analyzing the relationship between different data and disclose possible hidden issues to managers.

Thursday, 11 December 2014 • 14:00 – 15:45

## IF-21: mmW Coverage and Mobility for Next Generation Cellular Systems

**Organizers:** Ali Sadri and Reza Arefi, Intel

**Panelists:** Ted Rappaport, NYU-Poly  
Amitava Ghosh, NSN  
Philip Pietraski, InterDigital  
Thomas Haustein, Fraunhofer HHI  
Wen Tong, Huawei

Increasing the capacity of cellular networks is becoming one of the most challenging tasks of the mobile industry this decade. As traditional mechanisms to increase spectral efficiency approach their theoretical limits, new and disruptive techniques are needed to satisfy the growing demand of mobile data traffic. Consequently, the fifth generation (5G) cellular system is expected to make use of higher frequency bands in mmWave range to increase the density of the cellular network. While these bands provide potential for greater capacity it also imposes certain constraints in the design of the future systems to handle mobility and coverage.

For this panel discussion we are inviting speakers to address the possible challenges and requirements of such systems. Those topics and challenges may include: antenna design for eNB and UE, modulation and coding schemes, hand off, small cells, EIRP limits, frequency and channelization, regulatory challenges, form factor, power consumption and other related topics.

Thursday, 11 December 2014 • 14:00 – 15:45

## IF-23: Small Cell Solution and Design

**Organizer:** Tomas Novosad, Nokia

**Panelists:** Tomas Novosad, Senior RF Consultant, Nokia  
Amit Mehrotra, Manager, Nokia  
Simon Chapman, CEO, Keima, Ltd.,  
Benoit Fleury, VP, Products & Innovation, iBwave, Senior Member of IEEE  
Preben Mogensen, Aalborg University & Principal Engineer, Nokia  
Pablo Tapia, CTO, Tupl, Inc.

Small cell solutions are a natural element of high capacity solutions to support future data growth. The vision of 1000 times increase in traffic by 2020 requires adequate network solutions towards increased cell density and better spectral efficiency. Traffic distribution is uneven and always-connected users require small cell solutions which have a number of planning and deployment challenges.

Small cell solutions have certain networking and practical dynamics that necessitate adequate design tools and approaches. The forum intent is to discuss and summarize the following:

- LTE network planning and design challenges.
- Small cell design approaches.
- Planning & design tool challenges for indoor and outdoor small cell networks.
- The deployment of a large number of additional nodes, many of which may be of a lower quality than the current network equipment standard, poses many challenges in the day-to-day operation of a network. In order to cope with this problem, operators will need to rely on further automation of their network processes, with more intelligent methods that can detect, correct and notify of issues that occur at micro levels.
- Small cells are deployed in dense urban environment with important aspects of vertical dimension which could lead to certain spectral efficiency improvements.

Thursday, 11 December 2014 • 14:00 – 15:45

## IF-25: Internet of Things: From Standardization to Deployment and Commercialization: Standardization

**Organizers:** Rasmus Nielsen, Cisco Systems  
Neeli Prasad, SAI Technologies

**Panelists:** Seth Newberry, OMA  
Philip Jacobs, OneM2M  
Bilel Jamoussi, ITU  
Periklis Chatzimisios, TEIT

By 2020, the Internet of Things is expected to drive the deployment of 50 billion connected devices and a value-at-stake of \$19 trillions. What started as a concept for providing universal identities in the form of RFIDs has evolved into a domain encompassing numerous technologies from low-power sensor networks to cloud applications as well as a whole new breed of business models. From being a concept attracting plenty of research, the domain has been adopted by multiple standardization bodies consolidating the many industrial best practices across numerous verticals and industrial players from Machine-to-Machine approaches of service providers to the improvement of operational excellence by both larger and smaller enterprises.

The state of the Internet of Things has reached a breaking point with a large number of pure players providing offerings across the whole range of different services from low powered devices focusing on the ease-of-use to device management platforms including connectivity management. On the application side a number of platforms are available providing different sets of capabilities including support for application development to targeted platform where enterprises can develop their own vertical-targeted applications.

Thursday, 11 December 2014 • 14:00 – 15:45

## IF-27: Hands-on-Education and Training with Software Defined Radio

**Organizers:** Michele Zorzi, Università degli Studi di Ferrara  
Erik Luther, National Instruments

**Panelists:** Robert G. Maunder, IET  
Andreas Achtzehn, Aachen University  
Houman Zarrinkoub, Mathworks

Software defined radio is emerging as a valuable tool for hands-on communications education and training that overcomes many of the limitations associated with simulation-based approaches. In this session we provide a forum for in depth presentations and discussion to aid university educators and industry trainers in preparing to use software defined radio (SDR) as an instructional tool in their respective domains. We offer opportunities for our peer reviewed authors, publishing course and training best practices in the May 2014 issue of IEEE Communications Magazine an opportunity to extend their publications with live presentation and a panel discussion. The scope of this session includes discussion of undergraduate education, graduate curriculums, and software and hardware tools for advanced prototyping.



Thursday, 11 December 2014 • 14:00 – 15:45

## IF-29: Making Spectrum Sharing a Reality

**Organizer:** Prakash Moorut, Nokia Networks

**Panelists:** Durga Malladi, Qualcomm

Uli Rehfuss, Nokia Networks

Michael Ha, FCC

Max Solondz, Verizon Wireless

Dennis Roberson, Illinois Institute of Technology

Preston Marshall, Google

Mobile wireless communication networks will need to cope with the tremendous increase in data traffic anticipated over the next decade. Beyond the levers of increased network densification and enhanced spectral efficiency more radio spectrum is clearly needed for mobile networks to fulfil capacity and coverage demands. Clearing the spectrum, i.e., moving non cellular services out of their currently allocated spectrum bands is one straightforward way to free up more exclusive spectrum for Mobile Broadband use. This has been the best practice over the years, and will continue to be the preferred option for cellular networks. In most cases, however, clearing spectrum requires significant investment and/or can be lengthy. Therefore, in some cases spectrum sharing may be a very efficient means to gain at least partial access to additional spectrum resources for mobile broadband use. Spectrum sharing has become the new reality. It is no longer a question of “if” spectrum sharing will happen but “when” it will happen.

The goal of the panel is to bring together top innovators and thinkers in the spectrum sharing field to discuss technological and policy developments in spectrum sharing in the context of LTE, focusing on the AWS-3, 3.5GHz and 2.3GHz bands as the initial test bands and sharing in the context of future 5G systems. Innovative sharing approaches involving databases such as Authorized/Licensed Shared Access (ASA/LSA) and the FCC’s 3.5GHz Spectrum Access System as well as the value of sensing will be discussed among others.

Thursday, 11 December 2014 • 16:15 – 18:00

## IF-22: 5G System Design

**Organizers:** Preben Mogensen, Nokia

Reinaldo Valenzuela, Alcatel-Lucent

**Panelists:** Gerhard P. Fettweis, TU Dresden

Chih Lin I, China Mobile Research Institute

Takehiro Nakamura, NTT Laboratories

Erik Dahlman, Ericsson

Alexei Gorokhov, Qualcomm

5G is expected ready for commercial deployment around 2020. 5G will cover our next generation mobile communication needs towards 2030, where the traffic volume is expected to grow more than a x1000, end-user data to be x10-100 higher, latency to be 5-10 times lower, and the number of connected devices to be x10-100 higher. Other requirements to 5G are significantly improved network energy efficiency and improved battery life time for low power devices – and of course much lower cost per bit.

The target of this panel is to discuss the system aspects of 5G – how do we reach the above stretching targets? The panel will cover aspects of the promising research topics for 5G, the operator requirements to 5G, the roadmap for standardizing 5G, the spectrum aspects for 5G, the network aspects for 5G and the technology aspects for 5G.

We anticipate a lively discussion.

Thursday, 11 December 2014 • 16:15 – 18:00

## IF-24: Industry Harmonization for Unified Standards on SDN, NFV, Autonomic Management & Control (AMC), 5G, Unified Management of Fixed/Mobile Networks and (IPv6 in the picture)

**Organizer:** Ranganai Chaparadza, IPv6 Forum Research Fellow & ETSI AFI Group on Autonomic Future Internet

**Panelists:** Ranganai Chaparadza, IPv6 Forum & ETSI AFI

Tayeb Ben Meriem, Orange, ETSI AFI, TMF, NGMN

John Strassner, Huawei, TMF ZOOM

Steven Wright, AT&T Services Inc ETSI NFV

Francisco-Javier Ramón Salguero, Telefonica, ETSI NFV

Takashi Egawa, NEC, ITU-T SG13

Various Standardization Groups (SDOs)/Fora which are working on standards for SDN (Software-Defined/Driven-Networks), NFV (Network-Functions-Virtualization), AMC (Autonomic Management & Control of Networks and Services), NGMN NGCOR requirements on Converged Management of Fixed/Mobile Networks, 5G related topics and operator-requirements, and IPv6 as a horizontal topic that brings complementary value to all these areas, were invited to take part in the session: “Autonomic Management & Control (AMC) of Networks and Services, SDN, and NFV, as complementary emerging paradigms—From silo approach to cross-SDO combined approach: Follow-up Workshop to IEEE GLOBECOM 2013 Industry Forum Sessions (Date: 5 June 2014, hosted by TeleManagement™Forum Meeting)”—Report available under: <http://www.tmforumlive.org/ieee/>. The Groups that were invited to the workshop include: TMF, IPv6 Forum; ETSI NTECH/AFI; ETSI NFV; BBF; NGMN; OMG SDN WG; IEEE NGSON WG; ITU-T SG13 and SG2; 3GPP SA5; Multi-SDO; ONF; OMA; OpenDaylight; IEEE SDN and NFV Sub-Committee; OIF; other-groups. This session aims to communicate the outcome of the 5 June 2014 workshop, pertaining to the SDOs/Fora harmonization efforts on standards for the emerging complementary networking paradigms. The session covers the subject of how SDOs/Fora are now performing certain types of harmonization activities that could make use of Cross-SDO Instruments for Harmonization and Coordination which may enable experts from various groups to work together on harmonization of taxonomy on architectural frameworks, protocols, models, etc, corresponding to all the key emerging paradigms.

Thursday, 11 December 2014 • 16:15 – 18:00

## **IF-26: Internet of Things: From Standardization to Deployment and Commercialization: IoT Domain**

**Organizers:** Rasmus Nielsen, Cisco Systems  
Neeli Prasad, SAI Technologies

**Panelists:** David Canavan, Axeda  
Drew Johnson, Aeris  
Peter Hartley, ElectricImp  
Harvey Grasty, Xively

By 2020, the Internet of Things is expected to drive the deployment of 50 billion connected devices and a value-at-stake of \$19 trillions. What started as a concept for providing universal identities in the form of RFIDs has evolved into a domain encompassing numerous technologies from low-power sensor networks to cloud applications as well as a whole new breed of business models. From being a concept attracting plenty of research, the domain has been adopted by multiple standardization bodies consolidating the many industrial best practices across numerous verticals and industrial players from Machine-to-Machine approaches of service providers to the improvement of operational excellence by both larger and smaller enterprises.

The state of the Internet of Things has reached a breaking point with a large number of pure players providing offerings across the whole range of different services from low powered devices focusing on the ease-of-use to device management platforms including connectivity management. On the application side a number of platforms are available providing different sets of capabilities including support for application development to targeted platform where enterprises can develop their own vertical-targeted applications.

Thursday, 11 December 2014 • 16:15 – 18:00

## **IF-28: SDR Prototyping Challenges for Dense Deployments for Next Generation Wireless Networks (LTE, WiFi)**

**Organizers:** Rohit Gupta and Amal Ekbal, NI

**Panelists:** Sundeep Rangan, NYU-Poly  
Raymond Knopp, Eurecom  
Emilio Calvanese Strinati, CEA-LETI  
Nikolaos Bartzoudis, CTTC

Around the world, wireless consumers' insatiable demand for bandwidth has spurred unprecedented levels of investment from public and private sectors to explore new ways to increase network capacity and meet escalating demand. Against this backdrop, wireless researchers continue to put forth new ideas to address capacity challenges. Proposed ideas span new Physical Layer (PHY) algorithms, new upper layer medium access control (MAC) techniques and cross layer exploration of new heterogeneous network topologies incorporating pico and femto cells, and relays. In all probability, wireless service providers may not rely on one "silver bullet" to alleviate capacity constraints, but rather employ a combination of techniques. Although there is no shortage of new concepts and theories, the time to transition from concept to simulation to prototype to deployment in a real network can take many years. In particular, transitioning from concept/simulation, which is largely a software exercise, to a working prototype with real signals and waveforms requires extensive investments in time and money, and has been an impediment to the adoption of new techniques to alleviate the wireless bandwidth crunch. In this panel, we will address following PHY/MAC prototyping challenges, especially for 4G/5G cellular and wireless local area network (WLAN) radio technologies that we envision are the key drivers for the success of a scalable SDR prototyping platform.

Thursday, 11 December 2014 • 16:15 – 18:00

## **IF-30: Carrier Network Management: Applying Legacy Principles to New & Emerging Technology**

**Organizers:** Warren Volk and Chi-Ming Chen, AT&T

The telecommunications service industry has been known for providing reliable services. In addition to the design of highly reliable network elements, e.g., switches with 3 minutes downtime per year and network architectures with stringent end-to-end reliability objectives, the advanced network management capabilities play a major role in handling network anomalies and thus contributing to the achieved reliability.

This forum will highlight the Principles of Network Management which have been utilized by the TDM Switching Network Management community for over 25 years, and show examples where these same principles can apply with emerging technology. Network Management follows such guiding principles as: Keep all trunks filled with good messages, give preference to single link connections, and preserving the health of the network through traffic controls.

This discussion will show that although new technology offers greater capabilities to support increased traffic loads, dynamic routing & traffic path selection, the Principles of Network Management should still be the driving factor in building Network Management capabilities for protecting the Network and ensuring the best possible traffic completions.

In the end, we'll review the Network data measurement and uniform standards for providing this data in vendor generic Operations Support Systems (OSS), and how this enables much greater network performance visibility; and the opportunity for skilled Network Managers to implement dynamic routing and traffic controls to protect the network.

Tuesday, 9 December 2014 • 15:45 – 18:00

## IP-1: Mixed-mode Access for Robust Broadcast Multimedia Content Delivery

**Authors:** Kevin Shelby, Coherent Logix  
Mike Simon, Sinclair Broadcast Group

This paper proposes an evolution in Next Generation Broadcast Access aimed at enabling fixed rooftop and outdoor/mobile reception from a common wireless transport, providing indoor service capability to portable devices via content forwarding on a secondary wireless network (i.e. constituting a cooperative HetNet). The proposed method of Mixed-Mode Access introduces a Software Defined Remote Radio Head (SD-RRH), mounted on the rooftop, streaming IP to a centralized Content Distribution Point (CDP) both of which are maintained under configuration control from a network-side broadcast entity.

The SD-RRH provides the point of entry for over-the-air service distribution. The CDP in turn serves as Home Gateway aggregating transport from a variety of delivery mechanisms: over-the-air reception relayed from the SD-RRH, IP streaming via the consumer's Internet Service Provider (ISP), non-real-time file transfer to a local storage device. The CDP then relays content to consuming devices via: HDMI or Wi-Fi or Wired Ethernet to static television receivers, and Wi-Fi to mobile/portable devices completing the last leg in a mixed-mode transport arrangement. The CDP additionally provides the facility to augment the over-the-air stream with ISP derived content for improved error concealment or guaranteed NRT file transfer for off-air playback. Broadcast content emanates from a common point in the home regardless of its network origin.

The paper presents the Next Generation Broadcast Access mechanism including the SD-RRH and CDP architectures as components of a mixed-media transport arrangement.

Tuesday, 9 December 2014 • 15:45 – 18:00

## IP-2: Survey of Physical Layer Measurement of Wireless Standards

**Authors:** Steve Tenney and Yupeng Jia, National Instruments

Across all wireless standards, manufacturers and service providers need to insure the performance and compliance of their devices via manufacturing test. These tests are designed to demonstrate the wireless device's ability to adhere to the requirements of a particular standard by exercising different functionality such as transmitter and receiver performance. With the continuing evolution of wireless standards across the globe, the need to evaluate key performance parameters such as power, frequency and modulation quality is greater than ever. The different wireless standardization bodies each present the unique specifications for the Physical Layer (PHY) in their standard documents. The implementation and specification limits may differ from standard to standard, but the concepts for, and requirements of, PHY analysis are largely transferable between them. This paper explores the core tests required in a number of current wireless standards and the common principles behind each family of tests.

Tuesday, 9 December 2014 • 15:45 – 18:00

## IP-3: The CROWD Framework for tackling Challenges of Dense Small Cell Deployments using Software Defined Networking (SDN)

**Authors:** Arianna Morelli, INTECS  
Rohit Gupta, National Instruments  
Martin Draxler, Holger Karl, University of Paderborn  
Vincenzo Mancuso, IMDEA Networks  
Antonio De La Oliva, Universidad Carlos III de Madrid  
Erick Bizouarn, Alcatel Lucent Bell Labs  
Engin Zeydan, AVEA

The ICT CROWD (Connectivity management for eneRgy Optimised Wireless Dense networks) project is funded by the European Commission. Growing demand can only be satisfied by increasing access point density and combining different wireless technologies, for example (LTE, WiFi). Simply scaling existing networks by orders of magnitude, as required to fulfill traffic forecasts, would bring along several problems because of the limited backhaul capacity, the increased energy consumption, and the explosion of signaling. The FP7 project CROWD proposes a novel architecture based on Software-Defined Networking (SDN), as a solution to tame the density of wireless networks. CROWD pursues four key goals: (i) bringing density-proportional capacity where it is needed, (ii) optimising MAC mechanisms operating in very dense deployments by explicitly accounting for density as a resource rather than as an impediment, (iii) enabling traffic-proportional energy consumption, and (iv) guaranteeing mobile user's quality of experience by designing smarter connectivity management solutions.

Tuesday, 9 December 2014 • 15:45 – 18:00

## IP-4: MobiSDN: Vision for Mobile Software Defined Networking for Future Cellular Networks

**Authors:** Ying Li, David Choe, Thomas Novlan, Jianzhong Zhang, Glenn Morrow, Samsung

With the explosive growth of smart mobile devices, innovations for wireless networks are in great and urgent need. Software defined networking (SDN) has great potential for the future networks. SDN has been gaining momentum recently in the context of future wired networks, however, the concept and technologies of SDN for mobile or wireless networks are still in the very early stages. This paper provides vision for SDN for future mobile networks, referred to as mobile SDN (MobiSDN). The discussions include MobiSDN's definition, its architecture, its use cases including cloud based content distribution and augmented reality with big data analytics, and its potential enabling technologies.

Tuesday, 9 December 2014 • 15:45 – 18:00

## IP-5: Measurement of Radar Pulse Parameters with Under Sampled Signal

**Authors:** Sampath Desai, Abraham George, Varun Mannam, Jithin Madathil, National Instruments

Modern pulsed radar design requires generation of complicated modulated pulses that present significant measurement challenges. The pulses are phase or frequency modulated with narrow pulse width thus exhibiting high band width. Hence the bandwidth of measuring device and data conversion rate play a vital role in meeting the desired measurement precision. The pulse parameters of interest to be measured are Rise Time (RT), Fall Time (FT), Pulse Width (PW), Pulse Repetition Frequency (PRF), Modulation type and power. The measurement of RT, FT significantly depends on number of samples on the pulse. The rise time can go very low. This implies that one needs to have higher sampling rate

with wider front end analog filters to obtain accurate measurements. This requirement greatly increases the complexity of the test equipment hardware. We present a novel algorithm of estimating transient parameters of a train of pulses, sampled with an inadequate ADC.

Tuesday, 9 December 2014 • 15:45 – 18:00

## **IP-6: NI-AWR Integrated Framework for Radar Design**

**Author: Gent Paparisto**, AWR Corp., Inc.

Modern radar systems are very complex and depend heavily on advanced signal processing algorithms to improve the detection performance of the radar. At the same time, the radio frontend must meet the specifications that are often the combination of available devices, implementation technologies, regulatory constraints, requirements from the system and signal processing.

To overcome these challenges, there is increasing need for cooperation between digital and RF/microwave engineer such that the overall system performance metrics are jointly optimized across the two disparate domains.

In this presentation, we show how the AWR Design Environment can be combined with National Instruments LabVIEW and PXI instruments to design, validate, and prototype a radar system. NI-AWR integrated framework provides a unique avenue for both, digital and RF engineers, as well as system engineers, to collaborate on a complex radar system.

Tuesday, 9 December 2014 • 15:45 – 18:00

## **IP-7: Integrated RF and Digital Design-to-Prototype Flow with LabVIEW and AWR Design Environment**

**Author: Takao Inoue**, National Instruments

Despite the significant advance in wireless communication system development over the last several decades, there remains to be a huge dividing wall between the RF/microwave circuit designers and baseband algorithm designers. Each area requires significant depth of knowledge to master, and as a result, has evolved to a rather disparate design flow, tool chain, and the way of thinking.

We take a brief overview of what National Instruments is doing to bring together different domain experts and to crossover insights from both domains to more effectively design, simulate, and prototype a wireless communication system. Specifically, we show how a fixed point algorithm developed in LabVIEW can be co-simulated with a realistic RF frontend in AWR Design Environment to get an early insight on the system behavior. Then we show a path to create a real-time baseband transceiver that will connect to the physical implementation of the designed RF frontend.

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## **IP-8: Distributing and Expanding Processor Resources through National Instrument PXImc**

**Authors: Govind Viswambaran and Norm Kirchner**, National Instruments

Certain applications & measurements (ex. Cellular LTE Testing) can require very complex data processing and cause an imbalance in the distribution of work handled by the processor in a PXI based test system. PXImc (multi-computing) enables users to add a second processor in a PXI based test solution to help distribute the workload and reestablish balance. Being able to distribute memory usage and processing horsepower, PXI test system developers can reduce overall test time and recover critical system resources.

Wednesday, 10 December 2014 • 15:45 – 18:00

## **IP-9: Prototyping High-Throughput mmWave Small Cells for 5G**

**Authors: Vincent Kotsch and Eckhard Ohlmer**, National Instruments

Major challenges have to be addressed until first mmWave small cell solutions are ready to enter the market. Therefore mmWave systems need either better hardware or more sophisticated digital impairment-compensation techniques.

We show how National Instruments addresses these challenges with their hardware-software prototyping platform, which is designed for scalability in channel count, bandwidth and signal processing capabilities. This platform is intended to provide researchers with a tool to test their mmWave concepts and prove their viability under practical constraints. The NI platform is part of the European MiWaves project, where it is used to prototype a multi-Gbit/s mmWave backhaul and multi-user access link. We will specifically focus on the highly parallel baseband implementation that is key to overcome the challenge of designing Gbit/s transmission systems.

Wednesday, 10 December 2014 • 15:45 – 18:00

## **IP-10: Required Frequency Rejection in 39 GHz Millimeter-Wave Small Cell Systems: Intel's Preliminary Results**

**Authors: Joongheon Kim, Liang Xian, Alexander Maltsev, Reza Arefi, Ali Sadri**, Intel

This paper presents interference simulation study results in 39 GHz millimeter-wave small cell networks performed by Intel in terms of required frequency rejection calculation. In this simulation study, we calculated the amount of interferences gathered in a fixed service receive antenna. Two types of interferences are considered in this simulation study, i.e., (i) the accumulated interference to a fixed service receive antenna occurred by every single wireless transmission from a small cell base station to its associated small cell user (i.e., downlink interference); and (ii) the accumulated interference to a fixed service receive antenna occurred by every single wireless transmission from a small cell user to its associated small cell base station (i.e., uplink interference). Last, the future interference analysis scenarios are presented.

Wednesday, 10 December 2014 • 15:45 – 18:00

## **IP-11: Beamformed MAC: Medium Access Control with Beamforming in 5G Cellular Communications**

**Author: Ying Li**, Samsung

Beamforming is one of the key technologies that 5G system would be using. Due to beamforming, the designs for medium access control (MAC) will have fundamental changes in many aspects comparing to the legacy system. This work discusses fundamentals of MAC with beamforming, which is called as beamformed MAC in here.

Four major aspects of beamformed MAC are discussed, namely beamformed network access, beamformed control and data communication, beamformed mobility control, and beamformed energy conservation in idle mode support. These aspects cover the main activities in a mobile station's 'life'. The discussion reveals the fundamental problems and aspects to consider for system design and operations for beamformed MAC, which are critical to 5G system design. The discussion also reveals the fundamental research problems from resource allocation perspective based on the insights that we obtained from system design, which serve as good directions to involve academic efforts for 5G system design.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-12: PCRF Implementation as an Enabler for Smart Data Offers

Author: **Paweł Ziętek**, Orange Polska

A key challenge is – from one side – how to control the increasing traffic in the network and optimize network costs – and from another side – how to monetize the traffic through offering advanced business data offers, improve customer loyalty and reduce churn. Additionally, customer demand for personalized services across all access devices, requires that service providers expand their role in the communications ecosystem to differentiate from the competition and ensure long-term profitability.

The goal of the presented project is to answer these challenges through implementation of Policy and Charging Rules Function (PCRF) in Orange Polska network. The architecture required integration with multiple components including core network elements, billing systems, subscriber repository and provisioning. The implementation is based on available 3GPP/IEEE specifications with standard Diameter Gx, Sp/Sh, Sy and Rx interfaces.

The offer based on the implemented platform was also awarded by “Mobile Internet” magazine as a “Service of the year”.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-13: Virtual Optical Networks for Programmable Wide-area ICT Infrastructures

Authors: **Xi Wang, Qiong Zhang, Paparao Palacharla, Motoyoshi Sekiya**, Fujitsu Labs of America

As applications move to the cloud, geographically distributed data centers (DCs) are being deployed and interconnected using optical networks, forming wide-area Information and Communications Technology (ICT) infrastructures. Cloud applications rely on such infrastructures for improved user’s quality of experience (QoE), driving the need for the optical networks to provide greater capacity, flexibility, and dynamic bandwidth reconfiguration on shorter time scale under cloud orchestration systems using SDN. With the expected deployment of colorless/directionless/gridless ROADMs and multiple modulation format programmable transponders, the flexibility and agility of the optical networks can be easily managed using SDN. To enable multi-tenancy in these inter-DC networks, the concept of optical network virtualization enables service providers to provision multiple co-existing and isolated virtual optical networks (VONs) over the same physical infrastructure.

We present our recent results on node architecture and efficient resource utilization in physical infrastructure of flexible optical networks as well as efficient VON mapping method.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-14: The Targeted Job Search – How to get the Hiring Manager to Call You!

Author: **Marc Miller**, Career Pivot

We live in what is now called a referral economy. With over 80% of jobs being filled through referrals it is important that you have a network there to support you. We will be talking about building a target list of companies and then how to strategically network into the management chain so that they call you when a position opens up!

This is a multi-step process:

1. Build a target list of companies that can hire you.

2. Vet that list to determine whether you really want to work for these companies.
3. Build relationships strategically in your target companies.
4. Build a strategic referral network.
5. Strategically pursue positions via your referral network.
6. Once hired, you plan your next move in 18-24 months
7. Go to #1

The days of working for one company for your entire career are over. Strategically plan your move in a systematic fashion that an engineer can embrace.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-15: Effective Performance Improvement in the Presence of Multiple IQ Impairments along with High Carrier Frequency Offset

Author: **Vellachi Murugappan**, National Instruments

When we have a multi-dimensional estimation problem with several impairments superimposed on the signal, we face the challenge of a chicken and egg situation, where one impairment, cannot be estimated because the other impairment is too high, to allow a successful estimation. In this scenario, the systems estimation capability severely hampers the modulation accuracy measurements.

The challenge is addressed by looking into the impairments sources present and the sequence in which these would have been introduced in the Transmitter chain and the Channel. By doing so impairments are handled in a suitable order and using an iterative approach. It also suggests how high frequency offset correction needs to be handled in various stages of the algorithm to allow successful estimation of IQ impairments. The IQ impairments considered are IQ gain imbalance, IQ skew and IQ Origin offset. The typical pseudo inversion technique used to estimate these is also touched upon.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-16: Fine Resolution Frequency Estimation of Windowed Sinusoid Using Three DFT Points

Authors: **Mrinmoy Jana and Prabhat Pal**, National Instruments

We propose a fine resolution frequency estimator for a single frequency complex exponential signal weighted by a generalized cosine window the special cases of which include the Hann window, the Hamming window and the rectangular window. The proposed method estimates the frequency of the input windowed signal by taking N-point DFT of N time domain windowed samples of the signal and then non-linearly interpolating three DFT points comprising of the Peak Magnitude DFT point and its two immediate neighbors. For Hann and Hamming windowed sinusoid the proposed method provides better performance than Lyons’ method and the Root Mean Square Error (RMSE) of the new estimator closely follows the Cramer Rao Lower Bound (CLRB). For Rectangular Window the proposed method yields 2.5-3 dB better RMSE performance than Candan’s estimator for higher frequency offsets. We also derive the RMSE of the proposed estimator w.r.t. input Signal-to-Noise Ratio (SNR) for low frequency offsets.

Wednesday, 10 December 2014 • 15:45 – 18:00

## IP-17: S-Parameter Measurements in High-Volume Production Environments with a Single-Receiver Vector Signal Transceiver

Authors: **Alejandro Buritica and Andy Hinde**, National Instruments

Modern RF test stations for wireless semiconductor devices must support wide-bandwidth complex-modulated waveforms, minimal

operator intervention, faster test times, and lower cost. This paper offers a unique solution by multipurposing a single-receiver Vector Signal Transceiver (VST, a combined vector signal generator and analyzer), an instrument that is already present in modern RF test stations, along with an RF port module, to enable error-corrected S-parameter measurements of the Device Under Test (DUT). This paper will also examine the RF switching and test set architecture of the RF port module subsystem, and it includes the analysis of S-parameter measurements performed with serial sampling of incident and reflected waveforms by the single-receiver Vector Signal Analyzer (VSA) present in the VST. It will address the performance differences that the instrumentation achieves when using shared TX & RX Local Oscillators (LOs), versus independently synthesized LOs.

Thursday, 11 December 2014 • 15:45 – 18:00

## IP-18: NI-AWR Integrated Framework for WLAN 802.11ac

Author: **Gent Paparisto**, AWR Corp., Inc.

The latest WLAN standard, 802.11ac, achieves higher throughput over its predecessors by using higher order modulation schemes, wider channel bandwidth, and more spatial streams. It presents unique challenges during design and implementation. Finding the right test equipment becomes a bigger challenge than before due to the increased test accuracy and bandwidth requirements.

We show how the AWR Design Environment can be combined with National Instruments LabVIEW and test instruments to design, prototype and validate components or systems that comply with the WLAN 802.11ac standard. A unique feature of this solution is that it reuses the same IP for the 802.11ac generation and analysis in software simulations as well as in test instrumentation providing for both, digital and RF engineers, as well as system engineers, to collaborate from initial the design and implementation all the way to final production testing, resulting in a shorter design cycle and reducing time to market.

Thursday, 11 December 2014 • 15:45 – 18:00

## IP-19: Wireless Signaling Concepts for 802.11ac Devices with PXI Test Instruments

Author: **Dharmendra Lingaiah**, National Instruments

Wireless Signaling has become a critical part of RF Wireless LAN Devices testing in the recent days. While most of the Wireless Signaling in these boxed Instruments are proprietary, we felt the need for an open architecture based implementation of Wireless Signaling with PXI Test Instruments.

Our work has already been tested successfully on various Production Floors worldwide in testing Wireless LAN Access Points. The goal of our work was to connect to a Wireless LAN Access Point, put the Wireless Chipset into the appropriate test mode and perform Wireless LAN RF PHY Measurements. For Over the Air(OTA) Testing of WLAN AP, we have to emulate a WLAN STATION (read RFSG / RFSG+ RFSA Combined for real time signaling). Process involved is to replicate Signaling State Machine when STA tries to talk to AP as listed below:

1. Synchronization, 2. Association, 3. Authentication

Thursday, 11 December 2014 • 15:45 – 18:00

## IP-20: Estimation of Spectrum Demand in an LTE-Advanced Environment

Authors: **Fadel Digham**, National Telecom Regulatory Authority  
**Khaled Elsayed, Ahmed Khattab, Khaled Qorany**, Cairo University

It is of a paramount interest to different stakeholders in the telecommunications industry to plan appropriately how much spectrum is needed to be offered or acquired. For governmental authorities, the amount of spectrum to be granted should fulfill the national and social targets announced in their strategies, especially for broadband access. Likewise, wireless operators should be able to estimate the required bandwidth so that users' preferences are met along with the corresponding target QoS.

In an effort to respond to such an issue, we present a methodological approach for accurately estimating the spectrum demand on a certain time of day in a specific region in an LTE-A environment. The proposed approach is based on:

1. Traffic Model, 2. Traffic Mixes, 3. LTE-A Overheads

Thursday, 11 December 2014 • 15:45 – 18:00

## IP-21: A Novel Time Misalignment Estimation Algorithm for Envelope Tracking (ET) Power Amplifiers (PA)

Authors: **Craig E. Rupp, Zakir Ahmed, Sean P. Ferguson, Michael J. Lyons, Gerardo Orozco**, National Instruments

We present a novel algorithm for estimating the delay (dT) between the RF input of an RF power amplifier (PA) and the modulated supply voltage that is generated by an envelope tracking (ET) power modulator, also known as a power tracker. This algorithm estimates the delay by introducing artificial delays in the acquired baseband output of the RF amplifier and searching for the delay that result in the lowest error vector magnitude (EVM). A sufficient amount of band limited AWGN is added to the baseband at the input of the RF PA and power supply waveforms. The noise serves to decorrelate the output of the RF PA, improving delay estimation accuracy. The Algorithm has the ability to estimate delays in the range of 60nsec and upwards within a error of +/-4nsecs for wideband signals like WCDMA and LTE. Test results using a Vector signal generator and analyzer are presented.

Thursday, 11 December 2014 • 15:45 – 18:00

## IP-22: Emerging Characterization and Simulation Techniques Accelerate the Design of Handset Power Amplifiers for Modern Communication Signals

Authors: **Guillaume Paillancy, Haydn Nelson, Takao Inoue, Marc Vanden Bossche**, National Instruments

With the emergence of wideband communication signals, the design and characterization of today's handset power amplifiers (PA) are becoming more complex. We introduce a reference architecture that characterizes simultaneously the DC, low-frequency (LF) and RF behavior of the PA module under ET, DPD and/or load pull conditions. The system combines vector signal generators (VSG), vector signal analyzers (VSA) to generate and measure RF modulated signals, DC power supplies or source measure units (SMU) to bias the PA, as well as an arbitrary waveform generator (AWG) to dynamically shape the DC bias (power modulator). Based on PXI technology, this reference architecture takes benefit from the shared 10MHz reference clock to tightly synchronize the different PXI modules with less than 1ns of channel-to-channel skew. Using network analysis calibration techniques, accurate characterization under wideband modulation conditions can then be performed down to the different DC, LF and RF test ports of the PA.

Thursday, 11 December 2014 • 15:45 – 18:00

## **IP-23: A Novel Fast Method for evaluating the AM/AM and AM/PM Characteristics of a Power Amplifier using the Stored Reference Waveform**

**Authors:** Gerardo Orozco Valdes, Craig E. Rupp, Michael J. Lyons, Sean P. Ferguson, Zakir Ahmed, National Instruments

We present a method for performing AM/AM and AM/PM measurements on power amplifiers by using stored reference waveforms and triggers. Although several similar techniques have been used in literature previously like in [1], [2] and [3]; the advantage with this method is that we do not require sharing of the Local Oscillator (LO) between the VSG and VSA. This measurement has the ability to correct frequency offsets in the range of +/-2MHz. Additionally in this method we use trigger lines/pins that are typically available in most commercial VSGs and VSAs to help faster time synchronization and improve measurement speed.

Thursday, 11 December 2014 • 15:45 – 18:00

## **IP-24: Advances in Motion Video Compression**

**Author:** Raymond Westwater, Futureware

Conventional motion video algorithms are limited by their reliance upon a two-dimensional human visual model. Motion is encoded as a vector between a two-dimensional region of reference content and a target region to be reconstructed. The difficulty (and limit to compression efficiency) arises due to the lack of a good visual model to determine the visibility of the residue or error term.

What is presented is a compression algorithm based on a three-dimensional (time-varying) model of human vision, the Visibel(TM) model. This approach eliminates all redundant visual content within and between frames by removing all data which is imperceptible under the anticipated viewing conditions. Not only are aggressive compression ratios attained, but the resulting stream is continuously adaptive to dynamic transmission channel conditions.

A practical short-term application of the Visibel(TM) human visual model is presented - a pre-filter for existing motion estimation-based compression algorithms. This filter has been shown to produce dramatic compression savings on all popular and upcoming algorithms without requiring any changes to the playback devices. This technology is in the process of being adopted by industry leaders.

Tuesday, 9 December 2014 • 14:00 – 14:20

## **ID-1: A Demonstration of the NorNet Core Research Testbed for Multi-Homed Systems**

**Authors:** Thomas Dreiholz, Simula Research Laboratory

Henrik Vest Simonsen, University of Oslo

Ernst Gunnar Gran, Simula Research Laboratory

Due to the availability of reasonably inexpensive Internet connections, cloud computing is becoming increasingly more popular and widespread. Instead of maintaining servers locally, services are provided by remote virtual servers at data centers. In the recent years, a lot of research work has been done in the area of server redundancy and service migration. However, for many cloud computing users today, the access to the Internet constitutes a single point of failure. That is, if such an Internet connection is broken, all cloud services become unavailable. Further research on network resilience is necessary. The Simula Research Laboratory has therefore established the NORNET project, in order to create an open, multi-site research testbed platform for network resilience and multi-path transport experiments in real Internet setups. Particularly, all NORNET sites are multi-homed, i.e. connected to at least two Internet Service Providers (ISP). NORNET CORE denotes the wired part of the NORNET testbed. The testbed consists of research nodes distributed all over the country of Norway as well as further nodes in Sweden, Germany and China.

In order to illustratively demonstrate the functionalities of NORNET CORE in a multi-site, multi-homed Internet setup, a demonstration platform has been designed and implemented as part of a Masters thesis. The demonstration setup is particularly intended to also show the basic functionalities of NORNET CORE to an audience without a broader knowledge of resilience and multi-path transport. It particularly allows to demonstrate the implications of ISP combinations on QoS performance (bandwidth, delay, etc.), with support for IPv4 and IPv6 as well as state-of-the-art transport protocols like the Stream Control Transmission Protocol (SCTP) as well as Multi-Path TCP (MPTCP).

Tuesday, 9 December 2014 • 14:20 – 14:40

## **ID-2: Flowsim: A OpenFlow Data Plane Simulator**

**Authors:** Colton Chojnacki, C. Jasson Casey, Alex Sprintson, Flowgrammable

In this demo, we present Flowsim, a new OpenFlow switch simulator that requires no setup, and allows developers to experiment with various data plane capabilities provided by each version of OpenFlow (1.0, 1.1, 1.2, 1.3, 1.4).

Flowsim is a web application that enables the users to configure their own OpenFlow switches, issue OpenFlow messages, inject custom packet sequences into the data plane, and observe the resulting behavior. During a simulation the life cycle of an injected packet is visualized as it traverses the OpenFlow data plane. The user is presented with visualizations that included packet arrival, key extraction, table selection, flow selection, and action application.

Switch profiles are configured by specifying the actions, matches, and instructions capabilities that are supported by their switch. Users have the ability to configure a custom OpenFlow switch profile or choose a profile based on a vendor switch such as a Pica8. Once a switch is configured users issue OpenFlow messages such as Flowmod to populate the Flowtables of the switch. Users have the ability to craft packets and inject them into the data plane during the simulation. As a user crafted packet traverses the data plane, visualizations of the packets progress through data plane are presented to the user. The simulation results in a detailed summary of table selection flow selection, and action application.

Wednesday, 10 December 2014 • 14:00 – 14:20

## **ID-11: Highly Flexible and Scalable 5G Platform for Gbps Validation**

**Authors:** Wen Chiang Chen and Ying-Chuan Hsiao, Taiwan Industrial Technology Research Institute

As the 5G standard formulation evolves, it is crucial to have a flexible and scalable validation platform capable of handling any specification variation. This poster paper/demonstration presents an integrated 5G radio access experiment platform with extraordinary flexibility and scalability for newly defined features, and able to deliver higher data rates without changing hardware architecture. To be specific, this platform is developed to achieve a data rate higher than 1Gbps data rate by using 24 antennas and analog carrier aggregation technology. With this highly flexible and scalable platform, it not only significantly reduces the installation and hardware cost, but also ensures fast deployment of new technologies in practical platform. Such virtue greatly accelerates the production cycle, and permits reliable initial lab, field trials, proof of concepts, and system verification from the very early stage.

Wednesday, 10 December 2014 • 14:20 – 14:40

## **ID-12: LabVIEW based Platform for Prototyping Dense LTE Networks**

**Authors:** Rohit Gupta, Amal Ekbal, Achim Nahler, National Instruments

Vincenzo Mancuso, IMDEA

Antonio De La Oliva, University of Carlos III Madrid

Arianna Morelli, INTECS

Russell Ford, Sundeep Rangan, NYU Poly

Next generation wireless networks (5G) have to cope with significant traffic increase due to heterogeneity of different applications such as high quality video and cloud based applications. A dense heterogeneous deployment of small cells such as pico/femto cells in addition to high power macro cells is foreseen as one of the potential solutions to achieve these requirements. Such a deployment requires innovation at all layers of communication protocol stack (PHY, MAC and higher layers). SDR prototyping for showing such algorithms requires a need to overcome several challenges which arise due to the use of different design flows to address different components of the system (i.e. RF, baseband, and protocol stack). The NI LabVIEW graphical system design software is able to address these challenges by providing a common development environment for all the heterogeneous



elements in the NI SDR system (i.e., the GPP, RTOS, FPGA, converters and RF components), with tight hardware/software integration and a good abstraction layer. This integrated design environment is the primary reason we chose NI LabVIEW SDR platform for prototyping and it enabled us to quickly reach an initial working version of our demonstration system and rapidly iterate on that design. In this demo, we show a LabVIEW based PXI platform in which LTE-like SISO OFDM PHY Layer is integrated with an open source NS-3 protocol stack to prototype PHY/MAC cross layer algorithms within EU FP7 CROWD project (<http://www.ict-crowd.eu>), which proposes Software Defined Networking (SDN) framework as a solution to tame dense deployment of wireless networks.

Wednesday, 10 December 2014 • 14:40 – 15:00

## **ID-13: Rapid Prototyping for 5G Transmission System Emulation**

**Author: Mustafa Gurcan**, MKGSYS Ltd

This prototype demonstration, developed by MKGSYS Ltd, will present an end-to-end transmission and channel emulation rapid prototyping platform using a National Instruments USRP RIO 2953R transceiver and LabVIEW software for IEEE 802.11 p wireless communication over vehicle-to-vehicle communication channels.

This rapid prototyping platform could be configured to operate as a 2x2 MIMO with FPGA based real-time channel emulation and real RF transmission paths. The RF front end baseband processing operates at 120MS/s rate. The channel emulator operates at 100MS/s and the transceivers operate at the sampling rate determined by the transmission symbol rate. At different stages of the prototype implementation the sampling rates are either up or down converted using interpolation (up sampling) and decimation (down sampling) methods.

The National Instruments (NI) USRP RIO 2953R uses a Xilinx Virtex-7 FPGA. NI LabVIEW has been used to implement several Xilinx FIR filters using FPGA single cycle loops for filtering, interpolation and decimation purposes. Single Cycle Loops have been synchronised to provide an end-to-end streaming operation. The parameters for the IEEE 802.11p are used for USRP RIO 2953R transceiver implementation at FPGA level. The USRP RIO 2953 hardware and FPGA programming are used to provide a baseband vehicle-to-vehicle channel emulator in accordance with the vehicle-to-vehicle channel Power Delay Profiles.

The demonstration system uses LabVIEW FPGA programs for channel estimation and vehicle-to-vehicle communication transceiver implementation for a 5G mobile radio prototype system based on the IEEE 802.11 p wireless communication standard.

Wednesday, 10 December 2014 • 15:00 – 15:20

## **ID-14: Rapid Real-World System Prototyping for 5G Mobile**

**Authors: John Ye** and **Anna Acevedo**, BEEcube Inc

Programmable hardware devices, such as FPGAs, are used frequently as prototyping tools for the implementation of new products, algorithms, and other proofs of concept. However, in order to integrate these prototypes into the real-world environments where they will be used, careful consideration must be given to the features of the platform in order to achieve the necessary interoperability requirements. In addition, the value of a prototype increases dramatically when system level designers can use it directly and rapidly iterate through different architectures and implementations without the need for independent design expertise and time-intensive specification and validation hand-offs. This demo highlights a complete hardware platform and software solution for rapid system prototyping of a wide range of target applications, including 5G femtocells, 5G user equipment, and media or Internet of Things gateways.

Wednesday, 10 December 2014 • 15:20 – 15:40

## **ID-15: Rapid Prototyping of 5G Concepts with NIs Wireless Research Platform**

**Authors: Markus Unger**, **Rene Nuessgen**, **Thorsten Draeger**, **Eckhard Ohlmer**, National Instruments

NI hardware-software platforms' enable researchers to innovate faster by providing a path from theoretical research to rapid prototyping. The modular hardware concept, including standard PCs, real time controllers and FPGA modules with fast interconnects, allows to scale prototypes in terms of processing power, channel count and I/O bandwidth. This hardware is made available to the researcher in an abstracted, unified fashion using a single programming environment – LabVIEW.

To further enable researchers, National Instruments has been developing a real time PHY/MAC layer IP research platform, based on the 3GPP LTE standard. Conceptually, this research platform is designed such that all the essential components, for example, coding, synchronization, modulation, control channels, etc. are made available to the researcher. Modularity allows to replace these components by the proprietary component the researcher focuses on, for instance, modulator and demodulator for 5G waveform research. This concept is expected to reduce the ramp-up time of 5G prototyping projects by orders of magnitude.

As part of this demonstration, we will show an application running on the out-of-the-box base line research platform. In a second part, we will show an example of how researchers are able to integrate their individual 5G concepts into the research platform.

Wednesday, 10 December 2014 • 16:20 – 16:40

## **ID-16: Flexible Test Bed for Massive MIMO**

**Authors:** Ove Edfors, Lund University  
Karl Nieman, National Instruments  
Fredrik Tufvesson, Lund University

Lund University and National Instruments will demonstrate a flexible test bed for massive MIMO, based on the NI PXI and USRP software defined radio platforms, combined with LabVIEW graphical system design software. Massive MIMO relies on coherent transmission and reception on large numbers of antenna elements, allowing efficient use of the propagation environment for spatial multiplex of many communication links. Massive MIMO is also considered one of the most promising technologies for substantial increase of spectral efficiency in future wireless systems. Theoretical studies show that, in favorable propagation conditions, both spectral and radiated energy efficiencies can be improved by one or more orders of magnitude. Initial measurements also show that real propagation environments can be favorable, in the sense that a large fraction of the theoretical gains can be harvested. The time has come to extend investigations from simulations and theory to real-life environments, with test beds capable of real-time massive MIMO transmissions in real communication scenarios. This is what is being demonstrated by Lund University and National Instruments. The demonstrated test bed is a subset of the 100-antenna test bed system built at Lund University using National Instruments hardware and software. We will show the overall architecture of the test bed and how it is configured for different tests. Real-time communication between the massive MIMO base station and single-antenna terminals will be demonstrated, in what we believe to be the first public demonstration of its kind.

Wednesday, 10 December 2014 • 16:40 – 17:00

## **ID-17: Sparse Code Multiple Access (SCMA)**

**Authors:** Lei Lu, Yan Chen, Wenting Guo, Huilian Yang, Shunqing Zhang, Jianglei Ma, Peiyong Zhu, Huawei Technologies, Co., Ltd.

Sparse code multiple access (SCMA), proposed as a key enabling new waveform and multiple access technology for 5G physical layer, has shown its capability of greatly increasing the number of simultaneously served connections (keeping the same spectrum efficiency required by each connection), the so-called system overloading gain, and better link quality compared with existing non-orthogonal multiple access schemes, the so called shaping gain and spreading diversity gain. On top of the direct gains, second order benefits such as low latency and low overhead multiple access have also been envisioned.

In order to verify the SCMA technology and its advantages in real communication systems, we have developed a SCMA based uplink multi-user system prototype on real-time hardware platform. The prototype system is built with the soft baseband concept, namely that all the baseband processing is done by CPU instead of FPGA/DSP. At the base station side, one server (Huawei Tecal RH2288) is responsible for all the baseband processing, to which standard commercial radio frequency components (Huawei product RRU3232) are connected. At the user side, the CPU of 1 laptop (MacBook Pro ME294CH/A) is used to model the processing of 2 users' baseband, which then connects to 2 mobile RF modules developed by us. A user interface (UI) is developed to show the real-time throughput of each UE, supporting also the real time change of user status and system operation modes.

Wednesday, 10 December 2014 • 17:00 – 17:20

## **ID-18: Fragmented Spectrum and Asynchronous Multi-user for 5G Systems: Filter Bank Multi-carrier Physical Layer**

**Authors:** Jean-Baptiste Doré, Vincent Berg, Dimitri Ktenas, France CEA-Leti

The demonstration will highlight the advantages of Frequency Division Multiple Access for Filter Bank Multicarrier (FBMC) compared to OFDM in the context of fragmented spectrum and asynchronous multiuser access for the uplink of beyond 4G systems. This work is part of the European 5GNOW project ([www.5gnow.eu](http://www.5gnow.eu)), which is questioning the design targets of LTE and LTE-Advanced and the obedience to strict synchronism and orthogonality.

We plan to present a reconfigurable FPGA/ARM digital baseband hardware platform implementing fragmented spectrum processing both at transmit and receive parts using FBMC modulation and aiming at demonstrating the FBMC built-in filtering feature adapted to spectrum availability in the fragmented case. The proposed multi-user receiver architecture based on frequency domain processing combined with the fair frequency localization of the FBMC prototype filter provides an architecture that allows for more efficient multiuser asynchronous reception compared to OFDM. The objective of the demonstration is thus to prove the feasibility of FBMC multiuser access (FBMC-MA) in a multiuser asynchronous environment.

The setup will be composed of two user equipments (transmitters) and one receiver (acting as a base station). Real time transmission will be done through RF front ends at 2.7GHz via the National Instrument NI PXIe-1062 equipment. The application running on top of the physical layer is uplink video conference service and we demonstrate the robustness of FBMC compared to OFDM in the case of timing misalignment between the two user equipments (multi-user asynchronous access). The multiuser receiver architecture has been implemented on a Xilinx Kintex-7 (XC7K325T) FPGA of a custom-based platform developed by CEA-Leti.

Wednesday, 10 December 2014 • 17:20 – 17:40

## **ID-19: SW Demo of mmWave Propagation and Access in a Dense Urban Street Canyon Scenario**

**Authors:** Axel Klein, Mark Cudak, Berthold Panzner, Nokia

Through the availability of large contiguous bandwidths and the resulting applicability of simple air interfaces without complex and expensive techniques for optimized spectrum utilization, the use of mmWave spectrum presents an exciting option for the huge traffic demand expected in future wireless 5G networks. With the small wavelength large antenna arrays become feasible with strong directional gains that easily compensate for the higher pathloss in frequencies of 30 GHz and above, and allow for a deployment of cellular access networks in dense urban outdoor scenarios.

The SW demo proposed for presentation shows such a deployment scenario in a live interactive radio simulation of a 5G enhanced Local Area network with a mmWave propagation and channel model aligned with real-world measurements. It illustrates the dynamic cell selection triggered through terminal and scatterer mobility in a visually appealing 3D view of the dense urban street scenario, and it displays quantitative performance indications like throughput and handover statistics in various conditions and configurations.

Wednesday, 10 December 2014  
17:40 – 18:00

## **ID-20: Bell Labs Alcatel-Lucent 5G UFMC Air Interface Demonstrator**

**Authors:** Johannes Koppenborg, Thorsten Wild, Frank Schaich, Hans-Peter Mayer, Alcatel-Lucent Bell Labs

A new waveform approach “Universal Filtered Multi-Carrier” (UFMC), also known as UF-OFDM, being better suited for 5G has been invented by Bell Labs. The new waveform supports reduced interference between synchronous and asynchronous traffic. This allows for efficient transportation of small packet services, reducing signaling overhead and battery consumption.

Furthermore, UFMC delivers a significant spectral side lobe level reduction, which allows handling very heterogeneous services (from ultra-broadband to small packets) in the same frequency band in a flexible and scalable manner.

A live demonstration of synchronous and asynchronous traffic will be presented and compared with OFDM. A high speed Video with synchronous broadband traffic and an application with an asynchronous MTC application will be shown simultaneously, using the UFMC waveform. To visualize the big advantages of UFMC, the same scenario will be shown with OFDM to have a direct comparison.

Additional poster material provides the context of Bell Labs’ vision and benefits on a new 5G air interface design.

Thursday, 11 December 2014 • 14:00 – 14:20

## **ID-21: Enabling M2M Communications and IoT Applications through LoRa Technology**

**Authors:** Wael Guibene and Nicolas Sornin, France Semtech

This demonstration highlights the capabilities and different features of the LoRa technology (developed by Semtech) and LoRaMAC that enable efficient long range-low power M2M communications and IoT applications. This demonstration highlights the capabilities and different features of the LoRa technology (developed by Semtech) and LoRaMAC that enable efficient long range-low power M2M communications and IoT applications.

Thursday, 11 December 2014 • 14:20 – 14:40

## **ID-22: Noise Figure Measurement with National Instruments RF Platform**

**Authors:** Andy Hinde and Yupeng Jia, National Instruments

One key figure of merit for a receiver is sensitivity, or the ability to detect low-magnitude signals. Receiver sensitivity is limited by the intrinsic noise present in the device itself, which for the amplifiers and mixers present in a receiver signal chain, is characterized by noise figure. Noise figure measurements are commonly performed upon amplifiers and other active devices during design, but typically not performed during production due to the additional test station equipment cost, as well as the additional, usually long, test times involved. Noise figure meters are a class of RF instrumentation dedicated to noise figure measurements, but a vector signal analyzer (VSA) and complementary system low-noise amplifier (LNA) can be used to perform these same noise figure measurements, reusing equipment typically already in place for an RF test station, while taking advantage of the fast measurement speeds of NI’s world class RF analyzers. This presentation will provide a brief background of various noise figure measurement techniques, and discuss their implementation with the NI RF platform. In recent years, numerous improvements have been made in noise figure measurements through better algorithmic understanding of the measurements, analyzers with better sensitivity performance, and less error-prone methods of processing noise power measurements. The complementary demo will focus on noise figure measurement using the Y-factor method.

Thursday, 11 December 2014 • 14:40 – 15:00

## **ID-23: A Versatile, Reprogrammable IEEE 802.11ac FPGA Implementation for Wireless R&D**

**Author:** Robert Daniels, Kuma Signals, LLC

This demonstration presents a single-antenna IEEE 802.11ac wireless link with all physical layer processing and some MAC layer processing contained in the Xilinx Kintex 7 FPGA of the NI USRP RIO platform. The FPGA source is easily modified because it is entirely defined within the NI LabVIEW FPGA development environment. Low latency MAC testing is quickly enabled through an application programming interface (API) that already provides CRC-32, addressing, acknowledgements, and link configuration (e.g., bandwidth, modulation, coding, etc.). LabVIEW FPGA also drastically shortens the FPGA programming learning curve through graphical programming and drag-and-drop access to large library resources.

Thursday, 11 December 2014 • 15:00 – 15:20

## **ID-24: Open Architecture NFC RF Analog Test Framework for PXI Instruments**

**Author: Dharmendra Lingaiah**, National Instruments

Worldwide adoption of mobile phones with new technologies such as NFC embedded in them has seen an increasing upward trend. Chipset manufacturers are releasing multi standard all inclusive chips with 802.11ac, Bluetooth, GPS, FM & NFC to enable this trend. Until recently, NFC enabled mobile phones which were used for personal communications and media players have seen this trend of being used as a payment, ticketing & connection initiator devices. According to research estimates, wireless attach rates for NFC are being predicted at greater than five billion units in the next few years. NFC RF Analog testing plays a pivotal role in shaping the future of this adoption trend. For Mobile Devices NFC Analog testing, the need of the hour is a minimal footprint, modular, faster and open software test architecture which allows for all technologies 802.11ac, Bluetooth, GPS, FM & NFC to be tested. NI has recently worked on a NFC Analog Test Framework, which will be discussed highlighting how signal processing principles can be applied for all tests as defined by NFC Forum.

We discuss the implementation of the NFC Forum related Signal Generation APIs and Signal Analysis APIs which cover the various Scenarios such as Power Reception, Carrier Frequency & Modulation Polling to Listening Device.

Thursday, 11 December 2014 • 15:20 – 15:40

## **ID-25: Improved Test Times using Co-processing and FPGA-based Power Servo**

**Authors: Govind Viswambaran, Roy Kidagan, Norm Kirchner**, National Instruments

One major factor in calculating the total cost of test is test times. This demo will demonstrate improved RF power amplifier test times by utilizing 2 technologies 1) co-processing and 2) FPGA-based power servo.

A test solution typically consists of an instrument to acquire data and a processor to compute measurements. The processing involved in some measurements like LTE RF standard is huge and can overload the processor. In such scenarios, a possible solution is to utilize multiple threads of a multi-core processor. The co-processing technique using PXImc further extends a processor's capability by adding a second processor.

The NI PXIe-5644R Vector Signal Transceiver (VST) combines the features of a VSA, a VSG, and a user-programmable FPGA. Power servo is a big portion of a power amplifier test plan. The combination of VSA, VSG and FPGA allows for power servo that is FPGA-based which is much faster compared to traditional power servo methods.

In this demo, we will show some typical power amplifier measurements. We will then show an improvement in test times by using co-processing and FPGA-based power servo.

Thursday, 11 December 2014 • 16:20 – 16:40

## **ID-26: Sub-Nyquist Cognitive Radio System**

**Authors: Etag Israeli, Shahar Tsiper, Deborah Cohen, Eli Shoshan, Rolf Hilgendorf, Yonina C. Eldar**, Technion

We demonstrate of a real-time sub-Nyquist sampling and reconstruction system, based on prototype hardware and an embedded proprietary card, the modulated wideband converter (MWC). The MWC system is shown to comply with cognitive radios requirements.

Thursday, 11 December 2014 • 16:40 – 17:00

## **ID-27: Air Interface Technology and Infrastructure Test Solution beyond 4G and toward 5G**

**Authors: Li-Ke Huang, Yuan Zhang, Jin Wang, Duc To, Chi-Ming Leung**, Aeroflex Limited

Aeroflex TM500 test mobiles are designed in a modular structure. It is not only a platform for air interface but also a simulator for a whole cellular system. In the demonstration, we show the following new features in our TM500 products:

- 5G candidate air interface: Filter-Bank Multi-Carrier (FBMC) techniques are considered as a candidate for 5G air interface. FBMC air interface based on isotropic orthogonal transform algorithm (IOTA) has been developed and prototyped in our TM500 platform. The design of new Physical Layer protocol has been borrowed from the long term evolution (LTE) frame structure. We carry out comparison and show the advantages of FBMC over traditional OFDM in terms of throughput utilization and frequency error sensitivity.
- Interference cancelation techniques for 4G: In HetNet, high interference from macro-cell may cause problem to pico-cell cell-edge users. LTE-A Release 10 and latter allow users in multiple pico-cell to share some subframes without interference of data signals from the macro-cells (known as FeICIC in LTE Advanced). However, reference and synchronization signals transmitted by the macro-cells still cause interference. We present the techniques to mitigate: i) the interference of reference signal from the macro cell in decoding signals from a pico-cell and ii) the interference of synchronisation signals from the macro-cells in detecting a new pico-cell.
- Multi-User Mobility Model: The multi-user version of TM500 allows testing base stations in system perspective. TM500 simulates multiple users in different channel conditions and acts as an entire multi-user cellular network environment in working with a base station or group of multiple base stations. This infrastructure test solution will be presented in the demonstration.

These features are carefully designed with practical constraints. The implementation process includes technical feasibility, MATLAB simulations, DSP implementation, and test and verification.

Thursday, 11 December 2014 • 17:00 – 17:20

## **ID-28: A Sub-Nyquist UWB Communication System Demo**

**Author:** Yonina Eldar, Technion

Abstract: We introduce a hardware implementation and demo of a sub-Nyquist Ultra Wideband (UWB) communication system. We employ compressed sensing (CS) techniques in order to exploit the sparse nature of the channel impulse response. The system operates in two phases: first the channel impulse response is estimated using foldable sampling, followed by data detection of the information. We use the Xampling framework to reduce the sampling rate at the analog to digital converter to 1/10 of the transmitted signal Nyquist rate, during both channel estimation phase and data detection.

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Thursday, 11 December 2014 • 17:20 – 17:40

## **ID-29: Full Duplex Radios**

**Authors:** Minkeun Chung, Minsoo Sim, Byungwook Min, Dong Ku Kim, Chan-Byoung Chae, Yonsei University

Most prior work on full duplex radios has assumed that self-interference cancellation (SIC) is perfectly operated. In practice, however, SIC has been a critical issue to implement full duplex radios in a real wireless environment. We describe the main goals of the demo to overcome this issue. First, we implement an RF front-end that can provide SIC>60dB with a combination of antenna and RF SIC. The remaining TX self-interference is further cancelled at the LNA balun using the tapped TX signal from a directional coupler. The LNA balun needs to be carefully designed to provide SIC with a minimal RX path loss and matched port impedance. The variable and delay unit will be designed to compensate the antenna SIC level and delay of the remaining TX signal. Second, we also demonstrate digital band SIC cancellation algorithms in addition to implementing modules of wireless standard. We design a full duplex system that is capable of supporting the LTE with wide bandwidth (>20MHz) and 20dBm (or higher) average TX power. In this demo, we aim at realizing a testbed for showcasing an in-band full duplex radio system that can simultaneously transmit and receive on the same frequency and time resource band using PXIe products by National Instruments.

Monday, 8 December 2014 • 08:30 – 12:30

## I-1: Heterogeneous and Small Cell Networks: Theory, Standardization and Deployment

**Authors:** Ismail Guvenc, Florida International University, USA  
David Lopez-Perez, Bell Laboratories, Alcatel-Lucent, USA  
Sayandeep Mukherjee, DOCOMO Innovations Inc., USA

The tutorial will cover the following:

### Recent developments in HetSNets

- Range expansion in HetSNets
- Interference coordination techniques for HetSNets (Rel. 10 (eICIC) and Rel. 11 (FeICIC) techniques)
- Time domain interference coordination
- Frequency domain interference coordination
- Power control based interference coordination
- Mobility management issues and handover parameter optimization
- Enhanced PDCCH (ePDCCH) as a solution to solve control channel problems
- ON/OFF cells and energy efficiency enhancements
- Use of 256 QAM for HetSNets
- Dynamic TDD for HetSNets

### HetSNets performance analysis through stochastic geometry: bridging the gap between theory and practice

- Structure of the SINR distribution calculation problem
- The role of Poisson Point Processes in enabling tractability of the SINR distribution problem
- Results on SINR distribution for single and multi-tier heterogeneous cellular networks
- Analytical methods for SINR analysis with power control, e.g., eICIC
- Spectral and energy efficiency analysis for HetSNets with eICIC

### Deployment challenges for hyper-dense HetSNets

- 1 Gbps/user: Need for higher small cell densities, more spectrum, more antennas
- Mobility management: Dual connectivity and the Phantom cell concept
- Back-haul planning: Fiber, microwave and large-scale antenna systems
- WiFi and LTE coexistence in unlicensed bands

Monday, 8 December 2014 • 08:30 – 12:30

## I-2: Learn the Details of OpenFlow with Interactive Switch Visualization

**Authors:** C. Jasson Casey and Colton Chojnacki, Flowgrammable.org  
Alex Sprintson, Texas A&M University, USA

This tutorial session is aimed at researchers, hardware designers, software developers, and network operators that need a detailed explanation of the OpenFlow network abstractions and protocols. Participants will learn about the core data model that underlies the five existing versions of OpenFlow, its associated interface and semantics for packet processing. Focus will be given to the differences between OpenFlow versions and the process of writing OpenFlow applications. The lectures will use Flowgrammable's visual OpenFlow simulator, Flowsim, to allow participants to follow lecture examples and explore key ideas.

In this tutorial, we will present the OpenFlow abstract packet processing pipeline and its associated interface. We will provide an in-depth description of the data model of the existing five versions, describe the associated interface, contrast the differences between versions, and illustrate the feature discovery process. This will be accomplished with a combination of lecture material and interactive web-based visualization of an OpenFlow switch. Participants will be able to follow along and configure their own OpenFlow switches, issue OpenFlow messages, inject custom packet sequences into the pipeline, and observe the resulting behavior. Most importantly, participants develop an understanding of how the OpenFlow primitives: instructions, actions, meters, groups, ports, and queues can be used to specify common network functions. Finally, we will discuss current issues and research efforts as well as the technology outlook for OpenFlow and SDN technologies.

Monday, 8 December 2014 • 13:30 – 17:30

## I-3: Rapid Prototyping of Real-time Wireless Systems with NI LabVIEW (FREE: Sponsored by National Instruments)

**Authors:** Sanjay Challa and Douglas Kim, National Instruments, USA

In today's competitive wireless research space, the ability to quickly prototype ideas on hardware using real signals is more important than ever. In this half day tutorial, you will gain hands-on experience with National Instruments' integrated hardware and software platform for rapid prototyping of real-time wireless systems using the NI LabVIEW Communications System Design Suite (LabVIEW Communications) and the NI USRP-RIO FPGA-based software defined radio. At the end of the tutorial, you will be able to design, simulate, and prototype a 20 MHz LTE-based real-time OFDM link on a high performance FPGA, and transmit data over the air using the link you design on the NI USRP-RIO. The tutorial will cover the most important aspects of the idea-to-prototype flow in a single tool, including floating-point simulation, floating-point to fixed-point conversion, HW/SW partitioning, performance-complexity tradeoffs, and finally verification and testing on an FPGA-based software-defined radio. Note: no prior experience with FPGA's or NI hardware or software tools is required.

Monday, 8 December 2014 • 13:30 – 17:30

## 1-4: CloudRAN Architectures, Virtualization and Connectivity Solutions for 5G Cellular Communications

**Author:** Raghu M. Rao, Xilinx Inc., USA

The enormous growth in wireless network traffic has spurred the evolution of radio access networks. There is also a push towards energy efficiency (green base-stations) while trying to minimize cost of installing and maintaining base stations. Heterogeneous networks (HETNETs) which overlay "small cells" and wifi networks on top of the traditional macro cells are emerging to address the issues of increasing capacity and improving coverage. CloudRAN is another technology that is paradigm shift in radio access networks and its main motivation was to reduce costs and improve energy efficiency. CloudRANs centralize base-station processing by bringing signals from many different cells into a central server room and demodulate the signals in this one location. This minimizes operational costs and provides a means for energy efficiency also and now it is being seen as a means to improve network performance as well by minimizing inter-cell interference.

In this tutorial, we will present the evolution of the macro-cell RAN to the CloudRAN and also present a scheme for virtualization of baseband processing in a 3GPP-LTE network. We further discuss the various architectures for partitioning baseband processing which will determine the amount of data throughput needed between the base station pool and the radio heads (also known as front-hauling). We present some of the connectivity solutions being explored for front-hauling and for data transfer among the pool of physical resources for baseband processing.

Friday, 12 December 2014 • 08:30 – 12:30

## I-5: From 4G to 5G: a (r)evolution?

**Authors:** Marcin Dryjanski and Slawomir Pietrzyk, IS-Wireless, USA

LTE-Advanced as defined by 3GPP fulfills the ITU-R definition for being a 4G system. One of the most important requirement for such a system is achieving 1Gb/s for low mobile service. As the deployments of 4G already took off, a concept of 5G is brought to the research community. Will the 5G be "just" an evolution of 4G, a totally new radio interface or a communications revolution?

The session presents background and main features of LTE-Advanced being a 4G system, including Carrier Aggregation, CoMP and higher order MIMO. We firstly present 3GPP LTE from Release 8 up to Release 12 and then move to 5G concepts as seen by the research communities.

Friday, 12 December 2014 • 08:30 – 12:30

## I-6: Physical Layer Modeling of LTE and LTE-Advanced Systems in MATLAB

**Author:** Houman Zarrinkoub, MathWorks, USA

In this tutorial, we will showcase the use of MATLAB® and its new capabilities for physical layer modeling of LTE and LTE-A standards. The tutorial will introduce the LTE System Toolbox, which provides standard-compliant functions and tools for the design, simulation, and verification of LTE and LTE-Advanced communications systems. Through demonstrations you will learn how the Toolbox can help you measure and analyze the end-to-end performance of LTE and LTE-A communications links, can provide conformance test benches and wave forms to verify your designs and may be used as a golden reference model ensuring that your implementations comply with the LTE standard.

Friday, 12 December 2014 • 08:30 – 12:30

## I-7: Low Power Wide Area Machine to Machine Communications using LTE

**Authors:** Amitava Ghosh, Rapeepat Ratasuk, Nitin Mangalvedhe, Nokia Solutions and Networks, USA

The Internet of Things (IoT) refers to interconnection and exchange of data among devices. This capability will bring about tremendous improvements in user experience and system efficiency. To support IoT, machine-to-machine (M2M) communication is needed. An estimated 50 billion connected devices will be deployed by 2020 and the total M2M revenue is expected to grow from \$200 billion in 2011 to \$1.2 trillion in 2022. M2M services therefore are expected to be a key driver for growth in cellular. With the widespread introduction of LTE and decommissioning of legacy systems, M2M services on LTE are under consideration by many cellular operators. In LTE Rel-12, low cost M2M devices with material cost comparable to EGPRS devices are being introduced. In addition, coverage enhancement techniques, which would be required to support M2M, are being standardized in Rel-13.

The tutorial will cover the basics of LTE physical layer and data transmission. Although M2M services and requirements vary widely, we will focus on low-rate, low-mobility, and delay-tolerant applications such as smart meters, tracking, home security, remote diagnostics, and sensors. The introduction of low-cost devices in LTE to support these services will be discussed. Coverage enhancements techniques, which would be required to support M2M, will be standardized to allow LTE coverage to be extended to devices in poor locations such as the basement. In addition, system coverage and capacity will be addressed. We will show that LTE can be used to efficiently serve both human and machine traffic. In addition, capacity results for some representative M2M services will be provided and their impact on human traffic will be discussed. Finally, M2M analysis using real-world deployment scenarios will be presented.

Friday, 12 December 2014 • 13:30 – 17:30

## I-8: Vehicular Networking

**Authors:** Onur Altintas, Toyota InfoTechnology Center, Co. Ltd, Japan  
Falko Dressler, University of Paderborn, Germany

Researchers from academia and industry recently met at an international Dagstuhl seminar to discuss open research challenges as well as open issues related to market-oriented design. We are now entering an era that might change the game in road traffic management. This is supported by the U.S. federal government announcement in February 2014 that National Highway Traffic Safety Administration (NHTSA) plans to begin working on a regulatory proposal that would require V2V devices in new vehicles in a future year. This NHTSA announcement coincides with the final standardization of higher layer networking protocols in Europe by the ETSI.

From an industry point of view, vehicular networking serves as one of the most important enabling technologies required to implement a myriad of applications related to vehicles, vehicle traffic, drivers, passengers and pedestrians. In this tutorial, we will look into applications and use cases of vehicular networking followed by an overview of the standardization activities. Next we will cover the communication protocol design as well as the deployment plans. We will also briefly talk about simulation tools for evaluation of various protocol designs. Before concluding, we will take a glimpse at the recently emerging reality of electric vehicles and autonomous vehicles along with the issues surrounding them. Finally we will conclude with open issues that require further research.

Friday, 12 December 2014 • 13:30 – 17:30

## I-9: How to Build and Test a 5G Wireless Radio Access Network (RAN) Today

**Authors:** Chen Chang and Anna Acevedo, BEECube Inc., USA

There are over 5 billion mobile cellular users in the worldwide, and 1 out of 4 users are using a smartphone to surf the Internet today. By 2020, with the rapid growth of Internet of things (IoT), over 50 billion devices will be connected constantly. The next generation 5G wireless networks will need to support 1000-fold gains in capacity, connections, and a 10 Gb/s individual user experience capable of extremely low latency and response times.

World's leading telecommunication companies and government sponsored research institutes are planning to spend over \$5 billion US dollar in the next 5 years on 5G R&D alone, all for the same goal of a fully operational 5G network by year 2020 if not sooner. Nevertheless, 5G networks are not just an upgrade of 4G. It will require new technology breakthroughs in all aspects of the existing network, and fundamentally change the way we access the RF spectrum, process the data, and interconnect on a massive scale.

This tutorial addresses some of the key 5G challenges and requirements in the Radio Access Network (RAN) layer, as well as explores new design and development solutions that can demonstrate key technology advancements in carrier aggregation, spectral agility, and massive MIMO.

Monday, 8 December 2014 • 08:30 – 17:30: Workshop • 19:00 – 21:30: Demo Night

## **WI-1: New Air Interfaces for 5G**

**Organizers: The 5GNOW Consortium**

**Thorsten Wild**, Bell-Labs Alcatel-Lucent, Germany

**Gerhard Wunder**, Fraunhofer Heinrich Hertz Institute, Germany

**Gerhard Fettweis**, Technische Universität Dresden, Germany

**Dimitri Ktenas**, CEA-LETI, France

**Slawomir Pietrzyk**, IS-Wireless, Poland

**Bertalan Eged**, National Instruments, Hungary

In this workshop, we present the state-of-the-art in the development of New Air Interfaces for 5G which efficiently support such application visions. The workshop program will discuss several new waveforms for 5G (including a scientific-oriented waveform tutorial) from an industry-driven perspective and thereby discuss design principles, implementation details, performance results, and first demonstrations of selected results. Moreover all key players in this field will present their distinctive technical viewpoint on new air interfaces and possible candidate selection. In the course of this workshop, the participants will have the chance to discuss and connect with influential industry people working in this field. Altogether, it is an excellent opportunity to collect the latest views and developments regarding an exciting open field on the road towards 5G.

Monday, 8 December 2014 • 08:30 – 17:30: Workshop • 19:00 – 21:30: Demo Night

## **WI-2: Internet of Things and Services: Visions, Technologies & Research Challenges**

**Organizers: Andreas Mueller**, Robert Bosch, Germany

**Gerhard Wunder**, Fraunhofer Heinrich-Hertz-Institute, Germany

The goal of this workshop is to bring all these players together and to foster a better common understanding, to exchange visions and latest research results, to discuss promising new technologies and to highlight open research challenges. To this end, several renowned experts from industry have been invited, who will cover the topic in keynote speeches and invited talks from different perspectives in order to provide a rather comprehensive overview of all issues that have to be considered in this respect. Besides, the workshop will include a panel discussion on open research challenges and the way forward to finally make the IoT become reality. Furthermore, it will feature a demo session, during which latest (practical) research results will be showcased and demonstrated.

Friday, 12 December 2014 • 08:30 – 17:30

## **WI-3: In-Building Wireless Access: Infrastructure Solutions for Emerging Applications**

**Organizer: Michael Sauer**, Corning, USA

This workshop will discuss challenges, industry dynamic, and solutions for in-building wireless access infrastructure due to the combination of multiple technologies on common systems. The trend of combining distributed antenna system approaches, remote radio signal feeding, Small Cells, etc. for increased capacity, performance and dynamic traffic management leads to new ways for approaching infrastructure design. Migration to standards like LTE and LTE-Advanced requires the support of new features and capabilities. SON & HetNet is leading to new ways of in-building wireless access system design. Further, the increasing role and importance of new generations of WiFi technologies such as 802.11ac and 802.11ad/WiGig lead to a new set of considerations for how in-building wireless access is addressed. Emerging applications for healthcare, public safety, telemetry and technologies for services like in-building location positioning are supported by these multi-technology networks and will be discussed in the workshop. Experts from the industry will discuss solutions to these new challenges and the workshop will facilitate an exchange between industry and academia on technologies for in-building wireless access.

Friday, 12 December 2014 • 13:30 – 17:30

## **WI-4: Advanced RF Communications Technology for Public Safety/Homeland Security**

**Organizer: Fred Frantz**, Engility Corporation, USA

The landscape for public safety communications is changing rapidly. Traditional land mobile radio used by public safety agencies is rapidly being supplemented by wireless broadband communication. The National Public Safety Broadband Network (also known as FirstNet) will provide public safety users with LTE capability for data access. Advanced technologies such as cognitive radio, channel bonding across disparate networks, and steerable multiband antennas have the potential to provide public safety with significant communications capabilities that can meet their unique requirements for ubiquitous, robust, high capacity communications capabilities. In addition, capabilities such as mission critical voice over an LTE network, management of spectrum resources to meet mission requirements, and balancing local control of network operations without compromising interoperability among local agencies are all key to successful deployment and utilization of FirstNet.

The objective of this workshop is to identify from a public safety user's perspective the technology needs for communications, to discuss the federal government role in sponsoring research, development, test and evaluation of evolving technology to meet those needs, and to identify promising technologies that could have near- and long-term impact on both future land mobile radio systems as well as wireless broadband networks of the future.



The Technical Symposia will feature 859 peer-reviewed papers on current research and development organized into the following 12 Symposia consisting of 144 oral and interactive sessions.

<b>AHSN:</b>	Ad Hoc and Sensor Networking Symposium	<b>SAC-EH:</b>	Selected Area - e-Health
<b>CogRN:</b>	Cognitive Radio and Networks Symposium	<b>SAC-GCSN:</b>	Selected Area - Green Communications Systems and Networks
<b>CISS:</b>	Communications and Information Systems Security Symposium	<b>SAC-HCC:</b>	Selected Area - Human Centric Communications
<b>CQRM:</b>	Communications QoS, Reliability and Modeling Symposium	<b>SAC-IoT:</b>	Selected Area - Internet of Things
<b>CSSM:</b>	Communication Software, Services and Multimedia Applications Symposium	<b>SAC-NT:</b>	Selected Area - Nanotechnology
<b>CT:</b>	Communication Theory Symposium	<b>SAC-PLC:</b>	Selected Area - Powerline Communications
<b>NGN:</b>	Next-Generation Networking Symposium	<b>SAC-SSC:</b>	Selected Area - Satellite and Space Communications
<b>ONS:</b>	Optical Networks and Systems Symposium	<b>SAC-SN:</b>	Social Networks
<b>SAC-ANS:</b>	Selected Area - Access Networks and Systems	<b>SPC:</b>	Signal Processing for Communications Symposium
<b>SAC-CC:</b>	Selected Area - Cloud Computing	<b>WCS:</b>	Wireless Communications Symposium
<b>SA-DS:</b>	Selected Area - Data Storage	<b>WN:</b>	Wireless Networking Symposium

MONDAY, 8 DECEMBER 2014

Monday, 8 December 2014 • 18:00 – 19:00

## Best of IEEE GLOBECOM 2014 Poster Session

Featuring the 50 best and most interesting papers from the entire technical symposia as selected by the Symposia Chairs and Awards Committee. This corresponds to the top 2.2% of all papers submitted to IEEE GLOBECOM 2014! Best Paper Awards will be selected from this elite group, based on the presentations during this special 90 minute event. Join us for this event, and then network with colleagues at the Welcome Reception immediately following.

TUESDAY, 9 DECEMBER 2014

### 10:30 – 12:15

AHSN-1: Wireless Sensor Networks I  
 AHSN-2: Vehicular Networks I  
 CogRN-1: Spectrum Sensing in Cognitive Radio Networks I  
 CT-1: Communications with Energy Harvesting  
 NGN-1: Next Generation Wireless Network Design  
 ONS-1: Switching and Routing in Optical Networks  
 SAC-1-SN: Community Enabled Networking  
 SAC-2-GCSN: Green Cellular Networks

SPC-1: Signal Processing for Channel Estimation  
 WCS-1: Channel Coding and ARQ  
 WCS-2: Heterogeneous Networks  
 WCS-3: Cognitive Networks  
 WN-1: Architectural Design and Operation Models  
 WN-2: Self-Organizing Networks

#### Interactive Sessions

CT-I-1: Selected Topics in Communication Theory  
 WCS-I-1: Channel Measurement and Modeling

### 14:00 – 15:45

AHSN-3: Routing I  
 AHSN-4: Wireless Sensor Networks II  
 CogRN-2: Spectrum Sensing in Cognitive Radio Networks II  
 CT-2: Coding Theory  
 NGN-2: Virtual Network Design  
 ONS-2: Multiplexing, Modulation and Channel Capacity  
 SAC-3-EH: Body Area Networks  
 SAC-4-IoT: Managing and Building New Internet of Things Applications  
 SPC-2: Signal Processing for Cognitive Radio I

WCS-4: Cooperative Communications  
 WCS-5: Channel Estimation/Prediction  
 WCS-6: Heterogeneous Networks II  
 WN-3: Power Management and Energy Conservation Techniques  
 WN-4: Cross-Layer Design and Optimization

#### Interactive Sessions

WCS-I-2: Massive MIMO II  
 WN-I-1: WiMAX, LTE, WMAN and Other Emerging Broadband Wireless Networks

### 16:15 – 18:00

AHSN-5: Vehicular Networks II  
 AHSN-6: Wireless Sensor Networks III  
 CogRN-3: Spectrum Allocation and Resource Management in Cognitive Radio Networks I  
 CT-3: Heterogeneous Networks  
 NGN-3: Content Centric Network Design  
 ONS-3: Wireless-Optical Communications  
 SAC-5-CC: Evaluation of Data Center Network Topologies and Multipath Protocols  
 SAC-6-GCSN: Green Clouds and Data Centers

SPC-3: Signal Processing for Cognitive Radio II  
 WCS-7: Interference Coordination  
 WCS-8: Massive MIMO I  
 WCS-9: Millimeter Wave and Tera Hertz Communication  
 WN-5: Femtocell Networks  
 WN-6: Vehicular Networks

#### Interactive Sessions

SAC-I-1: eHealth & Nanotechnology  
 SAC-I-2: Green Communication Systems and Networks

## 10:30 – 12:15

AHSN-7: Wireless Sensor Networks IV  
 CogRN-4: Spectrum Allocation and Resource Management  
 in Cognitive Radio Networks II  
 CQRM-1: Cloud Computing and Networking  
 CSSM-1: Video Coding and Communications  
 CT-4: Network Coding  
 NGN-4: Software Defined Network Design  
 SAC-7-SN: Privacy, Security and Networking  
 SAC-8-GCSN: Green Optical Networking

SPC-4: Signal Processing for Compressive Sensing & Sparse Signals  
 WCS-10: MIMO I  
 WCS-11: Modulation and Transmission Processing  
 WCS-12: Performance Analysis and Design Tradeoffs I  
 WN-7: Routing  
 WN-8: Performance Analysis and Optimization

### Interactive Sessions

SPC-I-1: Signal Processing for Designs under Power & Cost Constraints  
 CogRN-I-1: Emerging Topics in Cognitive Radio Networks

## 14:00 – 15:45

AHSN-8: Delay Tolerant Networks and Crowdsensing  
 CQRM-2: Video Streaming  
 CSSM-2: Communication Services  
 CT-5: Physical Layer Security  
 NGN-5: Next Generation Network Design I  
 SAC-9-CC: Mobile Cloud Networking  
 SAC-10-IoT: Extending the Internet of Things through Mobile Wireless  
 Networks, RFID and Cloud Computing  
 SPC-5: Signal Processing for Distributed, Cooperative & Relayed  
 Communications

WCS-13: OFDM/Multi-Carrier/Multiple Access  
 WCS-14: Multiuser MIMO  
 WCS-15: Performance Analysis and Design Tradeoff II  
 WN-9: Resource Allocation  
 WN-10: Heterogeneous Networks

### Interactive Sessions

CISS-I-1: Attacks, Anomalies and Traffic Analysis  
 WCS-I-3: MIMO II

## 16:15 – 18:00

AHSN-9: Wireless Sensor Networks V  
 CogRN-6: Performance Issues in Cognitive Radio Networks  
 CSSM-3: Wireless Video  
 CT-6: MIMO Systems  
 NGN-6: Next Generation Network Design II  
 ONS-4: Optical Access Network, Metro Area Network and Elastic  
 Optical Network  
 SAC-11-PLC: Power Line Communications  
 SAC-12-GCSN: Green Wireless Networks I

SPC-6: Signal Processing for Estimation & Detection  
 WCS-16: Detection and Estimation  
 WCS-17: Physical Layer Security  
 WCS-18: Relaying I  
 WN-11: WLAN, WPAN, and Other Home/Personal Networking Technologies  
 WN-12: Cellular Networks I

### Interactive Session

AHSN-I-1: Security and QoS  
 AHSN-I-2: Scheduling and Coding

## 10:30 – 12:15

AHSN-10: Wireless Sensor Networks VI  
 AHSN-11: Localization and Tracking I  
 CISS-1: Privacy-Preserving Technologies  
 CISS-2: Wireless Network Security  
 CogRN-7: Security Issues in Cognitive Radio Networks  
 CQRM-3: Traffic Control and Network Virtualization  
 CT-7: Interference Management  
 SAC-13-DS: Data Storage  
 SAC-14-GCSN: Green Wireless Networks II  
 SPC-7: Signal Processing for OFDM, OFDMA & Multi-Carrier Communications

SPC-8: Signal Processing for Massive MIMO  
 WCS-19: Relaying III  
 WN-13: WLAN, WPAN, and Other Home/Personal Networking Technologies II  
 WN-14: Cellular Networks II

### Interactive Sessions

SACI-3-PLC: Power Line Communication  
 CQRM I-1: Network Coding

## 14:00 – 15:45

AHSN-12: Wireless Communications  
 CogRN-8: Game Theory in Cognitive Radio Networks  
 CISS-3: Smart Grid Security  
 CISS-4: Security and Privacy for P2P and OSN  
 CQRM-4: Resource Allocation in Wireless Networks  
 CT-8: Relay Channels  
 SAC-15-SSC: Satellite Networking  
 SAC-16-EH: eHealth Communications  
 SAC-17-GCSN: Smart Grid Communications

SPC-9: Signal Processing for Multi-Antenna Systems I  
 SPC-10: Signal Processing for Multi-Antenna Systems 2  
 WCS-20: Resource Allocation  
 WN-15: Emerging Wireless Technologies  
 WN-16: Resource Management and Admission Control I

### Interactive Sessions

NGN-I-1: Forwarding Design and Next Generation Network Management  
 ONS-I-1: SDN, Datacenter and Cloud

## 16:15 – 18:00

AHSN-13: Location and Tracking II  
 CISS-5: Physical and Lower Layer Security  
 CISS-6: Theoretical Studies for Security and Privacy  
 CQRM-5: Routing and Reliability  
 CT-9: Communication System Performance  
 SAC-18-SSC: Satellite Communications  
 SAC-19-CC: Virtual Machine Migration and Allocation  
 SAC-20-ANS: Access Networks and Systems  
 SPC-11: Signal Processing for Sensor Networks

SPC-12: Signal Processing for Synchronization  
 WCS-21: Small Cells  
 WCS-22: Wireless Energy Transfer/Energy Harvesting  
 WN-17: Resource Management and Admission Control II  
 WN-18: Wireless Computing and Scheduling

### Interactive Sessions

WCS-I-4: Relaying II  
 WN-I-2: User Cooperation and Incentive Schemes

Monday, 8 December 2014 • 08:30 – 12:30

## T-1: Stochastic Geometry for the Analysis and Design of 5G Cellular Networks

**Presenter:** Martin Haenggi, University of Notre Dame, USA

In the first part, the tutorial provides a rigorous introduction to stochastic geometry, including the main models and the key results that enable closed-form calculations of distributions and spatial averages of network performance metrics, including transmission success probabilities, throughput, and delay. Spatial averaging is the process of averaging over the likely realizations of the network topology. It yields results that are valid for general classes of networks, rather than being restricted to a particular deployment of the nodes in a network.

In the second part, we focus on emerging single- and multi-tier cellular systems. The main metrics of interest are the distribution of the signal-to-interference-plus-noise ratio (SINR) and the per-user capacity. First, focusing on a Poisson model for the base stations (BSs), we derive the complete SINR statistics for different cases of BS cooperation, including BS silencing, joint transmission, and interference cancellation, and we show the effects of network densification. Next, we turn our attention to more general network models that reflect the intra- and inter-tier dependencies that exist in heterogeneous cellular systems. Lastly, we present a novel and simple analytical framework based on the mean interference-to-signal ratio that yields simple expressions that provide very good approximations of the SINR distributions for many types of deployments and cooperation schemes.

Monday, 8 December 2014 • 08:30 – 12:30

## T-2: Green HetNets: Capacity Improvements, Coverage Expansion and Backhaul Requirements

**Presenters:** Muhammad Zeeshan Shakir, Texas A&M University, Qatar  
 Mohamed-Slim Alouini, King Abdullah University of Science and Technology, Saudi Arabia  
 Khalid A. Qaraqe, Texas A&M University, Qatar

In this tutorial, we will investigate and study the spectral- and energy-aware deployment of small-cells in heterogeneous networks and their several need-oriented deployments around the edges of the macrocells, such that the small-cell base stations (SBSs) serve the cell-edge mobile users, thereby expanding the network coverage and increasing the capacity. Moreover, the reduction in energy consumption is achieved by considering power control in the uplink where the mobile users are transmitting with adaptive power to compensate the path loss, shadowing and fading. In this context, in order to quantify the gains of the HetNets, we will introduce useful performance metrics such as area spectral efficiency (ASE) which is defined as bps per Hz per macrocell area and area green efficiency (AGE) which is defined as the aggregate energy savings in the uplink per unit macrocell area. In order to calibrate the reduction in CO2 emissions of mobile communication networks, this tutorial quantifies the ecological and associated economic impacts of energy savings in under-consideration deployments. Moreover, in order to calibrate the impact of power consumption on the system performance and network topology, this tutorial also presents a comprehensive end-to-end breakdown of total power consumption which includes backhaul, access and aggregation network power consumption.

Specifically, this tutorial will provide answers for the following:

- What are the Green competitive technologies to expand the cellular coverage?
- What are the contributing factors to the downlink and uplink energy consumption of HetNets (end-to-end power consumption breakdown including backhaul)?
- What are the recent capacity enhancement techniques for advanced HetNets?
- What are the ecological (carbon footprint) and economic (low carbon economy index) impacts of the future generations of wireless networks?

Monday, 8 December 2014 • 08:30 – 12:30

## T-3: Past, Present and Future of 802.11 toward Wireless Gigabit Experience

**Presenters:** Periklis Chatzimisios and Athanassios Iossifides, Alexander TEI of Thessaloniki, Greece  
 Jesus Alonso-Zarate, Centre Tecnològic Telecomunicacions Catalunya, Spain

A long time has passed since IEEE released the first 802.11 standard in 1997 for satisfying users' needs to access the Internet wirelessly (mostly webpages and emails) through Wireless Local Area Networks (WLANs). During the next years, IEEE 802.11 Working Groups have carried out a prolific program of introducing new standards (e.g. the well-known 802.11a/b/g/n) as well as improvements and extensions driven by a complete alphabet of amendments that led recently to fully revised standard 802.11-2012 incorporating most contemporary application requirements. Currently, a new generation of standards and amendments is making its appearance (IEEE 802.11ac and 802.11ad are the latest additions) that is capable of achieving speeds of multiple gigabits per second, supporting a wide variety of new applications and delivering rich Quality of Experience (QoE) to users.

This tutorial aims to bridge the gap between the well-known and widely applied IEEE 802.11 variants with the recently developed amendments, focusing on three major technical aspects/areas of interest: (i) the Physical layer (PHY) (ii) the Medium Access Control (MAC) layer and (iii) the new usage models and applications that will be supported in the coming years. The tutorial will cover both the research and engineering challenges as well as identify challenges and open issues. Therefore, the intended audience of the tutorial includes young and experienced researchers looking for inspiration and a clear presentation of the evolution of WiFi standards and open challenges, as well as industry players and practitioners looking for a clear understanding of the current state-of-the-art in the technology behind WiFi.

Monday, 8 December 2014 • 13:30 – 17:30

## T-4: Near-Capacity Wireless Multimedia System Design: Error-Resilient Source-Compression, Multi-Functional MIMOs and Efficient Streaming

**Presenter:** Lajos Hanzo, University of Southampton, UK

Most multimedia source signals are capable of tolerating lossy, rather than lossless, delivery to the human eye and ear, since the audio-visual impairment-masking properties of the human 'receiver' may be exploited. Hence the coding-induced impairments may be rendered almost imperceptible. The standardized multimedia source codecs however exhibit unequal error sensitivity, which is not the case for Shannon's ideal entropy codec. In this research-review, a unified treatment of near-capacity multimedia communication systems is offered, where we focus our attention not only on source and channel coding aspects but also on their iterative decoding, streaming and transmission problems. The design examples considered include cutting-edge near-capacity variable-length codes, multi-layer video streaming systems supported by multi-functional antenna arrays (MFAA) and three-stage concatenated receivers.

Monday, 8 December 2014 • 13:30 – 17:30

## T-5: Alternatives to TCP/IP

**Presenters:** John Day and Lou Chitkushev, Boston University, USA  
 Eduard Grasa, Fundacio i2CAT, Spain  
 Francesco Salvestrini, Nextworks, Italy  
 Dimitri Staessens, iMinds, Belgium

The goal of the tutorial is to provide the audience with an introduction to the concepts, motivation and state of the art of the Recursive InterNetwork Architecture (RINA), one of the most promising alternatives to TCP/IP. This tutorial is split into two parts: the first one will be dedicated to the theory and concepts behind RINA, while the second will explain real-world use

cases that motivate its deployment and introduce the RINA stack under development by the FP7 IRATI and PRISTINE projects. To conclude the session, a live demonstration of the IRATI prototype will be carried out.

Monday, 8 December 2014 • 13:30 – 17:30

## **T-6: Evolution toward 5G Cellular Networks: Radio Resource and Interference Management Issues and Approaches**

**Presenter: Ekram Hossian**, University of Manitoba, Canada

The evolving fifth generation (5G) cellular wireless systems will have a multi-tier architecture consisting of macrocells, different types of licensed small cells, relays, and device-to-device (D2D) networks to serve users with different quality-of-service (QoS) requirements in a spectrum and energy-efficient manner. In a co-channel deployment scenario (i.e., when the different network tiers coexist in the same licensed spectrum band), the existing algorithms for radio resource and interference management (RRIM) in single-tier wireless networks will not be efficient for prioritized multi-tier networks where users in different tiers may have different priorities for channel access. This tutorial will delve into the RRIM problem in 5G multi-tier and cognitive cellular networks. Starting with the visions and requirements for 5G cellular networks, several enabling technologies for these networks will be discussed. Then the challenges of radio resource and interference management (e.g. channel allocation and power control, user association) in these networks in co-channel deployment scenarios will be outlined. Open research issues and possible approaches to tackle those issues will be described. In particular, concepts of tier-aware resource allocation, distributed uplink cell association and power control, cognitive spectrum access by network tiers, mode selection and power control for D2D communication, radio frequency (RF) energy harvesting-based D2D communication, and interference management in multi-tier cellular networks in presence of energy harvesting will be discussed in detail.

Friday, 12 December 2014 • 08:30 – 12:30

## **T-7: Understanding Latency: A Root Cause and Mitigation Approach**

**Presenter: Joe Touch**, University of Southern California, USA

This tutorial presents a comprehensive exploration of latency by focusing on the independent root causes and their associated costs, and exploring mitigations directly focused on those causes. We begin with an analysis of the transaction latency budget and its relation to the communicating parties - whether human or computer, pairwise or group. We explore boundaries of that budget, whether binary or graded, and the complex ways in which latency costs can be usefully expressed. The root causes of generation, transmission, processing, multiplexing, and grouping are discussed in depth as well as corresponding mitigations of relocation, speed-up, resource dedication, and avoidance. We address these causes and mitigations in the context of examples including 'bufferbloat,' Internet and big-data search, and protocols specifically aimed at reducing or tolerating latency for a variety of environments including home Internet access, data center operation, high-speed trading, and interplanetary communication. This tutorial also focuses on emerging opportunities for latency reduction that resulted from resource trade-off changes, including reducing component message sizes and a variety of anticipation techniques. Finally, we discuss how to apply these mitigations and new opportunities in both current and future network architectures, including wireless and optical physical layers; packet and circuit systems; location, location-independent, and name-based services; and network management.

Friday, 12 December 2014 • 08:30 – 12:30

## **T-8: Optical Wireless Communications**

**Presenters: Jean Armstrong**, Monash University, Australia

**Maité Brandt-Pearce**, University of Virginia, USA

**Zhengyuan Xu**, University of Science and Technology of China, China

As the radio frequency spectrum congests, the optical medium provides an attractive alternative, supplying ample and easily-reusable spectral resources. Optical wireless communications (OWC) that use light to carry information through a tetherless channel can offer Gbps connectivity to wireless users. This tutorial covers the essential characteristics of optical wireless systems to provide communications engineers the ability to work within this exciting field. The material discussed focusses on the devices, algorithms, and analyses particular to optical wireless systems that differ from RF wireless. Components and techniques peculiar to OWC (optical signal manipulation, for instance) will be carefully explained for the non-expert. Classical approaches used in optical communications will be reviewed. Channel models, modulation, and signal processing techniques will be presented for various scenarios: short vs. long haul, directed vs. diffuse, indoor vs. outdoor, effect of atmosphere and weather, fading and multipath effects, etc. Then emphasis will be given to current research trends to help researchers transport state-of-the-art ideas from RF wireless to OWC, such as MIMO processing, relaying, higher-order modulation, coding, cross-layer design, optimized resource allocation, etc. Networking issue and approaches to facilitate the convergence of optical wireless with other techniques will be discussed. Application areas described include terrestrial free space optics (FSO), deep space channels, underwater communications, and indoor visible light communications. The tutorial will conclude with a review of current standardization efforts in various sub-disciplines of OWC (infrared transmission, visible light communication, FSO).

Friday, 12 December 2014 • 08:30 – 12:30

## **T-9: Greening the Edges**

**Presenter: Nirwan Ansari**, New Jersey Institute of Technology, USA

A variety of bandwidth-hungry applications and services such as high-definition television, video streaming, and social networking are being deployed rapidly, leading to a continuous surge in bandwidth demand across networking infrastructure, notably the access portion. Thus, both wireline and wireless telecommunications operators are driven to upgrade their access networks to provide broader bandwidth for their subscribers. Upgrading the provisioning capacity of access networks leads to a dramatic increase in energy consumption. For example, to guarantee a sufficient signal-to-noise ratio at the receiver side for accurate recovery of high data rate signals, advanced transmitters with high transmitting signal power and advanced modulation schemes are required, thus consequently resulting in high energy consumption of the devices. Also, to provision a higher data rate, more power will be consumed by electronic circuits in network devices to facilitate fast data processing. Besides, high-speed data processing incurs fast heat buildup and high heat dissipation that further incurs high energy consumption for cooling. It is estimated that the access network energy consumption increases linearly with the provisioned data rate. It has also been reported that the LTE base station consumes more energy in data processing than the 3G UMTS systems, and the 10G-EPON system consumes much more energy than the 1G-EPON system. Moreover, owing to the direct impact of greenhouse gases on the earth environment and the climate change, the energy consumption is becoming an environmental and thus social and economic issue. Therefore, it is important to design and build energy efficient high capacity access networks. This tutorial will discuss roadblocks in designing energy efficient access networks, cover the state-of-the-art on greening wire and wireless access networks, present the research challenges on achieving energy efficient high capacity access networks, and allude to 5G implications with respect to the greening effort.

Friday, 12 December 2014 • 13:30 – 17:30

## **T-10: Emerging Concepts and Technologies toward 5G Wireless Networks**

**Presenter:** Halim Yanikomeroglu, Carleton University, Canada

The overall goal of the tutorial is to identify (i) the emerging concepts and technologies, and (ii) the necessary analytical tools to study them (such as optimization, game theory, dynamic feedback control, and artificial intelligence). Towards that end, a number of important components will be presented in the single coherent framework of 5G cellular networks with a “systems” scope and approach.

In the first part of this tutorial, the following topics will be covered: fundamental dynamics of cellular communications, 3GPP operation, key technologies in LTE and LTE-Advanced, challenges and opportunities as we move forward, revisiting the theoretical basics: What we know and what we don’t know, enabling technologies in layer-1 and layer-2 as well in network architecture, and bottleneck problems in beyond-2020 wireless networks.

In the second part of the tutorial, the potential research directions towards coping with the bottleneck problems, especially in the context of radio access network (RAN), resource allocation, layers 1, 2, and 3, will be discussed.

In the absence of a clear technology roadmap towards 5G, the tutorial has, to a certain extent, an exploratory view point to stimulate further thinking and creativity. We are certainly at the dawn of a new era in wireless research and innovation; the next twenty years will be very interesting.

Friday, 12 December 2014 • 13:30 – 17:30

## **T-11: Heterogeneous and Hyper Small Cell Technologies in LTE Advanced and Beyond**

**Presenters:** Li-Chun Wang, National Chiao Tung University, Taiwan  
Chung-Jang Chen, Chunghwa Telecom Laboratories, Taiwan

In this tutorial, we discuss how hyper small cells play a key role in next generation wireless systems. We first give an overview on various deployments scenarios of small cells and heterogeneous networks (HetNet) in the 3GPP LTE Advanced standard. HetNet faces a very complicated interference scenario because they utilize a mix of macrocells,

remote radio heads (RRH) and low-power nodes such as picocells, femto-cells, and relay. Energy efficiency is also another critical issue for HetNet because of high operation costs. Thus we will focus on the following issues and their potential solutions:

- Current 3GPP enhanced Inter-cell interference cancellation techniques (eICIC);
- Other advanced interference mitigation techniques in HetNet, such as joint beamforming and power allocation, and interference alignment;
- Optimal small cell density analysis using stochastic geometry approach

Lastly, we highlight the potential research issues in radio access technologies for 5G wireless to conclude this tutorial.

Friday, 12 December 2014 • 13:30 – 17:30

## **T-12: Wireless Small Cell Networks: Past, Present, Future**

**Presenters:** Walid Saad, Virginia Tech, USA  
Mehdi Bennis, University of Oulu, Finland

Small cell networks (SCNs) are seen as a promising solution for boosting the capacity, coverage, and overall quality-of-service in wireless networks. In this tutorial, we provide a comprehensive overview on SCNs while highlighting key challenges, associated techniques, and future landscape. The tutorial starts by reviewing basic mathematical tools such as stochastic geometry required to better understand, model, and analyze SCNs. Then, we discuss latest developments on resource management techniques tailored to the unique features of next-generation SCNs. Beyond traditional concepts such as cell range expansion, cell association, and intercell and interference coordination (ICIC), we will introduce the novel paradigm of self-organizing, context-aware SCNs. In this respect, we show how machine learning, game theory, and related techniques can be synergistically married while providing the network with the capability to: 1) exploit new information from the SCN, such as smartphone features, social ties, or mobility patterns and 2) proactively manage the SCN resources in a self-organizing manner. We conclude the tutorial by discussing the latest trends and future opportunities in small cell research such as SCN caching, cellular-WiFi integration, dual connectivity, network-assisted D2D, and related ideas that will pave the way to the much anticipated 5G wireless systems.

08:30 – 12:30

**WT-7: Mobile Communications in Higher Frequency Bands (MCHF)**

08:30 – 17:30

**WT-1: Telecommunications Standards: From Research to Standards (TCS)**

**WT-2: Cloud Computing Systems, and Networks, and Applications (CCSNA)**

**WT-6: Emerging Technologies for 5G Wireless Cellular Networks (Wi5G, Formerly B4G)**

**WT-8: Optical Wireless Communications (OWC)**

**WT-12: Management of Emerging Networks and Services (MENS)**

13:30 – 17:30

**WT-4: Massive MIMO: From Theory to Practice (MassMIMO)**

08:30 – 12:30

**WT-3: Wireless Optical Network Convergence in Support of Cloud Architectures (WONC)**

08:30 – 17:30

**WT-9: Broadband Wireless Access (BWA)**

**WT-10: Green Broadband Access: Energy Efficient Wireless and Wired Network Solutions (GBA)**

**WT-11: Trusted Communications with Physical Layer Security (TCLS)**

**WT-13: Ultra-Low Latency and Ultra-High Reliability in Wireless Communications (ULTRA)**

**WT-14: Heterogeneous and Small Cell Networks (HetSNets)**

13:30 – 17:30

**WT-15: Wireless Networking and Control for Unmanned Autonomous Vehicles: Architectures, Protocols and Applications (WiUAV)**

# SOCIAL PROGRAM

For further updates, visit [www.ieee-globecom.org/2014/socialprogram.html](http://www.ieee-globecom.org/2014/socialprogram.html)



## WELCOME RECEPTION & EXHIBIT OPENING

Monday, 8 December 2014  
19:00 – 21:30

Enjoy networking with old friends as well as new acquaintances while listening to local music and partaking of traditional food and beverages with the unique opportunity of being immersed in the heart of the “Live Music Capital of the World.” Peruse our world-class exhibits to learn about the latest products and services. In parallel to the reception, there will be the unique opportunity to visit various demonstration events from the industry workshops ('Demo Night').

IEEE COMMUNICATIONS SOCIETY  
AWARDS CEREMONY  
@ IEEE GLOBECOM 2014

## AWARDS CEREMONY

Tuesday, 9 December 2014  
12:15 – 14:00

The Awards Ceremony honors the achievements of IEEE and IEEE Communications Society members. The Society's Career & Service Awards pay tribute to technical professionals whose exceptional achievements and outstanding contributions have made a lasting impact on technology, society, the engineering profession, and humanity. Recipients of these Awards are recognized as the most influential members in their chosen field. Career award recipients are revered for their resolve to discover, extend, or complement technological advancements in education, industry, research and service. Service award recipients are recognized and honored for their distinguished and exemplary service to ComSoc over a sustained period of time. Each year, new recipients join ComSoc's prestigious award honoree list through a selective nomination and approval process.



## YOUNG PROFESSIONALS NETWORKING DIALOGUE WITH INDUSTRY LEADERS RECEPTION

Tuesday, 9 December 2014  
17:30 – 18:30

Young Professionals (YP's) attending IEEE GLOBECOM 2014 will have an excellent opportunity to network with other YP's, as well as with members of the Dialogue with Industry Leaders Panel Session, at a reception in the Exhibit Hall on Tuesday evening. This joint reception will begin at 18:00 with the Young Professionals and a mix of Industry Leaders Panelists interacting while enjoying light hors d'oeuvres and beverages. As people arrive during the reception (non-YP's), they are welcome to participate in the networking opportunity, while awaiting the start of the Panel Session. A few minutes prior to the conclusion of the reception, there will be a toast by the YP's and Industry Leaders Panelists to the success of the IEEE GLOBECOM 2014, and an invitation will be extended to stay in the Exhibit Hall for the Dialogue with Industry Leaders Panel Session starting at 19:00. All attendees are also encouraged to take time to visit our IEEE GLOBECOM Exhibitors. You Gotta Be There!



## CONFERENCE BANQUET

Wednesday, 10 December 2014  
18:30 – 22:30  
Bullock Texas State History Museum

The conference banquet will provide an opportunity for attendees to participate in a unique experience at a truly world-class venue. Attendees will arrive at the Bullock Texas State History Museum to the sounds of a strolling Mariachi band. Guests can then proceed inside to enjoy three floors of the amazing Story of Texas exhibit galleries: Land (first floor); Identity (second floor); and, Opportunity (third floor). After exploring the exhibits, the banquet will begin with a brief program beginning at 19:45 – followed by dinner and networking with your colleagues.

## STARTUP ROUNDTABLE LAUNCHING A STARTUP: TAKING THE PLUNGE, PROTECTING YOUR INVENTION, AND SECURING FUNDING

Thursday, 11 December 2014 • 12:15 – 13:45

We are kicking off a Startup Speaker Series with a panel discussion covering the basic aspects of startups. This is a unique learning and networking opportunity for those of you who might be thinking of taking your research out of the lab and into the real world by commercializing a technology invention. Our panelists, recognized world-class leaders in their field, will introduce the key aspects to consider

### TAKING THE PLUNGE

Is launching a startup right for you? We will explore the fundamental questions you need to answer to make this decision, including how to turn research into a viable product, what talents are needed in early startup teams, how to determine the market potential, competition, and customers for your company's product, and how to plan product development and attain revenues.

### PROTECTING YOUR INVENTION

For all entrepreneurs, but more so for those working with Communications Technologies, IP (especially in the early-stage of the startup) is their most valuable asset. It allows a new company to differentiate from the competition or pioneer new markets. We will discuss what comprises Intellectual Property (IP) and how to protect it.

### SECURING FUNDING

Commercializing technology is typically a capital-intensive process. You will hear about how to build the business case and present it to people such as venture capitalists, angels and perhaps in the initial stages bootstrapping and friends & family.

## ROUNDTABLE PARTICIPANTS

The panel will feature experienced experts, mentors and IEEE Volunteers including:

**Entrepreneur:**  
Andrea Goldsmith,  
Stanford

**IP Experts:**  
Aamir Kazi  
Fish and Richardson

**VC, Investor Expert:**  
TBD

**Moderators:**  
Katie Wilson,  
Santa Clara University  
Elena Neira,  
Verizon



### 3-Day Intensive Wireless Communications Course 8 - 10 December 2014

This course covers seven key areas in which every professional working in wireless should be proficient. Get up to date on RF Engineering, Propagation and Antennas; Wireless Access Technologies; Network and Service Architectures; Wireless Network Management and Security; Infrastructure and Wireless Communication; Agreements, Standards, Policies and Regulations; as well as your basic fundamental knowledge.

Take this course to:

- Expand your understanding of current practices in wireless communications
- Gain a deeper appreciation of wireless network management and security, including industry standards
- Broaden your knowledge of wireless access technologies
- Bridge the gap in your current knowledge to areas you may not work on day to day
- Review your fundamental knowledge

#### Course Materials

A copy of the instructor's PowerPoint slides will be provided along with a copy of *The Wireless Engineering Body of Knowledge (WEBOOK)*, 2nd edition.

**INCREASE YOUR  
 SKILLS AND  
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[www.comsoc.org/training](http://www.comsoc.org/training)

**COURSE ADGENDA**

#### Monday, 8 December 2014

09:00 - 12:30:

- Lecture
- Comsoc Training Intro
- Fundamentals review
- RF Engineering, Propagation & Antennas

12:30 - 13:30:

Lunch

13:30 - 17:00:

- Lecture
- RF Engineering, Propagation and Antennas
- Wireless Access Technologies

#### Tuesday, 9 December 2014

09:30 - 12:30:

- Lecture
- Wireless Access Technologies

12:30 - 13:30:

Lunch

13:30 - 17:00:

- Lecture
- Network and Service Architecture

#### Wednesday, 10 December 2014

09:30 - 12:30:

- Lecture
- Network and Service Architecture
- Network Management and Security

12:30 - 13:30:

Lunch

13:30 - 17:00:

- Lecture
- Network Management and Security
- Facilities & Infrastructure
- Agreements, Standards and Policies

**COURSE PRICING**

#### Before or by 1 November

**US\$1350**

IEEE / ComSoc member

**US\$1500**

Non-member

#### After 1 November

**US\$1450**

IEEE / ComSoc member

**US\$1600**

Non-member

\*\*This course is not included in the conference registration fee for attending.\*\*

**ABOUT THE INSTRUCTOR**



**Lee Vishloff**  
 PEng, IEEE WCP

Mr. Vishloff is the principal engineer in a wireless consultancy focused on cellular-based M2M solutions and short-range wireless products. He has over 30 years of experience in wireless systems and product design. During his career, he has designed a wide range of wireless products including satellite systems, terrestrial radio systems, rural communications, aeronautical and others. Lee brings a wide range of practical experience with hands-on and management experience in wireless telecommunication systems, modem, RF, analog, digital, embedded firmware and mechanical design technologies. He has spent the majority of his career working with equipment manufacturers with stints in the semiconductor and consulting businesses. He has served on numerous joint industry-academic committees during his career, strengthening the link between academic research and practical industry needs. Lee has a degree in Electrical Engineering from the University of British Columbia and completed his management education at Simon Fraser University and the AEA/Stanford Executive Institute. He holds one patent and is a Professional Engineer in the Province of British Columbia, Canada and holds the IEEE WCP (Wireless Communications Professional) designation.

**- Practical, Vendor Neutral Content -**



## REGISTRATION

### FULL and LIMITED TECHNICAL PROGRAM REGISTRATION (Does not include Tutorials or Workshops)

	ON/BY 1 NOVEMBER	AFTER 1 NOVEMBER
RG-01 - Full IEEE ComSoc Member	US\$820	US\$945
RG-02 - Full IEEE Member <sup>1</sup>	US\$845	US\$970
RG-03 - Limited IEEE ComSoc Member	US\$620	US\$745
RG-04 - Limited IEEE Member <sup>1</sup>	US\$645	US\$770
RG-05 - Full Non Member <sup>2</sup>	US\$1100	US\$1280
RG-06 - Limited Non Member <sup>2</sup>	US\$900	US\$1080

- 1) includes complimentary IEEE ComSoc membership (digital delivery of IEEE Communications Magazine)
- 2) includes complimentary affiliate ComSoc membership (digital delivery of IEEE Communications Magazine)

### ONE DAY TECHNICAL PROGRAM REGISTRATION

	ON/BY 1 NOVEMBER	AFTER 1 NOVEMBER
RG-07 - 1 Day IEEE ComSoc Member	US\$435	US\$520
RG-08 - 1 Day IEEE Member	US\$460	US\$545
RG-09 - 1 Day Non Member	US\$645	US\$755

### OTHER REGISTRATIONS

	ON/BY 1 NOVEMBER	AFTER 1 NOVEMBER
RG-10 - IEEE Life Member	US\$50	US\$50
RG-11 - IEEE Student Member (FULL TIME STUDENTS ONLY)	US\$310	US\$370
RG-12 - Student Non Member	US\$385	US\$460
RG-13 - Workshop Only (2 Half or Full Day)	US\$250	US\$350
RG-14 - Tutorials Only	US\$100	US\$150

### INDUSTRY PROGRAM REGISTRATION

	ON/BY 1 NOVEMBER	AFTER 1 NOVEMBER
RG-15 - Full 3 day Industry Program	US\$400	US\$500
RG-16 - 1 Day Industry Program	US\$250	US\$350
RG-17 - IEEE Member: Live 3 Day Intensive Wireless Communications Course	US\$1350	US\$1450
RG-18 - Non Member: Live 3 Day Intensive Wireless Communications Course	US\$1500	US\$1600

### TUTORIALS

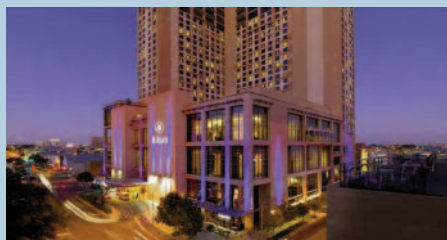
You may register for Tutorials without registering for the conference. Tutorials require an additional fee. Tutorials are not included in any conference registration category.

### WORKSHOPS

You may register for Workshops without registering for the conference. Workshops require an additional fee. Workshops are not included in any conference registration category.

To register online or download the registration form, visit [www.ieee-globecom.org/2014/registration.html](http://www.ieee-globecom.org/2014/registration.html)

## HOTEL



The IEEE GLOBECOM 2014 has chosen as its headquarters hotel, the Hilton Austin. All Technical Sessions, Keynotes, Exhibits, Industry Program, Tutorials and Workshops will be held at the Hilton Austin.



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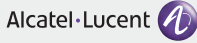





















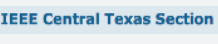






### HOTEL RATES

Room Rate:  
\$199.00 + tax  
(Single and Double)

Reservations must be  
made no later than  
4 November 2014.

>>> Group Code: <<<  
IEEE

To reserve your accommodations, visit [www.ieee-globecom.org/2014/hotel.html](http://www.ieee-globecom.org/2014/hotel.html)

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