GLOBECOM 2015 Highlights –

(Topics in 5G Mobile Networks, Molecular Communications, Vehicular Networks and Lightening Talks)

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Chair – IEEE Denver COMSOC Chapter
http://comsoc.ieee-denver.org

Denver, CO
9 February 2016
Dine and Learn
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- GLOBECOM – COMSOC’s Flagship Conference
  - 5G Mobile Networks
  - Nanoscale, Molecular, and Quantum Communications
  - Vehicular Networks
  - Lightening Talks
  - Future Conferences
  - GLOBECOM – It’s All About the Network
The Global Communications Conference (GLOBECOM) is an annual international academic conference organized by the IEEE Communications Society. Using the theme “Connecting All Through Communications,” IEEE GLOBECOM 2015 recently held its 58th annual event in San Diego, California with more than 2,500 attendees participating in 1,500 presentations focused on the hot topics in voice, data, image and multimedia communications including the Internet of Things (IoT), “5G” mobile network technology, Cloud Computing and next generation networks.
Highlights from the 2015 GLOBECOM Conference

Patrons and Exhibitors
Greatly Expanded Industry Program

- 8 Keynotes
- 3 Executive forum panel
  - “Dialogue with industry leaders” combined with YP.
- 1 Lightning talks
- 24 industry panels
- 2 Workshops
  - 4 converted to tutorial for low fee.
- 16 IF&E Tutorials
- 10 Interactive posters
- 23 Interactive demos
- Startup entrepreneur panel
GLOBECOM 2015 Keynote Speakers

Mark Dankberg, Co-Founder, CEO and Chairman of the Board of ViaSat, will discuss "Connecting the Un-connected: The Role of Satellites for Internet Access" and provide some surprising facts about the geographic distribution of demand for connectivity, trade-offs among the technical and economic factors that determine cost effective supply, and the role that space can play in serving that demand.

Eric Starkloff, Executive Vice President of Global Sales and Marketing of National Instruments, will speak on "Transforming Traditional Design Paradigms in 5G Wireless Communications" and overcoming complex system challenges with software defined radio and new graphical approaches.

Matt Grob, EVP and CTO, Qualcomm Technologies, Inc., will talk about "From 4G to 5G: The Evolution of Mobile Communication" and the arrival of LTE in unlicensed spectrum, expanded connectivity needs and new connectivity paradigms.

Ron Neresian, President and CEO, Keysight Technologies, will address "The Future of Test and Measurement for Commercial Communications" including the drive to further simulation, measurement, and validation dimensions with an unprecedented emphasis on software and applications relating to network performance.

Seizo Onoe, CTO, EVP, Member of Board of Directors, and Managing Director of R&D Innovation Division of NTT DOCOMO, INC., will cover "Evolution toward 5G and Beyond" as well as the current status of LTE, LTE-Advanced and the latest technology trends.

Wen Tong, Huawei Fellow and Wireless CTO at Huawei, will discuss "Bringing 5G into Reality" and the global progress with respect to 5G requirements, spectrum identification and standardization, the views on the early market applications and long term full span of a 5G-world.

Kenneth Stewart, Intel Fellow and Chief Wireless Technologist at Intel, will talk about the "Future of Wireless Technologies – From 5G to IoT/MTC" and the development of new radio access technologies (RAT(s)) focused on flexible and efficient physical layer frameworks: efficient and flexible time and frequency domain multiplexing providing the optimal tradeoff between reliability, latency and efficiency.
Highlights from the 2015 GLOBECOM Conference

11/27/18

IEEE GLOBECOM 2015: Keynotes, Workshops and Lightening Talks

- #GLOBECOM: National Instruments VP on 5G, IoT and more
- #GLOBECOM: Mark Dankberg of ViaSat on satellite-based wireless communications
- #GLOBECOM: Mark Dankberg of ViaSat on satellite-based wireless communications, part 2
- #GLOBECOM: National Instruments VP on 5G, IoT and more, part 2
- #GLOBECOM: Qualcomm EVP/CTO on evolution from 4G to 5G
- #GLOBECOM: Qualcomm EVP/CTO on evolution from 4G to 5G, part 2
- #GLOBECOM: Keysight SVP/CTO on the future of test and measurement
- #GLOBECOM: IEEE event General Chair discusses Globecom, 5G and more
- #GLOBECOM: 5G a key theme of IEEE annual event.
- #Globecom: Intel LTE Wi-Fi aggregation demo
- #Globecom: Intel mmWave MAA client access & backhaul platform
- #Globecom: Keysight Technologies’ IoT testing solutions
- #Globecom: Keysight Technologies’ EXM product demo
- #Globecom: Keysight 5G candidate waveform testing solution
- #Globecom: National Instruments 2x2 MIMO communication system
GLOBECOM 2015 Keynote Talks

#GLOBE.COM: IEEE event General Chair discusses Globecom, 5G and more
#GLOBE.COM: 5G a key theme of IEEE annual event.

#GLOBE.COM: National Instruments VP on 5G, IoT and more
#GLOBE.COM: National Instruments VP on 5G, IoT and more, part 2

#GLOBE.COM: Mark Dankberg of ViaSat on satellite-based wireless communications
#GLOBE.COM: Mark Dankberg of ViaSat on satellite-based wireless communications, part 2

#GLOBE.COM: Qualcomm EVP/CTO on evolution from 4G to 5G
#GLOBE.COM: Qualcomm EVP/CTO on evolution from 4G to 5G, part 2

#GLOBE.COM: Keysight SVP/CTO on the future of test and measurement

#Globecom: Future of Wireless Technologies – From 5G to IoT part 1
#Globecom: Future of Wireless Technologies – From 5G to IoT part 2

#GLOBECOM: NTT Docomo CTO talks evolution toward 5G and beyond
#GLOBECOM: NTT Docomo CTO talks evolution toward 5G and beyond part 2

#Globecom: Huawei SVP - Bringing 5G into Reality part 1
#Globecom: Huawei SVP - Bringing 5G into Reality part 2
23 Interactive Demos

ID-1: 10Gbps E-band Radio Link
ID-2: 5G Architecture and 5GPPP
ID-3: A Prelude to the 5G Core Network Architecture
ID-4: A Real-time 20 MHz 128 Antenna Base station Massive MIMO with 12 UEs based on TDD Channel Reciprocity
ID-5: Bi-directional In-band Full Duplex Communication for Real-Time Video Contents Streaming
ID-7: Dense Cooperative Wireless Cloud Networks (DIWINE) **BOOTH in EXPO**
ID-8: fuseami the smarter networking app **BOOTH in EXPO**
ID-9: Intelligent Electric vehicle charging System (IEVCS)
ID-11: Pre 5G Wireless Concepts: DAN Anchor Booster **BOOTH in EXPO**
ID-13: Pre 5G Wireless Concepts: LTE/ WIFI Aggregation **BOOTH in EXPO**
ID-14: Pre 5G Wireless Concepts: Millimeter Wave Backhaul **BOOTH in EXPO**
ID-15: Pre 5G Wireless Concepts: Open Internet Consortium SmatTap **BOOTH in EXPO**
ID-16: Radio-as-a-Service 4G LTE Network
ID-17: Real-time Prototyping of 5G Software Defined Networks using National Instruments SDR Platform and the NS3 Network Simulator
ID-18: RF DSP Inc.’s Massive MU-MIMO Development Platform **BOOTH in EXPO**
ID-19: Role of Biometric Systems to Improve Security and Performance in Big Data
ID-20: SDN-Based Security Enforcement in Mobile Networks using VNFs
ID-21: SDR Testbed for Carrier Frequency Offset Correction in Uplink Multi-user MIMO for Next-Generation WiFi
ID-22: Sub-Nyquist Systems
ID-23: Demonstration of Real-time MIMO Full-duplex Radio with Adaptive Self-interference Cancellation
GLOBECOM 2015 Vendor Demonstrations

#Globecom: Intel LAA carrier aggregation demo
#Globecom: Intel LTE Wi-Fi aggregation demo
#Globecom: Intel mmWave MAA client access & backhaul platform

#Globecom: Keysight Technologies’ IoT testing solutions
#Globecom: Keysight Technologies’ EXM product demo
#Globecom: Keysight 5G candidate waveform testing solution

#Globecom: National Instruments 2×2 MIMO communication system
#Globecom: NI Massive MIMO real-time prototyping system
#Globecom: National Instruments 8×8 MIMO
#Globecom: National Instruments talks real-world 5G prototypes

#GLOBECOM: Qualcomm LAA/Wi-Fi interactive demo
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Evolution of the Cell Phone (WWII)

http://content.time.com/time/photogallery/0,29307,1636836_1389493,00.html

Highlights from the 2015 GLOBECOM Conference
### WHAT IS 5G?

**CONTRIBUTION OF EU RESEARCH**

<table>
<thead>
<tr>
<th>What 5G will bring to you?</th>
<th>What's new with 5G?</th>
<th>EU projects</th>
<th>5G applications</th>
<th>Why not today?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>amazing volume</strong></td>
<td>spectrum extension; millimetre waves; cell densification; increase spectrum efficiency; advanced antennas; 3D beam-forming techniques; new electronic components; backhaul optimization; D2D; moving networks (vehicle based cells)</td>
<td>5GNOW, HARP, MOON, TROPIC</td>
<td>hologram TV, immersive presence, augmented reality, ultra large volume transfers</td>
<td>spectrum saturation; limited spectrum aggregation; current hardware not able to function at high frequencies; expensive deployment &amp; maintenance of small cells</td>
</tr>
<tr>
<td><strong>amazingly fast</strong></td>
<td>combination of 4G, 5G, Wi-Fi, &amp; new radio access to create an integrated &amp; dynamic radio access network; connectivity management mechanisms</td>
<td>CROWD</td>
<td>staying connected everywhere including high-speed trains, planes, crowds</td>
<td>seamless handover (e.g., cellular to Wi-Fi) not supported</td>
</tr>
<tr>
<td><strong>always best connected</strong></td>
<td>ultra-low latency; software-defined networks; decoupling functional architecture from the underlying physical infrastructure; network intelligence closer to users; MEC (mobile edge computing), D2D</td>
<td>5GNOW</td>
<td>tactile internet; reactive interfaces; electricity grid control, vehicle to vehicle, robot control, connected cars, remote surgery</td>
<td>4G latency ≥ 10ms</td>
</tr>
<tr>
<td><strong>no perceived delay</strong></td>
<td>new waveform; cell densification; much less signalling traffic &amp; no synchronisation; RAN architecture</td>
<td>MEC M2M</td>
<td>internet of things, smart cities, connected cars, e-health</td>
<td>current OFDM waveform limitations, interference prevents scaling up, 4G chips cost, energy consumption</td>
</tr>
<tr>
<td><strong>massive amount of</strong></td>
<td>millimetre waves for front-haul &amp; backhaul; new operating mechanisms for dense networks; pooling of base station processing; on-demand consumption; massive machine communications; power amplifiers; DSP (digital signal processing) - enabled optical transceivers; harvesting ambient energy; optimization of sleep mode switching</td>
<td>5GNOW</td>
<td>80% energy saving; deployment in developing countries</td>
<td>Base stations idle time not optimised; unused functions activated; air interface/hardware not energy optimized</td>
</tr>
<tr>
<td><strong>connected things &amp; people</strong></td>
<td>flexible programmable networks</td>
<td>5GNOW</td>
<td>new business models for innovative SMEs providing network functions; emergence of super MVNOs; pan European operators, faster innovation in network services</td>
<td>many various network management software, not interoperable; bundling of network functions in hardware boxes</td>
</tr>
<tr>
<td><strong>energy efficiency</strong></td>
<td>software-defined networks; network function virtualisation; decoupling functional architecture from the underlying physical infrastructure; APIs</td>
<td>5GNOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>secure networks</strong></td>
<td>physical channel authentication; virtualised authentication</td>
<td>5GNOW</td>
<td>networks for police &amp; security professionals; privacy</td>
<td>Security as add-on not by design; fragmented approach</td>
</tr>
</tbody>
</table>
**International Workshop on Emerging Technologies for 5G Wireless Cellular Networks**

In conjunction with IEEE GLOBECOM 2015, Thursday, December 10, 2015, San Diego, CA, USA

### Workshop Chairs
- Wei Yu, University of Toronto, Canada
- Tommy Svensson, Chalmers University of Technology, Sweden
- Lingjia Liu, University of Kansas, USA

### Technical Program Chairs
- Halim Yanikomeroglu, Carleton University, Canada
- Charlie (Jianzhong) Zhang, Samsung Research America at Dallas, USA
- Peiying Zhu, Huawei Technologies, Canada
- Huseyin Arslan, Istanbul Medipol University, Turkey

### Plenary Speakers
- Mouez Debbah, Huawei Technologies
- Syed Ali Jafar, University of California, Irvine
- Eduard Jorswieck, TU Dresden
- Andreas Molisch, University of Southern California
- John Sme, Qualcomm
- Geng Wu, Intel

### Panel Program
**Driving Innovations in 5G**
- Nada Golmie, NIST
- Thiraviraj Nandagopal, NSF
- Sean Cai, ZTE
- Maziar Nekove, Samsung/mmMagic
- Sanyopita Shamsunder, Verizon

### Workshop Program

<table>
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<tr>
<th>Time</th>
<th>Session Description</th>
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</thead>
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<tr>
<td>8:25 am - 8:30 am</td>
<td>Opening and Welcome (Room: Indigo G)&lt;br&gt;Wei Yu, University of Toronto, Canada</td>
</tr>
<tr>
<td>8:30 am - 9:00 am</td>
<td>Plenary Talk #1 (Room: Indigo G)&lt;br&gt;5G Systems Design Across Services (Presentation)&lt;br&gt;Dr. John Sme, Senior Director of Engineering, Qualcomm Technologies Inc., USA</td>
</tr>
<tr>
<td>9:00 am - 9:30 am</td>
<td>Plenary Talk #2 (Room: Indigo G)&lt;br&gt;Network Slicing for Future 5G Wearable Devices and Internet of Things (Presentation)&lt;br&gt;Dr. Geng Wu, Fellow and Chief Wireless Technologist, Intel, USA</td>
</tr>
<tr>
<td>9:30 am - 11:00 am</td>
<td>Poster Session 1 (Room: Indigo G)&lt;br&gt;Chair: Jonathan Ashdown, U.S. Air Force Research Laboratory&lt;br&gt;- 09:30 am - 10:00 am Poster Overview (2 minutes/paper)&lt;br&gt;- 10:00 am - 11:00 am Poster Session&lt;br&gt;- MIMO &amp; Interference Alignment&lt;br&gt;Robust Transmit Design for MISO Gaussian Broadcast Channel with Integrated Services&lt;br&gt;Weiqing Kong (University of Electronic Science and Technology of China, P.R. China); Zhi Chen (University of Electronic Science and Technology of China &amp; University of California, Riverside, P.R. China); Lingsiang Li and Chuan Huang (University of Electronic Science and Technology of China, P.R. China)</td>
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**11/27/18**

Highlights from the 2015 GLOBECOM Conference
5G Systems Design Across Services (Presentation)
Dr. John Smee, Senior Director of Engineering, Qualcomm Technologies Inc., USA

Network Slicing for Future 5G Wearable Devices and Internet of Things (Presentation)
Dr. Geng Wu, Fellow and Chief Wireless Technologist, Intel, USA

An Information Theoretic Perspective on Avoiding Strong and Ignoring Weak Interference (Presentation)
Prof. Syed Ali Jafar, University of California, Irvine, USA

Optimal Resource Allocation in Distributed Heterogeneous 5G Wireless Networks (Presentation)
Prof. Dr.-Ing. Eduard Jorswieck, Technische Universität Dresden

Massive MIMO for Maximal Spectral Efficiency: How Many Users and Pilots Should Be Allocated? (Presentation)
Dr. Mérouane Debbah, Mathematical and Algorithmic Sciences Lab, Huawei

Hybrid Transceivers for Massive MIMO - Some Recent Results (Presentation)
Prof. Andreas Molisch, University of Southern California, USA

Driving Innovations in 5G (Symposium Panels)

Nada Golmie Chief, Wireless Networks Division, (NIST) (Presentation)
Thyagarajan Nandagopal, Program Director, National Science Foundation (NSF), (Presentation)
Sean Cai, Vice President, CTO Group, ZTE Corporation, (Presentation)
Maziar Nekovee, Chief Engineer, Samsung Electronics R&D Institute UK, (Presentation)
Sanyogita Shamsunder, Director of Strategy-Technology/Network CTO Office, Verizon Wireless, (Presentation)
Highlights from the 2015 GLOBECOM Conference

Huawei Vision of 5G (Potential Technologies)

Potential Technologies to Meet ITU Requirements

- New waveform e.g. f-OFDM
- Wider Bandwidth
- Adaptive frame structure
- Non-Orthogonal Multiple Access, e.g. SCMA
- UCNC
- Massive MIMO
- Polar Code

eMBB
Enhanced Mobile Broadband

- Shorter TTI
- SCMA based grant-free Tx
- Fast system re-entry scheme
- ACK/NACK less re-transmission
- UE cooperation diversity
- New data notification methods
- Polar Code

mMTC
Massive Machine Type Communications

- Grant-free multiple access
- Narrow band SCMA
- Asynchronous (TA-free) Transmit
- UE dedicated connection ID
- Polar Code for small packet

uMTC
Ultra-reliable and Low-latency Communications


Highlights from the 2015 GLOBECOM Conference

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Proposed Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>20 Gbps</td>
</tr>
<tr>
<td>5G</td>
<td>20 Gbps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spectral Efficiency</th>
<th>5G will improve downlink spectral efficiency (bits per second per hertz) threefold.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>0.1 b/s/Hz</td>
</tr>
<tr>
<td>5G</td>
<td>4.5 b/s/Hz</td>
</tr>
<tr>
<td>5G</td>
<td>4.5 b/s/Hz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Processing</th>
<th>4G will be able to process 100 times as much data in a given area (megabits per second per square meter).</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>10 MB/s/㎡</td>
</tr>
<tr>
<td>5G</td>
<td>0.1 MB/s/㎡</td>
</tr>
<tr>
<td>5G</td>
<td>0.1 MB/s/㎡</td>
</tr>
<tr>
<td>5G</td>
<td>0.1 MB/s/㎡</td>
</tr>
</tbody>
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<tr>
<th>Device Density</th>
<th>About 900,000 more devices per square kilometer will be able to connect to the network.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>100K/㎞²</td>
</tr>
<tr>
<td>5G</td>
<td>1M/㎞²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mobility</th>
<th>5G can provide data to devices moving at up to 350 kilometers per hour. 5G will provide data to devices moving at up to 500 km/h.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>350 km/h</td>
</tr>
<tr>
<td>5G</td>
<td>500 km/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transmission Delay</th>
<th>5G will have one-tenth the latency (milliseconds) of 4G</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td></td>
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<tr>
<td>5G</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Energy</th>
<th>4G takes 1 millijoule to transfer a 1,000-bit data packet. 5G will be able to transfer packets 100 times as efficiently</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td></td>
</tr>
<tr>
<td>5G</td>
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http://spectrum.ieee.org/telecom/wireless/telecom-experts-plot-a-path-to-5g

Highlights from the 2015 GLOBECOM Conference

Proposed Technologies Explained

Millimeter wavelength spectrum: To the surprise of many, engineers have demonstrated mobile data speeds higher than 1 gigabit per second on millimeter-wave frequencies (30 to 300 gigahertz). This will expand the amount of cellular spectrum beyond the prized but limited ultrahigh-frequency band used today.

Massive multiple-input, multiple-output (MIMO): One way to use the millimeter wavelength is through massive MIMO, which uses a huge array of antennas to steer and finely focus a radio beam so that it hits a receiver. Engineers have been able to fit 64 antennas in a space the size of a Post-it note.

Device-to-device (D2D) communication: D2D will allow direct communication between devices in close proximity without network assistance. Skipping the base station means one less step in getting information to devices.

Full duplex system: This allows the transmitting and receiving of data at the same time and on the same frequency.

Small cells: Increasing the number of small-cell base stations will increase bandwidth. This will provide enough capacity for devices to consume hundreds of megabits per second.

Radio-access network virtualization: General radio-access network processor functions will be virtualized into the cloud. Today’s radio-access network is built with many individual base stations. By virtualizing the network, multiple service providers can physically share the same data center platform without any impact on connection strength.

Heterogeneous network architectures: Made of a combination of pico cells, small cells, macro cells, and different layers, these networks will provide appropriate coverage as the distance between a device and a base station changes. This kind of network will also be able to handle real-time location tracking and quick handoffs between base stations so that devices can keep working even when they’re moving at high speeds.

Content caching close to users: Information that is accessed frequently will be cached closer to the user so that it takes less time to get the data.

http://spectrum.ieee.org/telecom/wireless/telecom-experts-plot-a-path-to-5g

Highlights from the 2015 GLOBECOM Conference
5G Timeline (Huawei)


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- GLOBECOM – It’s All About the Network
How can we communicate at very small length scales? This question may unlock new applications in nanorobotics and medicine, but has only recently attracted attention from communication and information theorists. The answer to the question is surprisingly difficult: not only are the required techniques the unfamiliar to communication engineers, but the mathematical details of the communication environment are complicated.

Attendees of this tutorial will: understand the basic physics and mathematics of nanoscale communication; understand nanoscale EM techniques; receive a basic introduction to the biological machinery of molecular communication; understand the communication and information theory of nanoscale communication; and understand some of the applications, both at nanoscale (e.g., nanomedicine) and macroscale (e.g., robots communicating via chemical “tags”). Signaling and interaction in some bacterial systems will also be considered. The tutorial will conclude with a brief exploration into a new research topic on quantum communications taking a short walk down Lajos' Quantum Ave.
TT-9 Guest Speakers

- **Dr. Urbashi Mitra**, IEEE Fellow, Professor of Electrical Engineering and Computer Science (USC Viterbi School of Engineering). Chief Editor IEEE Transactions on Molecular, Biological and Multi-Scale Communications ([http://www.comsoc.org/tmbmc/editorial-board](http://www.comsoc.org/tmbmc/editorial-board))

- **Dr. Andrew Eckford**, Associate Professor in the Department of Electrical Engineering and Computer Science at York University, Toronto, Ontario. Co-author of the textbook Molecular Communication (Cambridge University Press) and co-editor IEEE Transactions on Molecular, Biological and Multi-Scale Communications

- **Dr. Lajos Hanzo**, IEEE Fellow, Chair of Telecommunications, University of Southampton, He has co-authored 20 John Wiley/IEEE Press books totaling about 10 000 pages on mobile radio communications, 1200+ research papers and book chapters at IEEE Xplore
Highlights from the 2015 GLOBECOM Conference
Concepts of Nanoscale, Molecular, and Quantum Communications

Next Generation Wireless Communication Lab - http://nwcl.ku.edu.tr/nanoquantum.html
Concepts of Nanoscale, Molecular, and Quantum Communications

Molecular Communication Mechanisms

- **Walk**
  - Molecules propagate through pre-defined pathways by using carrier substances, such as molecular motors

- **Flow**
  - Molecules propagate through diffusion in a fluidic medium whose flow and turbulence are guided and predictable

- **Diffusion**
  - Molecules propagate through spontaneous diffusion in a fluidic medium
Concepts of Nanoscale, Molecular, and Quantum Communications

What is capacity for bacteria?

- Bacteria as “devices” that sense the environment, estimate, and react
- Idea: tools from information theory and communications to model and predict bacterial networks:
  - Interactions, dynamics, formation
  - Do bacteria realize optimal control strategies?
  - E.g.: optimize MFC growth
Concepts of Nanoscale, Molecular, and Quantum Communications

Physical Building Blocks

The Central Dogma of Molecular Biology

- What is DNA?
  - A 4-ary string (A, T, C, G) which “hybridizes” with itself (A-T, C-G) to form a double helix

- What is RNA?
  - Similar to DNA, a 4-ary string (A, U, C, G)
  - Single-stranded
  - RNA transcription
    - Reading from a DNA strand, starting from a promoter and ending with a terminator, RNA is formed as the dual of the DNA nucleotide

- What is a protein?
  - A polymer of amino acids, connected with peptide bonds
  - An amino acid is:
    - An amine group (-NH₂)
    - A carboxyl group (-COOH)
    - An “R group”
Concepts of Nanoscale, Molecular, and Quantum Communications

Physical Layer Examples

- Inter-organ examples (1 mm – 2 m)

<table>
<thead>
<tr>
<th>Example</th>
<th>Transmitter/Receiver</th>
<th>Signal molecule</th>
<th>Scale (Distance)</th>
<th>Mode (Speed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphogen</td>
<td>Anchor cells/Preceptor cells</td>
<td>LIN-3 (EGF)</td>
<td>Inter-org (0.1 cm)</td>
<td>Passive (5&lt;10^-7 cm/s)</td>
</tr>
<tr>
<td>Hormonal</td>
<td>Pituitary gland cells/Thyroid gland cells</td>
<td>TSH (Hormone)</td>
<td>Inter-org (1 m)</td>
<td>Passive (5 cm/s)</td>
</tr>
<tr>
<td>Neuronal</td>
<td>Brain cells/Heart cells</td>
<td>Action Potential</td>
<td>Inter-org (2 m)</td>
<td>Passive (100 m/s)</td>
</tr>
</tbody>
</table>

- Data Link Layer
  - Physical addressing: DNA hybridization

Key Challenge: How to control physical layer “hardware” (wetware)?
Concepts of Nanoscale, Molecular, and Quantum Communications

Highlights from the 2015 GLOBECOM Conference
Nanoscale, Molecular, and Quantum Communications – Terms and References

- Molecular Nano-Communication Networks (Georgia Tech): Dr. Ian Akylidis and colleagues. [http://www2.ece.gatech.edu/research/labs/bwn/monaco/index.html]


- Nanonetworking: a New Frontier in Communications: Dr. Ian Akylidis and colleagues. [http://www2.ece.gatech.edu/research/labs/bwn/nanos/projectdescription.html]

- The Internet of Bio-Nano Things: Dr. Ian Akylidis and colleagues. [http://www2.ece.gatech.edu/research/labs/bwn/papers/2015/j3.pdf]


- Quantum-assisted and Quantum-based Communications – Lajos Hanzo research area [http://www-mobile.ecs.soton.ac.uk/newcomms/?q=res/int/quantum]


**Molecular Communication:** Molecular communication is a new and interdisciplinary field that spans nano, bio, and information and communication technologies (ICT). Unlike previous communication techniques, the integration of molecular transceivers in nanomachines is more feasible due to their size and natural domain. These transceivers are nanomachines able to react to specific molecules and to release others as a response to an internal command. The high bio-compatibility, the lower power consumption with reference to the classical communication schemes and the exploitation of truly nanoscale structures (molecules) enable the feasibility of this approach for solving nanocommunications problems.
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TWIF-4: Opportunities and Challenges with Vehicular Networks

- With the prospect of deployment of vehicular networks, there are challenges and debates. Viable deployment models, pros and cons of different air interfaces, spectrum sharing issues and security and privacy concerns are but a few. These sessions cover these multiple aspects of opportunities and challenges with vehicular networks by first describing the near-term opportunities for deployment, not only with Dedicated Short Range Communications (DSRC) but also with evolving concepts in LTE, spectrum sharing across unlicensed technologies, up to and including 5G. The session will also cover network security and privacy issues, and will conclude with panels and presentations that describe current research in network simulation, vehicular cloud computing and vehicle telematics.

- Tim Weil, Principal, SecurityFeeds, LLC (Moderator)
- Dedicated Short Range Communication (DSRC) - Ready for Prime Time (Walton Fehr - US DOT)
- 5.9 GHz Spectrum Sharing - (John Kenney - Toyota ITC)
- Is there LTE in V2V? (Jim Misener - Qualcomm)
- Why We Need a New Paradigm for Securing the Internet of Vehicles (Tao Zhang - Cisco)
- Research and Prototyping Activities of Dedicated Short Range Communications (DSRC) at the University of Michigan (Weidong Xiang – University of Michigan)
- Towards the Vehicular Cloud - Falko Dressler: Professor of Computer Science, University of Paderborn
TWIF-4 Guest Speakers

- **Dr. John B. Kenney:** is Network Division Director and Principal Researcher at the Toyota InfoTechnology Center in Mountain View, CA. He leads a team researching vehicular communication, including DSRC, Automated Driving, and Smart Grid. His personal research focuses on performance and standardization of DSRC, especially channel congestion control and spectrum sharing.

- **Jim Misener** is Director, Technical Standards at Qualcomm Technologies, Inc., leading Qualcomm’s international automotive standardization efforts. Mr. Misener is Chair for the SAE Dedicated Short Range Communication Technical Committee and a member of the IEEE P1609 Working Group. He is US Expert in ISO TC/204 WG 17 (Nomadic Devices) and 18 (Cooperative ITS).

- **Dr. Tao Zhang** joined Cisco in 2012 as the Chief Scientist for Smart Connected Vehicles. Since then, he has also been developing architectures and strategies for Internet of Things and Fog Computing. Prior to joining Cisco, he had been Chief Scientist and Director of Mobile and Vehicular Networking at Telcordia Technologies. He was elected a Fellow of the IEEE in 2010. Dr. Zhang is author of *Vehicle Safety Communications: Protocols, Security and Privacy (Wiley 2012).*

- **Dr. Weidong Xiang** is an Associate Professor at University of Michigan, Dearborn (UMD) where his research interest includes vehicular communications and networks, ultra-wideband (UWB), wireless networked control systems, Internet of Things and wireless positioning. He established and leads the Center for Vehicular Communications and Net-work Laboratory at UMD focusing on dedicate short range communications (DSRC), machine type communications (MTC), LTE for high mobility applications and UWB positioning. Dr. Xiang is author of *Physical Layer Technology for Connected Vehicles (Springer)*

- **Dr. Falko Dressler** is a Full Professor for Computer Science and head of the Distributed Embedded Systems Group at the Dept. of Computer Science, University of Paderborn. He is an editor for journals such as IEEE Trans. on Mobile Computing, Elsevier Ad Hoc Networks, Elsevier Computer Communications, and Elsevier Nano Communication Networks. Dr. Dressler is author of *Vehicular Networking (Cambridge University Press 2015)*

- **Walton Fehr** is an engineering professional with extensive experience in a wide variety of engineering and marketing roles in the automotive industry, including electronic component design, technology introduction, and business development. Specialties: Lead multi-discipline engineering teams, designed products for rigorous automotive applications, transferred technology from Internet and telecom into automotive.
Secure Automotive Networking for ITS - A Work in Progress

### Security Architecture - Vehicle Communications

- TCV (Transport Collaboration Vehicle)
- U.S. DOT National ITS Architecture
- Security Lessons from the US Army
- Container Security
- Network on Wheels (NOW)
- System Architecture - ITS Japan

### National Projects (US)

- DOT DOT Connected Vehicle
- US DOT Safety Pilot (Connected Vehicle)
- Intelligent Drive Project (IVP)
- DOT RITA Library
- V2I POC Results and Findings: Infrastructure (HTML)
- V2I POC Results and Findings: Summary (Vehicle) (HTML)
- V2I POC Technical Description: Infrastructure (PDF)

### Vehicle Safety Communications (VSC-a) 2009 Project Results

- NETSA Office of Crash Avoidance, TechPubs
- VSC-A Final Report, September 2011
- VSC-A System Design & Objective Test: September 2011
- VSC-A Communications & Positioning: September 2011
- VSC-A Safety: September 2011

### State Projects

- USITS Resources
- Michigan ITS
- California PATH
- ITS Florida - Connected Vehicle
- ITS Viridis
- Rocky Mountains ITS

### EU Consortium Projects (EU)

- Secure Vehicle Communication (SaVeCom)
- Car-To-Car Consortium (Car2Car)
- ITS-Europe/Erico
- GeoNet
- ITS-Europe/PreVent
- CVIS - Cooperative Vehicles Infrastructure Systems
- PRECOSA - ITS Privacy Project

### Research and Development

- IEEE Intelligent Transportation Systems Society
- IEEE Vehicular Technology Society
- KPL Secure Vehicular Communications Workshop
- California Partners for Advanced Traffic and Highways
- Vehicular (Vienna, Austria - University of Vienna)
- Vehicular Call for Papers
- Southwest Research Institute (SWRI) - VITEC
- SANT research resources
- SaVeCom Research Bibliography (000-3659)

### Security Feeds – Security Automotive Networking


### Testbeds and Commercial Markets

- ITS America
- Daimler/DSRC Consortium
- Telecommunications Update
- Japan ITS Manufacturers
- Medium-Range Application Vehicle (VRC)
- Dependable Traffic Communication
- Vehicle - Embedded Security Systems
- Renessei/NTT/VTI
- China Technical - VC Projects
- O2 (Berlin) - ITS Toll and Surveillance Solutions

### Connected Vehicle (CV) - Safety Pilot Program (6 Venues)

- US DOT CV Research 2011
- US DOT CV Research 2011 - V2V Safety Applications
- US DOT CV Research 2011 - Safety Pilot Program Overview
- CV Security Environment - Policy Workshop
- CV Security Environment - Certificate Management (Glides)
- CV Security Environment - Certificate Management (Report)
- CV Security Environment - Communication Data Delivery
- CV Security Environment - AAMTC CV Environment Analysis Report

### ITS Conferences and Books

- 7th ETSS Security Workshop (Greetsiel 2011)
- 7th ETSS Security Workshop (Greetsiel 2011)
- ITS World Congress 2011 (Shanghai, China)
- IEEE Vehicular Technology Society
- IEEE GLOBECOM - V2V and VANET Workshop
- IEEE GLOBECOM - Vehicular Networking (V2V)
- IEEE Vehicular Networking (VANET)
- ITS America Conference Presentation
- Vehicular Networking (V2V and VANET)
- Infrastructure: ITS Experiences and Forum

### Wiki ITS References

- Vehicle Telematics (Wiki)
- DSRC - Dedicated Short Range Communication (Wiki)
- WAVE 802.11p - Wireless Access for Vehicular Environment (Wiki)
- ITS Vehicles: Communication Systems (Wiki)
- Intelligent Transportation Systems (Wiki)
- Switzerland: ITS Experiences and Forum

### 11/27/18

Highlights from the 2015 GLOBECOM Conference
A New Era of Connected Car Capabilities

The variety of connected vehicle applications can be handled by a variety of over-the-air technologies, depending on application requirements.
US DOT ITS CV Pilot –
http://www.its.dot.gov/pilots/index.htm

Highlights from the 2015 GLOBECOM Conference
**USDOT Application Research**

## Connected Vehicle Applications

### V2I Safety
- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Gap Assist
- Spot Weather Impact Warning
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized Crosswalk Warning (Transit)

### V2V Safety
- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DPNW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

### Agency Data
- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- Vehicle Classification-based Traffic Studies
- CV-enabled Turning Movement & Intersection Analysis
- CV-enabled Origin-Destination Studies
- Work Zone Traveler Information

### Environment
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
- Connected Eco-Driving
- Wireless Inductive/Resonance Charging
- Eco-Lanes Management
- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Eco-Traveller Information
- Eco-Ramp Metering
- Low Emissions Zone Management
- AFV Charging / Fueling Information
- Eco-Smart Parking
- Dynamic Eco-Routing (light vehicle, transit, freight)
- Eco-ICM Decision Support System

### Mobility
- Advanced Traveler Information System
- Intelligent Traffic Signal System (I-SIG)
- Signal Priority (transit, freight)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)
- Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)
- Connection Protection (T-CONNECT)
- Dynamic Transit Operations (T-DISP)
- Dynamic Ridesharing (D-RIDE)
- Freight-Specific Dynamic Travel Planning and Performance
- Drayage Optimization

### Road Weather
- Motorist Advisories and Warnings (MAW)
- Enhanced MDSS
- Vehicle Data Translator (VDT)
- Weather Response Traffic Information (WxTINFO)

### Smart Roadside
- Wireless Inspection
- Smart Truck Parking

---

Most of these use V2I, on channels other than Ch. 172

*Source: US Department of Transportation*
A Variety of Communication Media, Data Transport Needs

Resources: wired and wireless, the Internet

• 3,000 miles, 3,000 meters, 300 meters, 3 meters.

Would like to be able to use the best medium for the communication purpose,

Be able to opportunistically use whatever medium is available as a traveler moves through their environment.
DSRC – a Key Part of Communications

• Large-scale pilots are underway that will exercise the full capability of DSRC
• Arrived at a consensus of interpretation of standards for the next generation of installations
• Production programs are underway

Yes, DSRC is ready for Prime Time
DSRC Spectrum Sharing
What is the issue?

- FCC has given DSRC a “Primary” allocation in 5.850-5.925 GHz
- Wi-Fi community has asked FCC to let them share the spectrum on the condition that they cause “no harmful interference” to DSRC
- Basic question: Is this feasible and if so how would it work?
DSRC Spectrum Sharing

- Initial FCC allocation 1999
- definition of channels and rules in 2003 & 2006

<table>
<thead>
<tr>
<th>5850 MHz</th>
<th>CH 175</th>
<th>20 MHz</th>
<th>CH 181</th>
<th>20 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>5850-5855 MHz</td>
<td>CH 172</td>
<td>Service</td>
<td>CH 174</td>
<td>Service</td>
</tr>
<tr>
<td>Reserve</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td>CH 176</td>
<td>Service</td>
</tr>
<tr>
<td>5 MHz</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td>CH 178</td>
<td>Control</td>
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<td>10 MHz</td>
<td>10 MHz</td>
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<td>CH 180</td>
<td>Service</td>
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<td>CH 182</td>
<td>Service</td>
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<td>10 MHz</td>
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<td></td>
<td>CH 184</td>
<td>Service</td>
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<td>10 MHz</td>
<td>10 MHz</td>
</tr>
</tbody>
</table>

- Ch. 172: Collision Avoidance Safety
- Ch. 178: Control Channel, advertises services on service channels
- Ch. 184: Public Safety
DSRC Deployment

• Attention on V2V safety: Ch. 172
  – GM Cadillac model year 2017
  – NHTSA mandate likely ~2020

• US DOT Pilot Deployments:
  – Awarded 2015
  – New York, Tampa, Wyoming I-80
  – Likely to use channels throughout the band

• DSRC can address ~80% of crash scenarios

• 32,719 US traffic fatalities in 2013
Rechannelization Concept

- Move V2V safety from Ch. 172 to upper band (non-overlap portion)
- Cancel highest 20 MHz Wi-Fi (Ch. 181)
- DSRC use 20 MHz channels in overlap portion instead of 10 MHz
V2X Global Landscape - V2X been discussed for ~15 years

Technology

• **802.11 (DSRC)**
  - Specs published in 2010
  - Hasn’t matured as WiFi tech evolved
  - Many concerns about lack of features to support new use cases, privacy & security

• **LTE V2X**
  - Study started end of 2014 in 3GPP
  - Normative specification targeted for 2017
    - Product: ~ 2019 (dep. on market pull)
  - Key advantage is ability to leverage the whole cellular ecosystem & capability set

• **5G**
  - Next generation cellular radio
  - Over time, it will augment LTE V2X

Regional Adoption

• **United States**
  - IEEE 802.11 (DSRC) specified in FCC Report and Order, since 1999
  - Probable NHTSA rulemaking – late 2016
  - Expected mandated V2V deployment – 2020 or 2021
  - Must address and resolve privacy and security issues in an scalable manner

• **Europe**
  - Will LTE V2X technology gain momentum?

• **China**
  - Competitor H promoting non-standard “LTE-V”
  - Field trials will compete 802.11 against LTE
  - Expected to harmonize to mainstream 3GPP path
Overall Cellular Industry Trend

From LTE to 5G

- LTE strongly established as mobile broadband solution globally
- Ability to aggregate multiple pieces of spectrum
  - Carrier Aggregation / Dual Connectivity (CA/DC)
  - Licensed Assisted LTE in Unlicensed Spectrum (LAA)
  - LTE-WiFi aggregation (LWA)

- LTE also expanding into vertical markets
  - Public Safety, Machine-Type/IOT, Broadcast, V2V/V2X

- Activities on 5G getting started with likely initial focus on mobile broadband
  - Vertical markets (including V2V) expected to stay on the LTE baseline for significant time
From LTE to 5G

Is LTE V2V “the real thing” or should we wait for 5G?

- First iterations of 5G will focus on mobile broadband & will occur in 2020/2022

As for other major technology transitions, 5G won’t be ubiquitous from day 1
- First deployments will be in dense areas
- First deployments will also most likely in relatively high frequency bands (eg ~4GHz)
- Initial 5G deployments will be about capacity (and not about coverage)
- NOTE: history of LTE more or less went as follows
  - 2004: concept proposed in standards
  - 2008: first end-to-end demo at MWC
  - 2009 (December): first commercial deployment in 2 cities
  - 2015: ~70% population under LTE coverage in Germany (not territory)

- Vertical markets are developing now over LTE & will remain on LTE for a long time

- LTE V2V is real & is here to stay
  - 5G will augment it & complement it over time
Securing Connected Vehicles

Connected Vehicles Have Many Security Vulnerabilities

Vulnerabilities of Vehicle-to-Infrastructure/Cloud Communications

Vulnerabilities of Onboard Diagnostic Interface

Vulnerabilities of Onboard Networks, Devices, and Applications

Malware May Infect Vehicle Through Any Communication Channel
**Securing Connected Vehicles**

**What’s Unique about Securing Connected Vehicles?**

<table>
<thead>
<tr>
<th><strong>Vehicles</strong></th>
<th>Vehicles have long lifespans and yet highly constrained resources that cannot be upgraded or replaced easily</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environment</strong></td>
<td>Vehicles operate in highly vulnerable or completely unprotected environments</td>
</tr>
<tr>
<td><strong>Vehicle Operations</strong></td>
<td>Vehicles have little tolerance for down times</td>
</tr>
<tr>
<td><strong>Security Operations</strong></td>
<td>Vehicles are not managed by IT experts, and sending them to repair shops can cause intolerable disruption/inconvenience to users</td>
</tr>
</tbody>
</table>

- Vehicles will need external help/services for adequate security
- Existing “Firewalled Garden” security paradigm no longer sufficient
- Existing “Shutdown-Cleanup-Restart” incident response paradigm no longer adequate
- Security operations must be significantly more automated and manageable
- Remote online threat mitigation will be essential
Securing Connected Vehicles

Fog/Cloud-Assisted Vehicle Security Architecture

4. Security Cloud/Fog
   ✓ Update vehicle onboard security systems
   ✓ Assist vehicles in threat defense
   ✓ Detect misbehaving vehicles
   ✓ Remove threats before they reach vehicles
   ✓ Remote removal of malware
   ✓ Remote security management (provisioning, key management, monitoring, …)

Remote Security Management

Threat Information & Suspicious Files

Updates & Threat Defense Assistance

3. Secure V2I Communications
   - Dynamically established on demand at proper protocol layers
   - Scalable to support 10+ M vehicles

1. Fog-based Security Functions Onboard
   ✓ Secure vehicle access and external communications
     ✓ Defend vehicle against malware
   ✓ Manage keys and credentials for onboard devices and apps
   ✓ Monitor and report onboard security-related activities

2-A. Secure Local Communication
2-B. Secure V2V communications

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http://www.mtc.umich.edu/

Connected and automated vehicles

Enabling vehicles to communicate with one another via wireless devices holds the potential to automate vehicles while dramatically improving safety, reducing congestion, and conserving energy.
Highlights from the 2015 GLOBECOM Conference

11/27/18

Highlights I: DSRC Development Kits

Highlights II: Connected and Automated Vehicle Emulator

Highlights V: Secure DSRC Module

Authentication in Multihop Wireless Networks (PHY-CRAMR)
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Lightening Talks at GLOBECOM 2015

Wednesday, Dec. 9, 2015 - 16:15-18:00.

Moderator: Leonard Reder, JPL, USA

Lightening Talks are short five minute talks on technical topics. About 20 talks will be presented in this 120-minute session. The point of a lightning talk is not to give a detailed talk, but rather to present briefly the main point. The topics acceptable for talks are any subject that is conference related.

Come to talk about your company’s product, a nifty algorithm trick, some thoughts triggered by presentations at the conference, or if you are a student, share the highlight of your thesis project. The main goal of the talk is to make your point fast and we move on to the next subject. No hard and fast rule about the presentation format, no judgment either. However, the five-minute time limit is strictly enforced and you will be asked to stop at the end of 5 minutes.

Speakers that desire to present lightening talks can sign up here on a first come first serve basis before Tuesday noon. Logistic instructions for the session will be posted at the conference. Speakers will need to provide name, affiliation, contact email, and most importantly the title of the talk when they sign up online. Each speaker is permitted five minutes to speak and zero to three slides for their presentation. Speakers must be present at the start of the session or their slot is forfeited to the next speaker signed up.

Everyone should be prepared for a fun, dynamic and entertaining session!

Please sign up using the Google Form below.
Lightening Talks at GLOBECOM 2015

- Intro/Frequency Modulation in Foggy Mountain Breakdown
- "Why won't my funny video load?" asked my Mom.
- UL Tx Diversity to Improve Cell Edge Performance, TRP, and SAR
- Massive MIMO testbed Calibration
- Is design of 5G about customer experience?
- Cognition MBRI: MANET scale-able Adhoc Mesh Communication
- Vertical Backhaul/fronthaul for 5G
- Qbadge: A wearable networking platform
- Radio-as-a-Service
- The 5G puzzle: R&D Democratization
- Underwater wireless communications
- Connect The Next Billion
- Designing for The Elderly
- MATLAB and your wireless (5G) journey
- TV White Spaces in Europe Will be late!
- Plexxi - Simply a Better Network
- The 5G puzzle: R&D Democratization
- Polar Codes Are OCBM Codes
- Rich Communications Suite
- Modular Optical Wireless Elements
- Non-Sense!
- Encounter based Opportunistic Network Simulator
- Technical Writing Skills for English-as-a-Second Language Engineers

http://sites.ieee.org/denver-com/files/2016/02/GC15_LIGHTNING_TALKS.pdf
Frequency Modulation in Foggy Mountain Breakdown

- Foggy Mountain Breakdown is a bluegrass tune written by Earl Scruggs and first recorded in 1949
  - It was background music in the 1967 motion picture *Bonnie and Clyde* and various other shows
  - The most recognizable part of this tune is the slide on the fourth string, from first fret to the second forming the E minor chord, followed by slow backward roll
  - The slide effectively frequency modulates a note from D# to E creating pronounced breaks within the tune

- A Mathematical Analysis of this FM characteristic of the Banjo can be found in: *String Stretching, Frequency Modulation, Banjo Clang* by David Politzer, Caltech, [http://www.its.caltech.edu/~politzer/FM.pdf](http://www.its.caltech.edu/~politzer/FM.pdf)
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GLOBECOM 2016-2019

- WASHINGTON DC – 2016
- SINGAPORE – 2017
- KANSAS CITY – ICC 2018
- ABU DHABI - 2018
- BIG ISLAND, HAWAII - 2019

- PUBLISH, PRESENT, VOLUNTEER,
- ATTEND
GLOBECOM – It’s All About the Network
Tim Weil is a Security Architect/IT Security Manager with over twenty five years of IT management, consulting and engineering experience in the U.S. Government and Information Technology and Communications industries. He is an IEEE Senior Member, industry-certified Security and Privacy professional (CISSP), Project Management Professional (PMP), IT Auditor (CISA) and Risk and IS Control (CRISC). He works as a Network Project Manager for SCRAM Systems (Littleton, CO) and supports ISO 27001 compliance and information security programs.

Highlights from the 2015 GLOBECOM Conference

http://securityfeeds.com