IEEE Communications Society – Denver Section

GLOBECOM 2015 Highlights –

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

Tim Weil– CISSP, CISA/CRISC, PMP
Chair – IEEE Denver COMSOC Chapter
http://comsoc.ieee-denver.org

Denver, CO
9 February 2016
Dine and Learn

IEEE | Denver Section

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2007 - Washington DC

2008 - New Orleans

2009 - Honolulu

2010 - Miami

2011 - Houston

2012 - Anaheim

2013 - Atlanta

The **Global Communications Conference (GLOBECOM)**is an annual international academic conferenceorganized 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.

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IEEE GLOBECOM 2015
GLOBAL COMMUNICATIONS CONFERENCE, EXHIBITION & INDUSTRY FORUM
6-10 DECEMBER 2015 // SAN DIEGO, CA, USA

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Highlights from the 2015 GLOBECOM Conference

IEEE GLOBECOM 2015
GLOBAL COMMUNICATIONS CONFERENCE, EXHIBITION & INDUSTRY FORUM
6-10 DECEMBER 2015 // SAN DIEGO, CA, USA

IEEE COMMUNICATIONS SOCIETY

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

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GLOBECOM 2015 Keynote Speakers

IEEE Denver Section

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 Nersesian, 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.

http://sites.ieee.org/denver-com/home/globecom-2015-ieees-globecom-dec-6-10-san-diego-ca/

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IEEE

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IEEE GLOBECOM 2015: Keynotes, Workshops and Lightening Talks

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Welcome

Mission : Promote knowledge and growth of communication technologies in the Denver-Boulder Area.
The Denver ComSoc is a community

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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 2×2 MIMO communication system

GLOBECOM 2015 Keynote Talks

#GLOBECOM: IEEE event General Chair discusses Globecom, 5G and more
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#GLOBECOM: Qualcomm EVP/CTO on evolution from 4G to 5G, part 2

#GLOBECOM: 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

IEEE GLOBECOM 2015
GLOBAL COMMUNICATIONS CONFERENCE, EXHIBITION & INDUSTRY FORUM
6-10 DECEMBER 2015 // SAN DIEGO, CA, USA

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-10: Live End-to-End Ecosystem Trial of New Spectrum Sharing Concepts: European Licensed Shared Access (LSA) Evolution towards US Spectrum Access System (SAS)
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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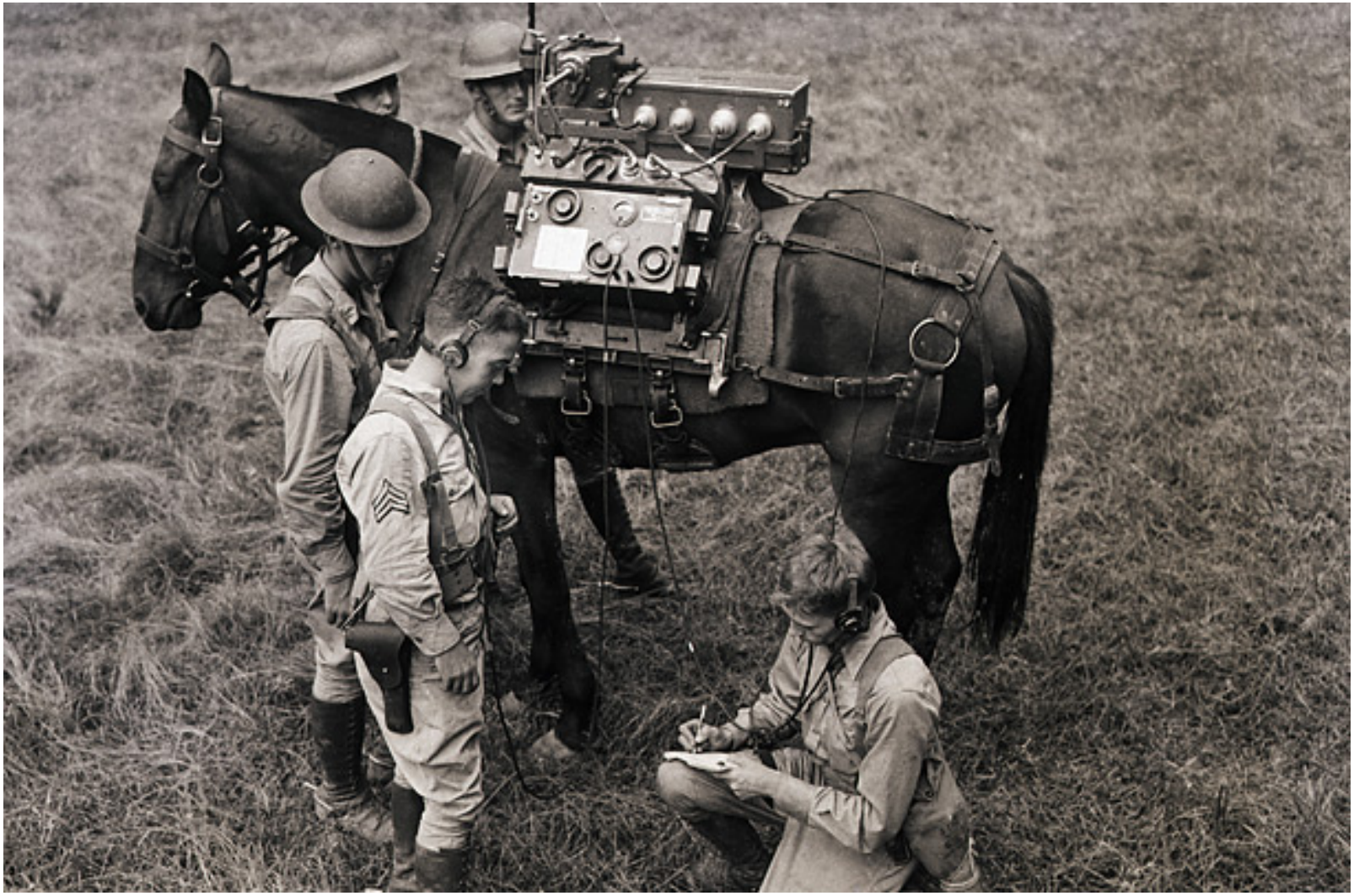
Evolution of the Cell Phone (WWII)

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



WHAT IS 5G? CONTRIBUTION OF EU RESEARCH

European Commission

What 5G will bring to you?	What's new with 5G?	EU projects	5G applications	Why not today?
amazing volume amazingly fast	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)	METIS, SESORUM, 5GNOW, HARP, chaple, MAVEBA, MiWaveS, E'NET/WORK	hologram TV, immersive presence, augmented reality, ultra large volume transfers	spectrum saturation; limited spectrum aggregation; current hardware not able to function at high frequencies; expensive deployment & maintenance of small cells
always best connected	combination of 4G, 3G, Wi-Fi, & new radio access to create an integrated & dynamic radio access network; connectivity management mechanisms	METIS, SESORUM, MCN, Tropic, CROWD	staying connected everywhere including high-speed trains, planes, crowds	seamless handover (e.g. cellular to Wi-Fi) not supported
no perceived delay	ultra-low latency; software-defined networks; decoupling functional architecture from the underlying physical infrastructure; network intelligence closer to users; MEC (mobile edge computing), D2D	METIS, MCN, iJOIN	tactile internet; reactive interfaces; electricity grid control, vehicle to vehicle, robot control; connected cars, remote surgery	4G latency ≥ 10ms
massive amount of connected things & people	new waveform; cell densification; much less signalling traffic & no synchronisation; RAN architecture	METIS, 5GNOW, iJOIN	internet of things, smart cities, connected cars, e-health	current OFDM waveform limitations; interference prevents scaling up; 4G chipsets cost; energy consumption
energy efficiency	millimetre waves for front-haul & backhaul; new operation 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	MCN, iJOIN, CROWD	80% energy saving; deployment in developing countries	Base stations idle time not optimised; unused functions activated; air interface/hardware not energy optimized
flexible programmable networks	software-defined networks; network function virtualisation; decoupling functional architecture from the underlying physical infrastructure; APIs	unify, TNOVA	new business models for innovative SMEs providing network functions; emergence of super MVNOs; pan European operators, faster innovation in network services	many various network management software; not interoperable; bundling of network functions in hardware boxes
secure networks	physical channel authentication; virtualised authentication	CONFINE, LAWS	networks for police & security professionals; privacy	Security as add-on not by design; fragmented approach

IEEE COMMUNICATIONS SOCIETY | IEEE computer society | http://wcsp.eng.usf.edu/5g/2015/ | IEEE Denver Section

International Workshop on Emerging Technologies for 5G Wireless Cellular Networks

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

Home Committee Plenary Talks Panelists Workshop Program

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

Merouane Debbah, Huawei Technologies
Syed Ali Jafar, University of California, Irvine
Eduard Jorswieck, TU Dresden
Andreas Molisch, University of Southern California
John Smee, Qualcomm
Geng Wu, Intel

Panel Program

Driving Innovations in 5G

Panelists:
Nada Golmie, NIST
Thyagarajan Nandagopal, NSF
Sean Cai, ZTE
Maziar Nekovee, Samsung/mmMagic
Sanyogita Shamsunder, Verizon

Technical Program Committee

Workshop Program

Workshop Program International Workshop on Emerging Technologies for 5G Wireless Cellular Networks, San Diego, CA, USA, Thursday, December 10, 2015

- **8:25 am - 8:30 am: Opening and Welcome** (Room: Indigo G)
  Wei Yu, University of Toronto, Canada
- **8:30 am - 9:00 am: Plenary Talk #1** (Room: Indigo G)
  5G Systems Design Across Services
  (Presentation)
  Dr. John Smee, Senior Director of Engineering, Qualcomm Technologies Inc., USA
- **9:00 am - 9:30 am: Plenary Talk #2** (Room: Indigo G)
  Network Slicing for Future 5G Wearable Devices and Internet of Things
  (Presentation)
  Dr. Geng Wu, Fellow and Chief Wireless Technologist, Intel, USA
- **9:30 am - 11:00 am: Poster Session 1** (Room: Indigo G)
  Chair: Jonathan Ashdown, U.S. Air Force Research Laboratory

  - 09:30 am - 10:00 am Poster Overview (2 minutes/paper)
  - 10:00 am - 11:00 am Poster Session

  o MIMO & Interference Alignment

  Robust Transmit Design for MISO Gaussian Broadcast Channel with Integrated Services
  Weiqing Kong (University of Electronic Science and Technology of China, P.R. China); Zhi Chen (University of Electronic Science and Technology of China & University of California, Riverside, P.R. China); Lingxiang Li and Chuan Huang (University of Electronic Science and Technology of China, P.R. China)

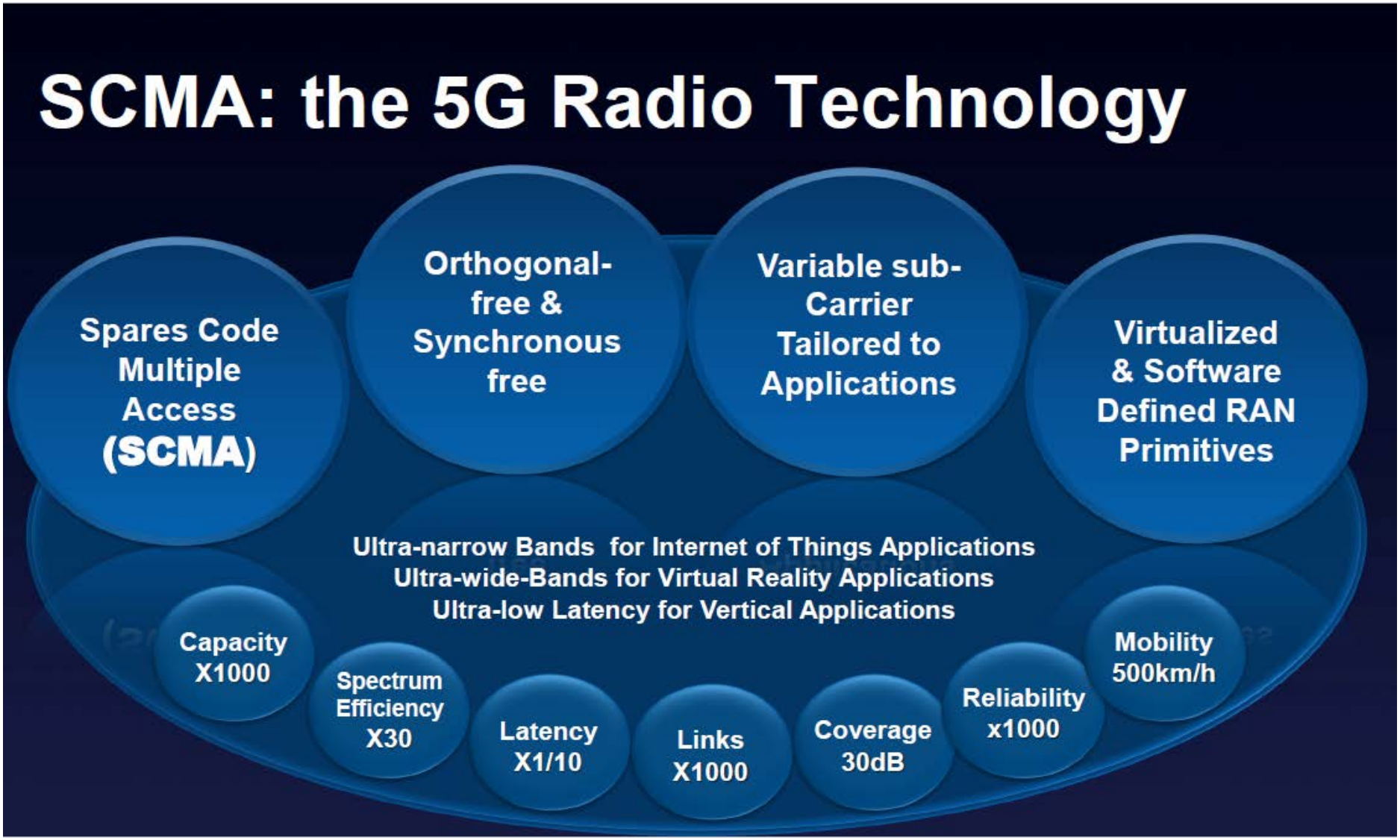
GLOBECOM 2015 5G Workshops and Panels

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)

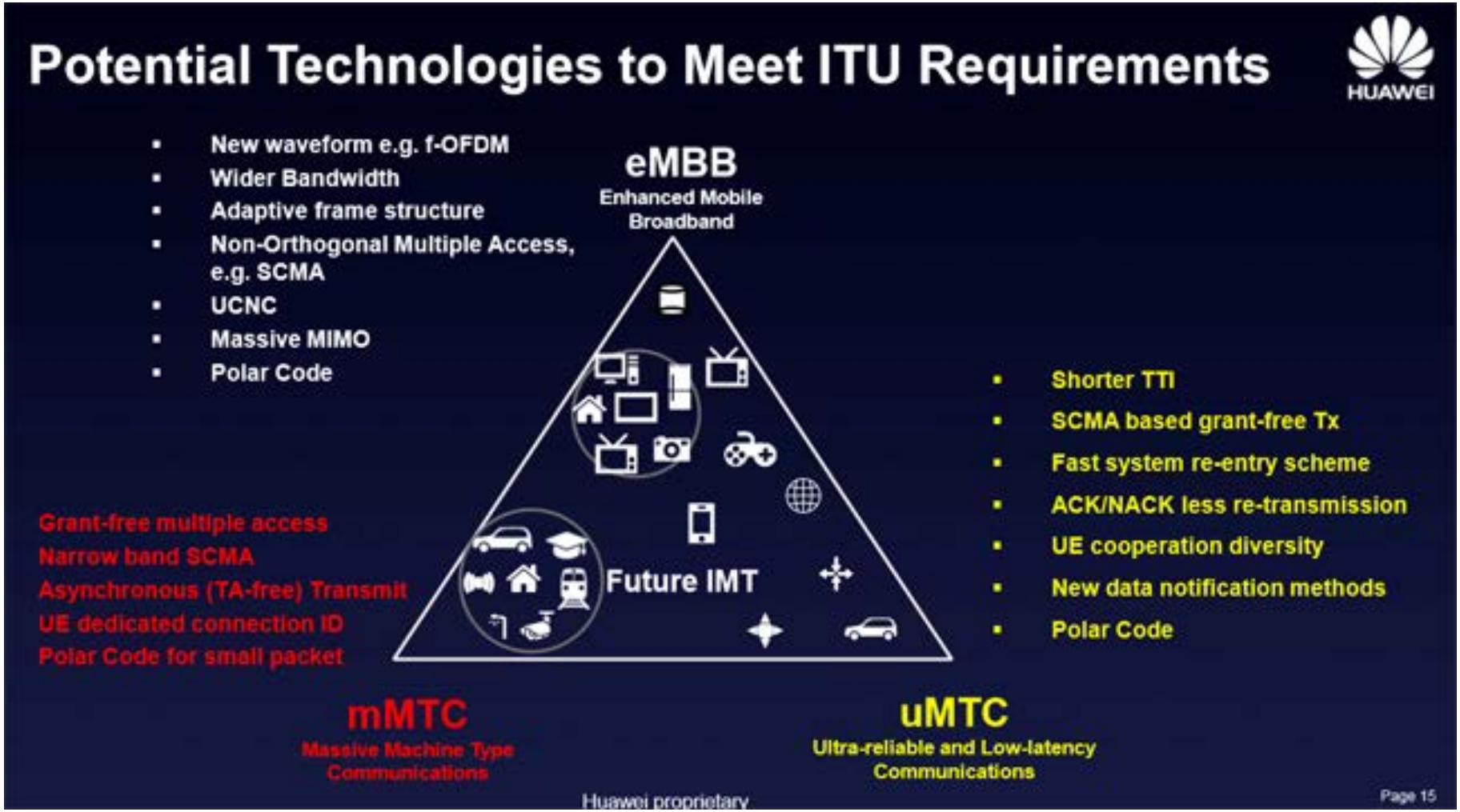
Nada Golmie Chief, Wireless Networks Division, (NIST) (Presentation)
Thyagarajan Nandagopal , Program Director, National Science Foundation (NSF), (Presentation)
Sean Cai, Vice President, CTO Group, ZTE Corporation, (Presentation)
Maziar Nekovee, Chief Engineer, Samsung Electronics R&D Institute UK,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

Huawei Vision of 5G (Dr. Wen Tong)



http://www.ieee-ctw.org/2014/slides/plenary1-2014CTW_Wen.pdf

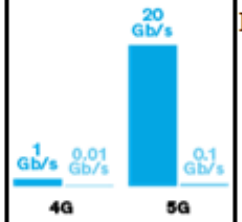
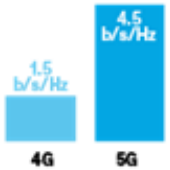
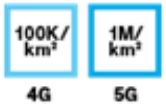
Huawei Vision of 5G (Potential Technologies)

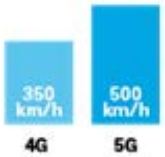
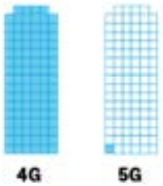


http://www.winlab.rutgers.edu/iab/2015-02/Slides/04.pdf

Highlights from the 2015 GLOBECOM Conference

What 5G Will Do and How It Could Do It (IEEE Spectrum Oct 2015)

Data Rate The maximum transmission data rate (gigabits per second) will be 20 times as fast as 4G LTE, while the average user will experience rates 10 to 100 times as fast.		**Proposed Technologies** • Massive multiple-input, multiple-output (MIMO) • Millimeter wavelength spectrum
Spectral Efficiency 5G will improve downlink spectral efficiency (bits per second per hertz) threefold.		• Device-to-device (D2D) communication • Full duplex system • Massive MIMO
Data Processing The network will be able to process 100 times as much data in a given area (megabits per second per square meter).		• D2D • Millimeter wavelength spectrum • Radio-access network virtualization • Small cells
Device Density About 900,000 more devices per square kilometer will be able to connect to the network.		• D2D • Small cells

Mobility 4G 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.		• Heterogeneous network architectures
Transmission Delay 5G will have one-tenth the latency (milliseconds) of 4G		• D2D • Content caching close t users
Energy 4G takes 1 millijoule to transfer a 1,000-bit data packet. 5G will be able to transfer packets 100 times as efficiently		• Massive MIMO

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

What 5G Will Do and How It Could Do It (IEEE Spectrum Oct 2015)

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.

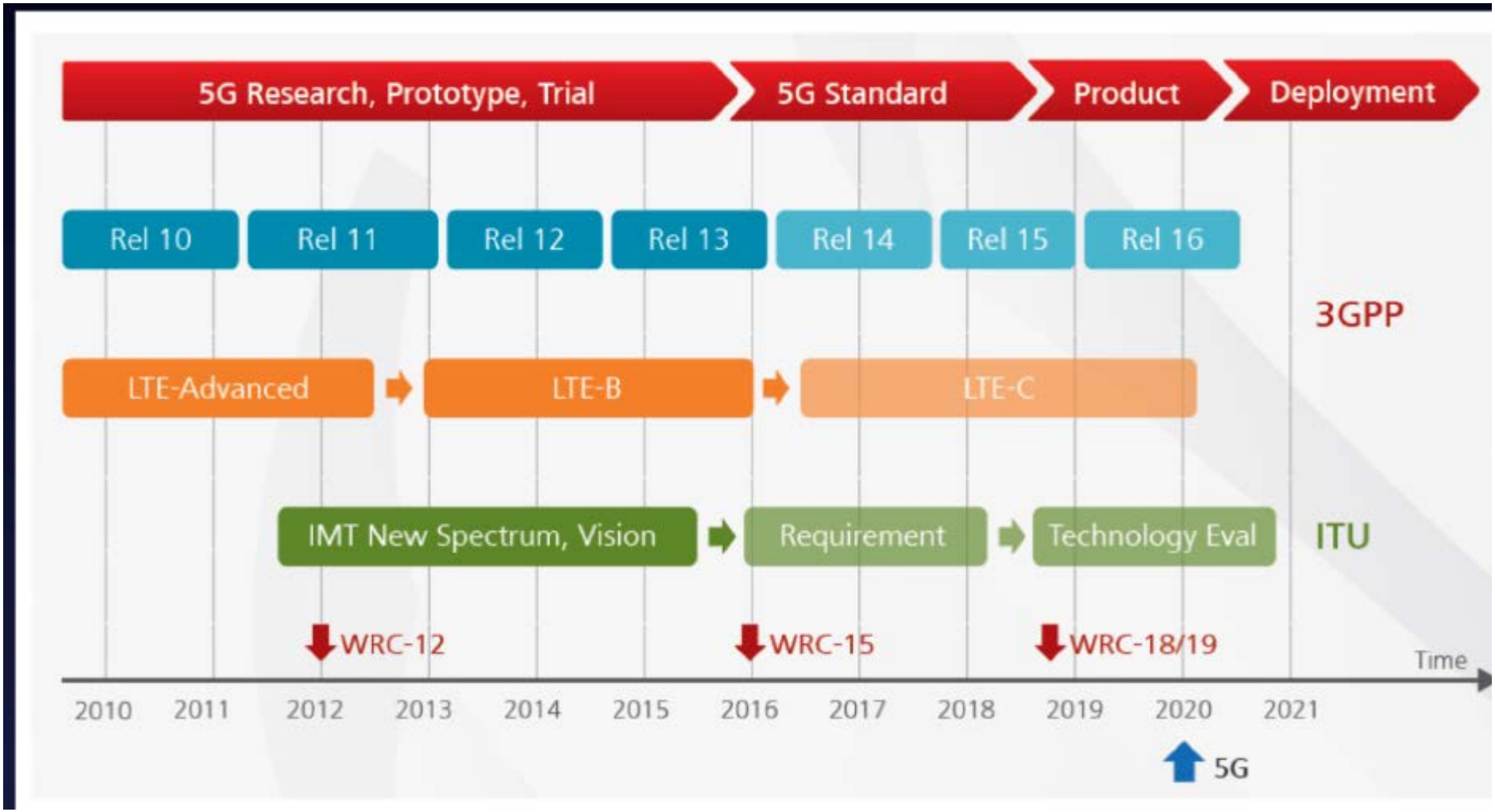
Radio-access network virtualization: General radio-access network processor functions will be virtualized into the cloud. Today's radio-access network is built with many individual base stations. By virtualizing the network, multiple service providers can physically share the same data center platform 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

5G Timeline (Huawei)



http://www.ieee-ctw.org/2014/slides/plenary1-2014CTW_Wen.pdf

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TT-9: Tutorial on Nanoscale, Molecular, and Quantum Communications

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 communicaton; 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

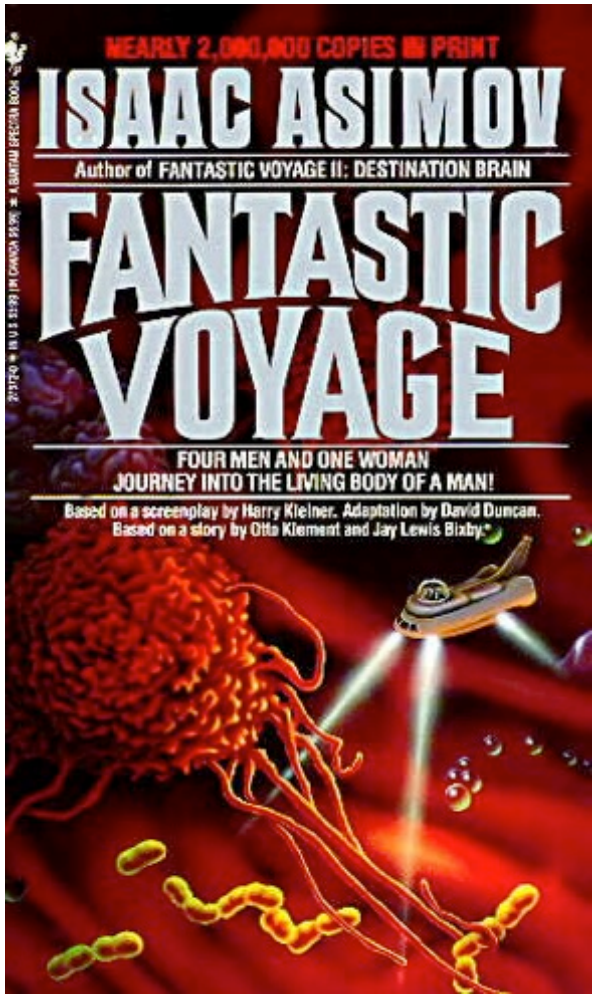
- Dr. Urbashi Mitra, IEEE Fellow, Professor of Electrical Engineering and Computer Science (USC Viterbi School of Engineering). Chief Editor IEEE Transactions on Molecular, Biological and Multi-Scale Communications (http://www.comsoc.org/tmbmc/editorial-board)

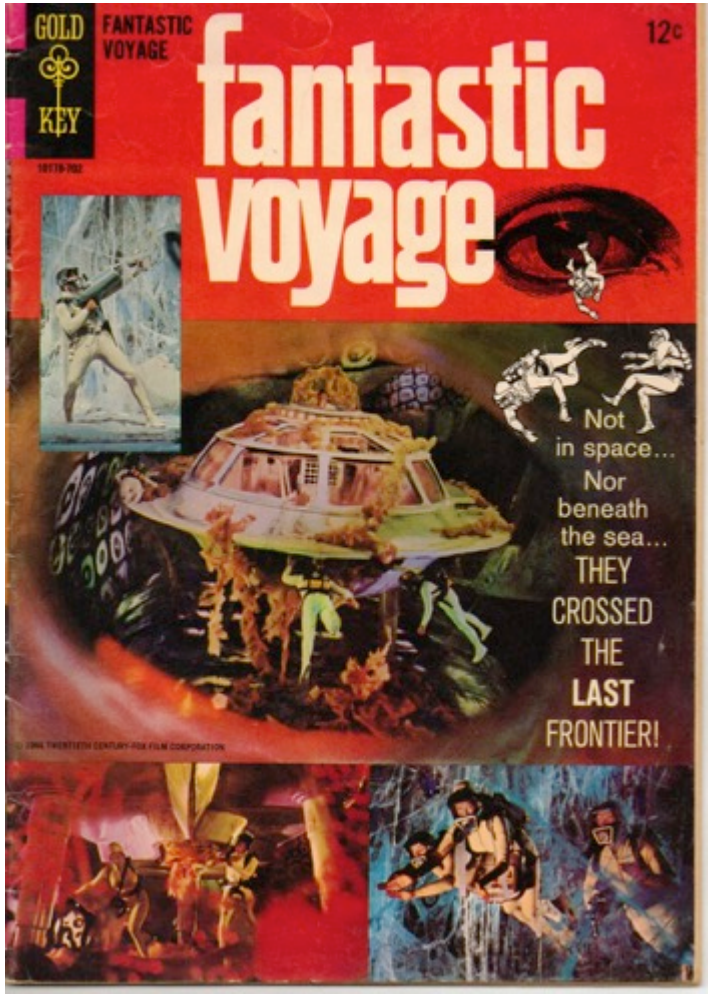
- Dr. Andrew Eckford, Associate Professor in the Department of Electrical Engineering and Computer Science at York University, Toronto, Ontario. Co-author of the textbook Molecular Communication (Cambridge University Press) and co-editor IEEE Transactions on Molecular, Biological and Multi-Scale Communications

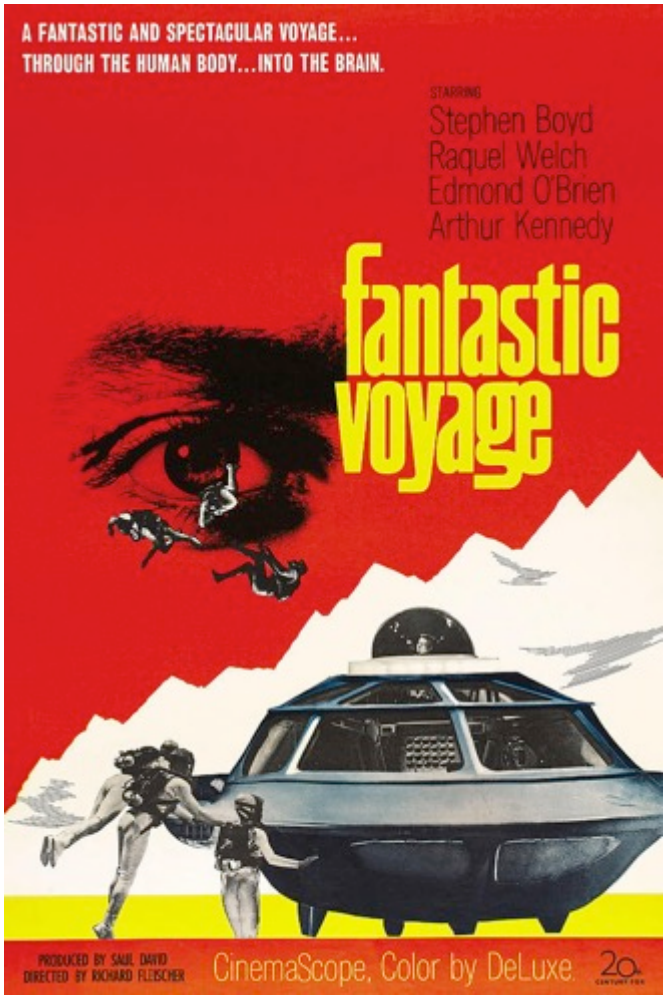
- Dr. Lajos Hanzo, IEEE Fellow, Chair of Telecommunications, University of Southampton, He has co-authored 20 John Wiley/IEEE Press books totaling about 10 000 pages on mobile radio communications,1200+ research papers and book chapters at IEEE Xplore

Nanomedicine Art Gallery (Fantastic Voyager 1966)

http://www.foresight.org/Nanomedicine/Gallery/FanVoy/







Concepts of Nanoscale, Molecular, and Quantum Communications

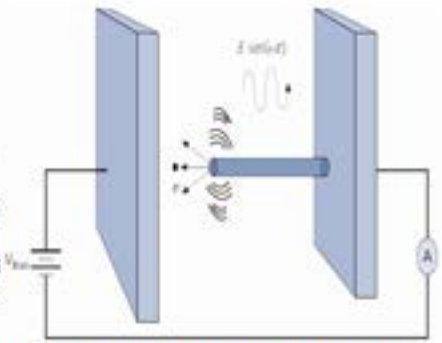
Next Generation Wireless Communication Lab - http://nwcl.ku.edu.tr/nanoquantum.html

Nanoscale and Quantum Communications

Nano Communications is the area of research for finding efficient means of communication for the future nanodevices. These devices are planned to have a wide range of application areas. Today, research on nano-communications is divided into two main streams: EM Nano Communications and Molecular Nano-Communications.

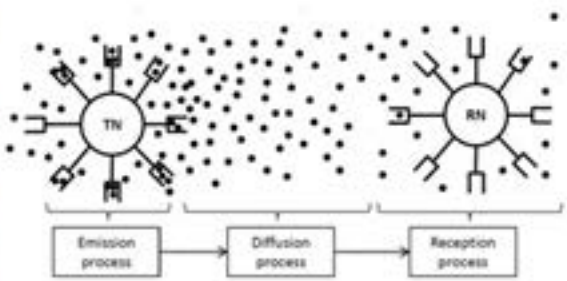
Terahertz Electromagnetic Communications

EM based Nano Communications uses electromagnetic waves as information carriers similar to classical communication. However classical methods cannot be directly applied to nano domain due to extreme scarcity of resources and quantum effects of materials. Hence novel materials and techniques need to be utilized. CNTs are the most famous and promising material for nano-communications. The charged CNT resonates with the exciting wave and its distance to the plate changes in accordance with the wave amplitude. Variation of distance changes the field emission properties of CNT resulting a variation in current. This is the main idea for using a single CNT as antenna and demodulator together.

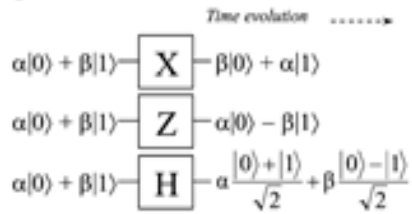


Molecular Communications

Molecular Communications is the natural communication technique used by living organisms (e.g insects communicating via pheromones) and is envisioned to become aviable method for future nano devices. Concentration of the molecule at close proximity of the receiver may be used to understand the molecular bit transmitter sent.



Quantum Communications



Quantum single qubit gates.

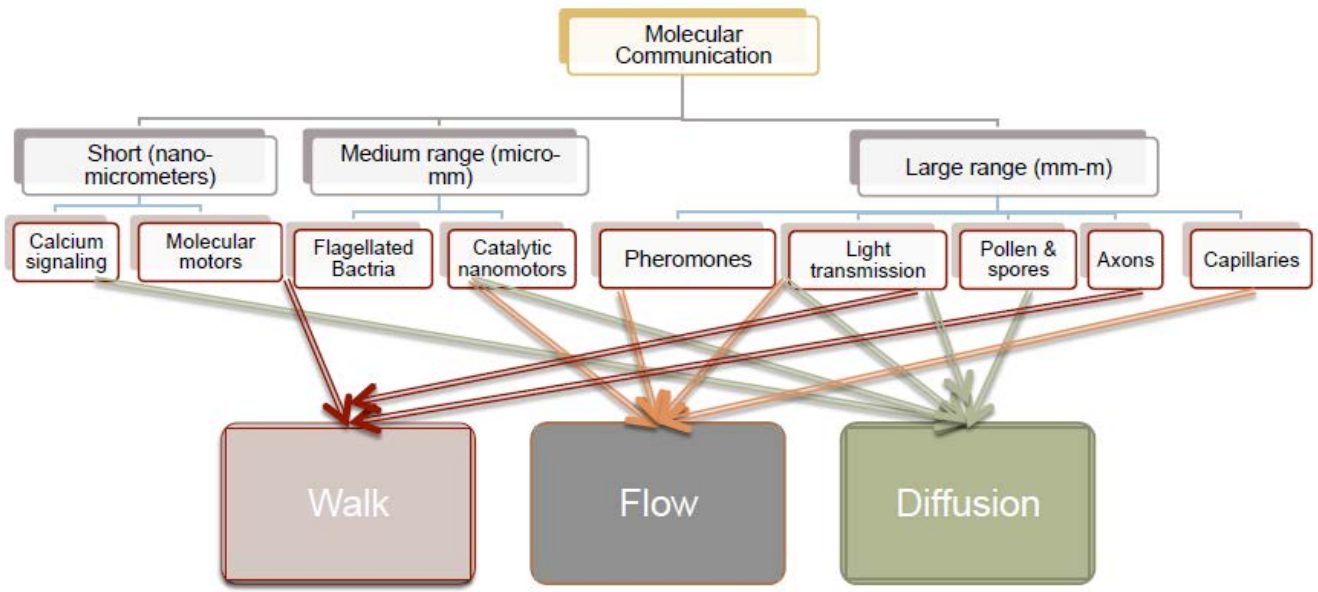
Quantum Communication is based on transferring entangled pairs from one location to another, with the help of swapping, repeating and purification. Quantum Interference, or Quantum Parallelism provides us immense computational power, especially in source coding, where rather than individual inputs, information regarding the whole content is required.

ACM NanoCom 2015
http://nanocom.acm.org/nanocom2015/tsessions.html#s1

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?

USC Viterbi

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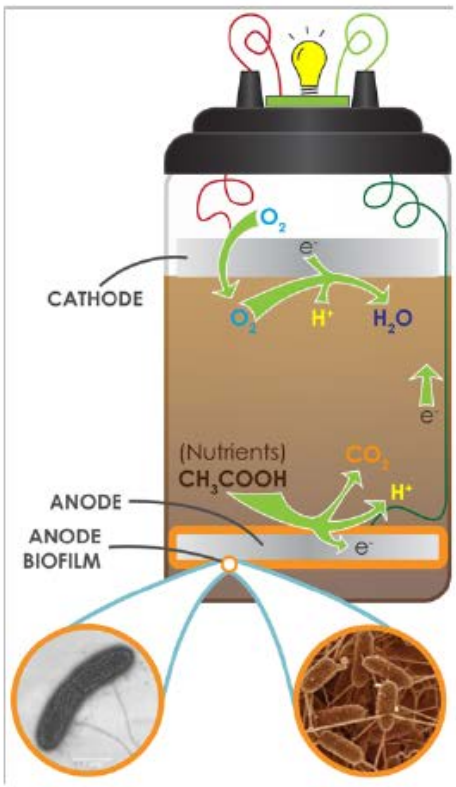
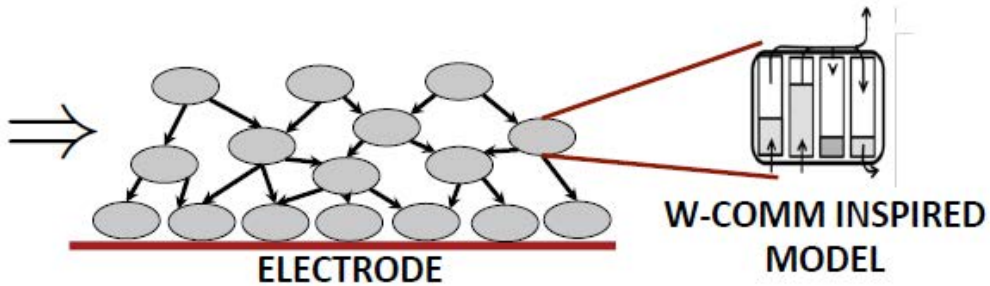
MICROBIAL FUEL CELL (MFC)



- Bacteria as "devices" that sense the environment, estimate, react
- **Idea**: tools from information theory and communications to model & predict bacterial networks:
  - Interactions, dynamics, formation
  - Do bacteria realize *optimal* control strategies?
  - *E.g.*: optimize MFC growth



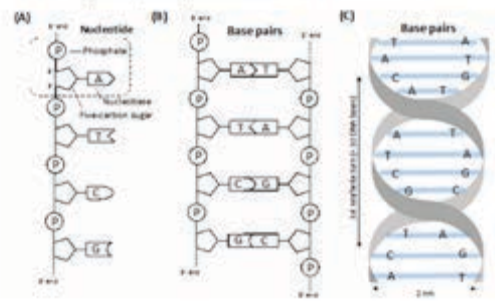
Concepts of Nanoscale, Molecular, and Quantum Communications

Physical Building Blocks

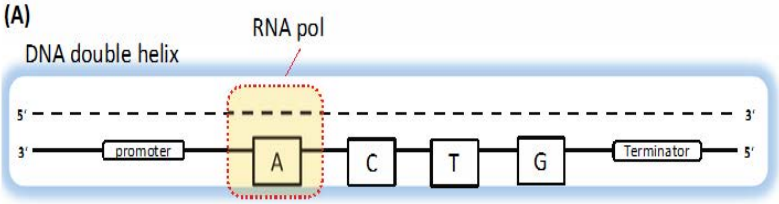
The Central Dogma of Molecular Biology

Replication ↻ DNA —*Transcription*→ RNA —*Translation*→ Protein

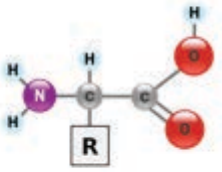
- What is DNA?
  - A 4-ary string (A, T, C, G) which "hybridizes" with itself (A-T, C-G) to form a double helix



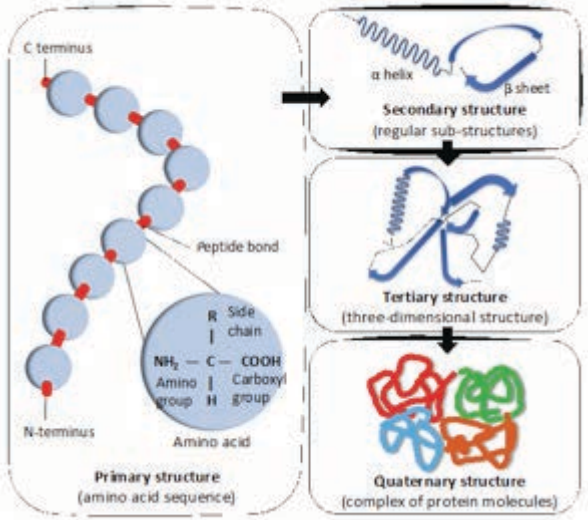
- What is RNA?
  - Similar to DNA, a 4-ary string (A, U, C, G)
  - Single-stranded
- RNA transcription
  - Reading from a DNA strand, starting from a *promoter* and ending with a *terminator,* RNA is formed as the dual of the DNA nucleotide



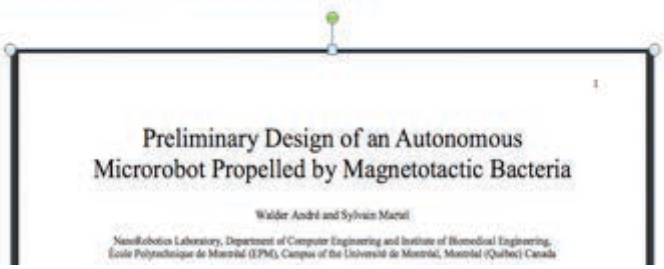
- What is a protein?
  - A polymer of amino acids, connected with peptide bonds
  - An amino acid is:
    - An amine group ($-NH_2$)
    - A carboxyl group (-COOH)
    - An "R group"



Concepts of Nanoscale, Molecular, and Quantum Communications



- Key Challenge: How to control physical layer "hardware" (wetware)?


Preliminary Design of an Autonomous Microrobot Propelled by Magnetotactic Bacteria

Walder André and Sylvain Martel

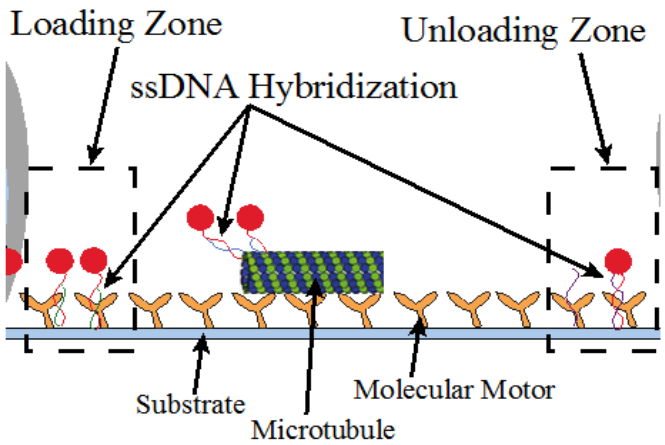
NanoRobotics Laboratory, Department of Computer Engineering and Institute of Biomedical Engineering, École Polytechnique de Montréal (EPM), Campus of the Université de Montréal, Montréal (Québec) Canada

Physical Layer Examples

- Inter-organ examples (1 mm – 2 m)

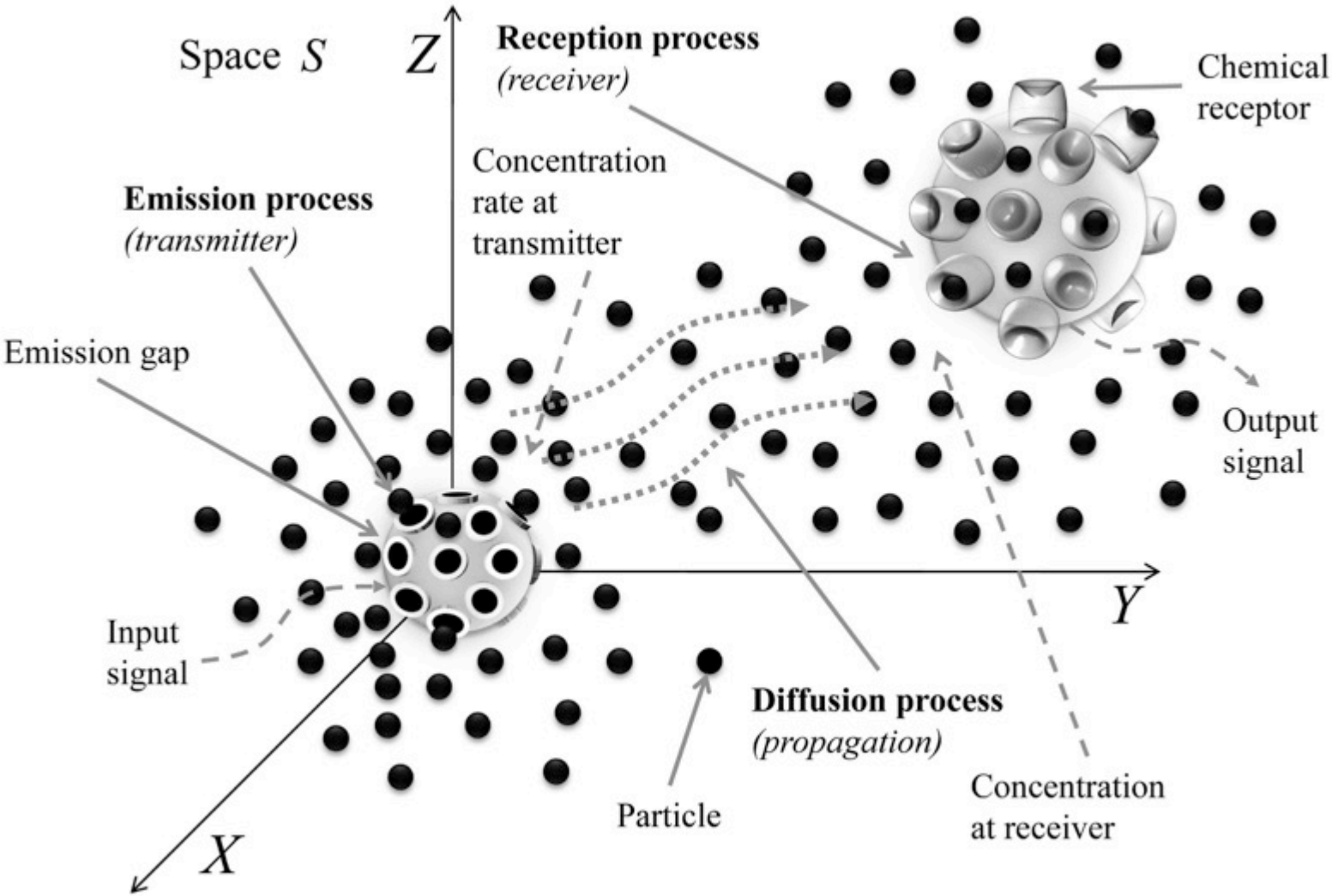
Example	Transmitter/ Receiver	Signal molecule	Scale (Distance)	Mode (Speed)
Morphogen signaling	Anchor cells/ Precursor cells	LIN-3 (EGF)	Inter-org (0.1 cm)	Passive (5× 10^{-7} cm^2/s)
Hormonal signaling	Pituitary gland cells/ Thyroid gland cells	TSH (Hormone)	Inter-org (1 m)	Passive* (5 cm/ s)
Neuronal signaling	Brain cells/ Heart cells	Action Potential	Inter-org (2 m)	Passive+ (100 m/s)

- Data Link Layer
  - Physical addressing: DNA hybridization



S. Hiyama et al., "Autonomous loading, transport, and unloading of specified cargoes by using DNA hybridization and biological motor-based motility," *Small*, vol. 4, no. 4, 2008.

Concepts of Nanoscale, Molecular, and Quantum Communications



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
- **Molecular communication options for long range nanonetworks:**Lluís Parcerisa Giné , Ian F. Akyildiz; Computer Networks 53 (2009) 2753–2766 (Elsevier) - http://www2.ece.gatech.edu/research/labs/bwn/papers/2009/j2.pdf
- **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

- **IEEE ComSoc Emerging Technical Subcommittee on Nano, Molecular, and Quantum Networking):** Andrew Eckford and colleagues http://nano-networks.blogspot.com/

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

- **Molecular communication options for long range nanonetworks:**Lluís Parcerisa Giné , Ian F. Akyildiz; Computer Networks 53 (2009) 2753–2766 (Elsevier) - http://www2.ece.gatech.edu/research/labs/bwn/papers/2009/j2.pdf

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.

IEEE Transactions on Molecular, Biological and Multi-Scale Communications (http://www.comsoc.org/tmbmc/editorial-board)

IEEE TRANSACTIONS ON

MOLECULAR, BIOLOGICAL, AND MULTI-SCALE COMMUNICATIONS

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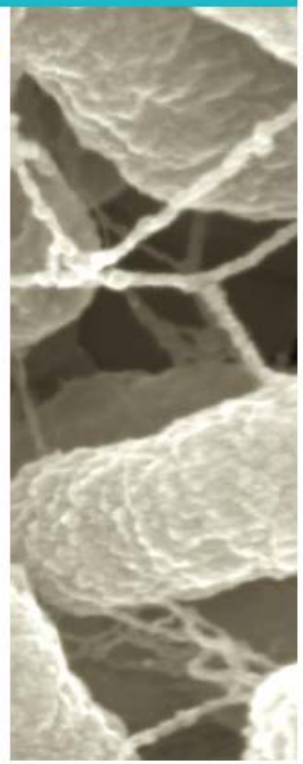

principles, design, and analysis of signaling and information systems beyond conventional electromagnetism, small-scale and multi-scale applications. molecular, quantum, chemical and biological techniques

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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 Misene**r 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.

SecurityFeeds – Security Automotive Networking

http://securityfeeds.net/tweil/dwd.html

Secure Automotive Networking for ITS - A Work in Progress

ITS Industry Around the World

National Projects (US)

- US DOT Connected Vehicle
- US DOT Safety Pilot (Connected Vehicle)
- US IntelliDrive Project (VII)
- US DOT RITA Library
- VII POC Results and Findings - Infrastructure(HTML)
- VII POC Results and Findings Summary-Vehicle(HTML)
- VII POC Technical Description-Infrastructure(PDF)

Vehicle Safety Communications (VSC-A) 2009 Project Results

- NHTSA Office of Crash Avoidance: TechPubs
- VSC-A Final Report: September 2011
- VSC-A System Design & Objective Test: September 2011
- VSC-A Communications and Positioning: September 2011
- VSC-A Security: September 2011

State Projects

- US ITS Resources
- Michigan ITS
- California PATH
- ITS Florida - Connected Vehicle
- ITS Virginia
- Rocky Mountains ITS

EU Consortium Projects (EU)

- Secure Vehicle Communication (SeVeCom)
- Car-To-Car Consortium (Car2Car)
- ITS-Europe(Ertico)
- GeoNet
- ITS-Europe(PreVent)
- CVIS - Cooperative Vehicles Infrastructure Systems
- Preciosa - ITS Privacy Project)

Security Architecture - Vehicle Communications

- TransAtlantic Collaboration Program
- US DOT National ITS Architecture
- SeVeCom Security Architecture
- Continuous Communications for Vehicles(CALM)
- Network on Wheels(NOW)
- System Architecture - ITS Japan

Anonymity and Privacy

- Preciosa (EU ITS Privacy Project)
- Privacy in the VII POC

Data Protection

- V-DTLS (Telcordia)

Communication Protection

- Raj Jain-Washington University (St. Louis)
- 802.11p
- 802.11p Standards Update
- Dedicated Short Range Radio (DSRC)

Infrastructure Protection

- Cooperative Vehicle Infrastructure Systems (CVIS)

Research and Development

- IEEE Intelligent Transportation Systems Society
- IEEE Vehicular Technology Society
- Ecole Polytechnic-Lausanne (EPFL) Vehicular Network Security
- EPFL Secure Vehicular Communications Workshop
- California Parthners for Advanced Traffic and Highways
- Vehi-Com (Weidong Xiang - University of Michigan)
- Vehi-Com Call For Papers
- Southwest Research Institute (SWRI) - VII/DSRC
- VANET Research Resources
- SeveCom Research Bibliography (2003-2008)
- Intelligent Transportation Using VANET
- VANET Syllabus - National Tapei Univ. (Yuh-Shyan Chen)
- VANET Portal(Dr. Frank Kargl- Univ. of Twente)
- Vehicular Networks (Dr. Michele Weigle - ODU)
- V2V and V2I (Dr. Evlem Elcici - OSU CAR Program)
- Using DSRC for Vehicle Safety Applications (VSC 2005 Study)
- Fischer-Tech (Dr. Hans-Joachim-Fisher)
- Swiss UNJobs Site(VANET Research)

Testbeds and Commerical Markets

- ITS America
- OmniAir(DSRC Consortium)
- Telematics Update
- Japan ITS Manufacturers
- Michigan Testbed Application - VII Consortium (VIIC)
- Kapsch Traffic Communications
- Escrypt - Embedded Security Systems
- Raytheon/SIRIT/Transcore
- China TransInfo - ETC Products
- Q-Free (Norway) 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 Secure Environment - Policy Workshop
- CV Secure Environment - Certificate Management (Slides)
- CV Secure Environment - Certificate Management (Report)
- CV Secure Environment - Communications Data Delivery
- CV Secure Environment - AASHTO CV Deployment Analysis Report

ITS Conferences and Books

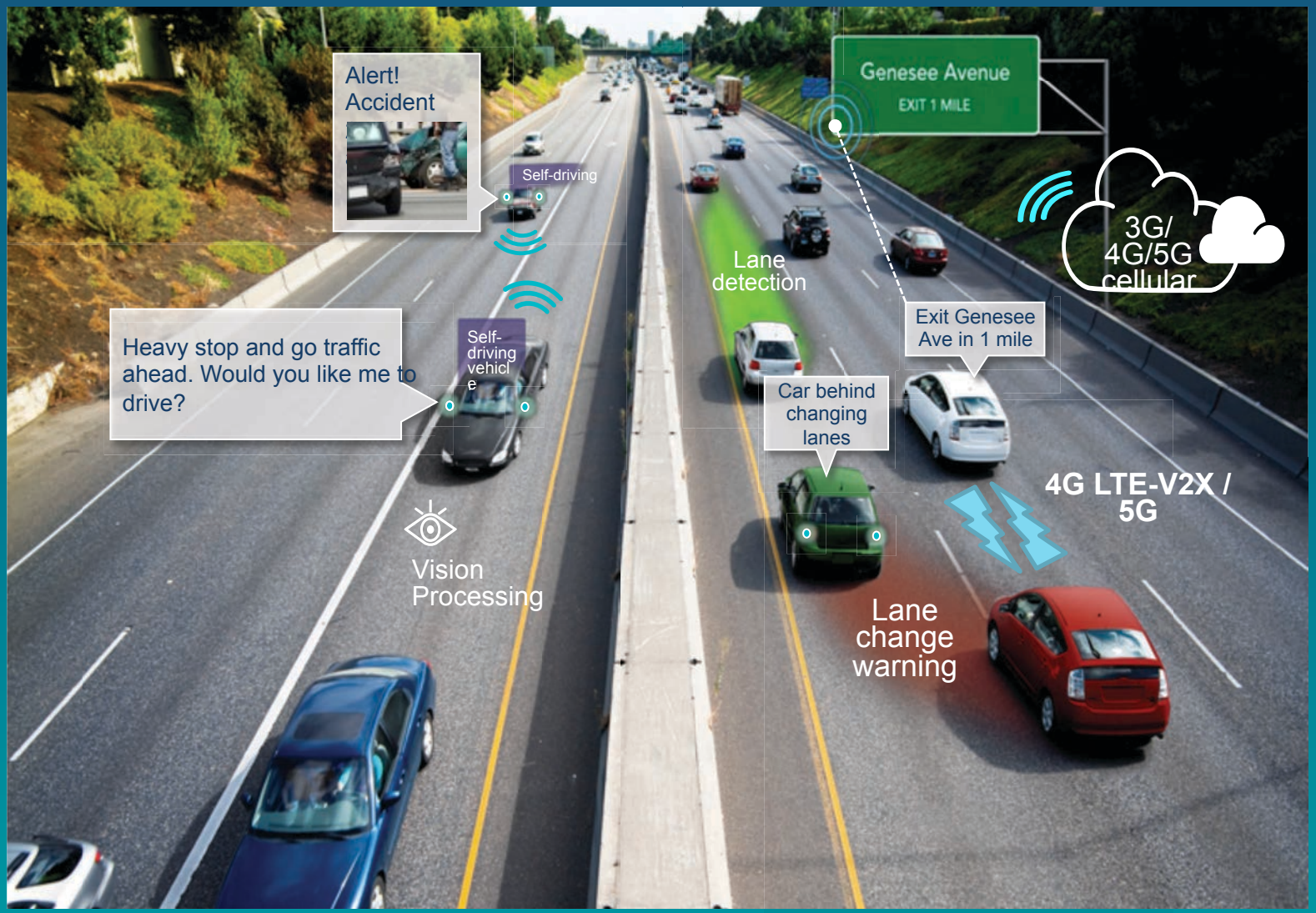
- 7th ETSI Security Workshop (Greece-2012)
- ITS World Conference 2011 (Orlando)
- ITS World Conference 2010 (Busan, Korea)
- IEEE Vehicular Technology Society
- IEEE GLOBECOM - WAVE Designers and Developers Workshop
- IEEE GLOBECOM - ITS Service Management Using WAVE 1609.3 Networking (Weil)
- IEEE NIVI 2009-Networking Intelligent Vehicles and Infrastructures
- ITS America 2009 Conference Presentations
- Vehicular Networks (Weigle and Olariu)
- Asia-Pacific ITS Exhibition and Forum

Wiki ITS References

- Vehicle Telematics (Wiki)
- DSRC - Dedicated Short Range Communication (Wiki)
- WAVE/802.11p - Wireless Access for Vehicular Environments(Wiki)
- Vehicular Communication Systems (Wiki)
- Intelligent Transportation Systems (Wiki)

Site Managed by Tom Weil, E-mail: tweil@securityfeeds.com
ITS Security Architect

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

United States Department of Transportation

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Office of the Assistant Secretary for Research and Technology
Intelligent Transportation Systems
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  - Pilot Deployment Program
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- Intermodal Research
- Exploratory Research
- ITS Cross-Cutting Support
- Success Stories

Quick Links

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Connected Vehicles
CV Pilot Deployment Program

Latest News & Updates

- USDOT Connected Vehicles Pilot Deployment Program Technical Assistance Webinar Series to be held in early February 2016: Privacy Operational Concept, Performance Measurement Plan and SCMS Proof-of-Concept Interface Requirements 1/29/16
- The Concept of Operations Webinar of the ICF/Wyoming Connected Vehicle Pilot Deployment Project will be held on February 5, 2016, 1:00 - 2:00 pm EST 1/28/16
- The Concept of Operations Webinar of the Tampa (THEA) Connected Vehicle Pilot Deployment Project will be held on February 8, 2016, 2:00 - 3:00 pm EST 1/28/16
- The recording and the presentation material of the CV Pilots Technical Assistance Webinar - Human Use Approval is now available 1/27/16

More news »

Ready for Deployment

On September 14th, 2015, the USDOT announced the selection of three connected vehicle deployment sites as Wave 1 participants in the Connected

CV Pilots Portal

- Wave 1 Sites
- Technical Assistance Events
- CV Applications
- Sample Deployment Concepts
- Publications
- Featured Links

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 (DNPW)
- 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-Traveler 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

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

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

Smart Roadside
- Wireless Inspection
- Smart Truck Parking

Source: US Department of Transportation

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

A Variety of Communication Media, Data Transport Needs

<u>Resources</u>: 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

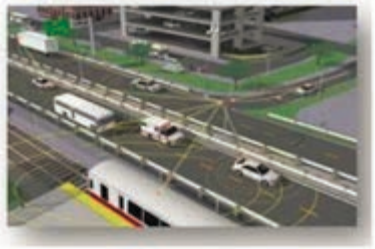
http://www.its.dot.gov/connected_vehicle/pdf/DSRCReportCongress_FINAL_23NOV2015.pdf

- 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

Status of the Dedicated Short-Range Communications Technology and Applications

Report to Congress

www.its.dot.gov/index.htm
Final Report—July 2015
FHWA-JPO-15-218



U.S. Department of Transportation

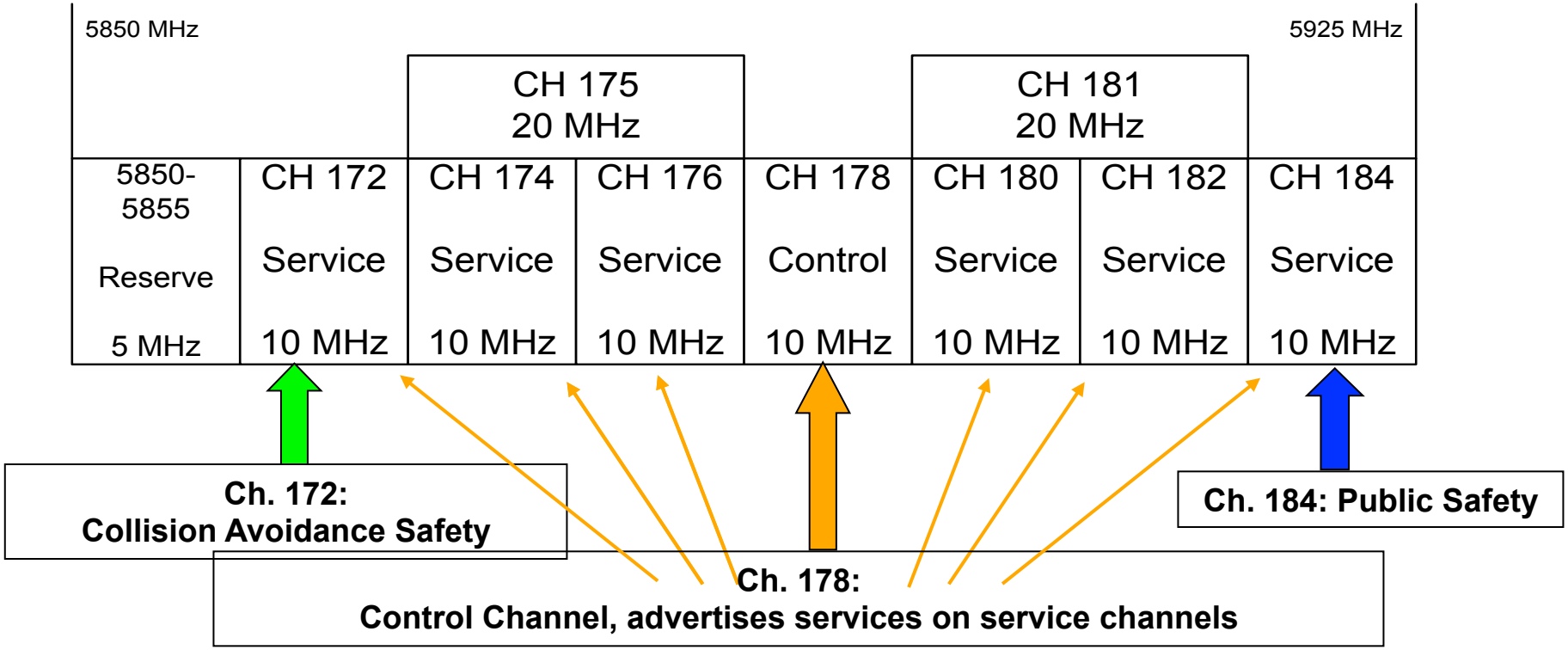
Yes, DSRC is ready for Prime Time

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

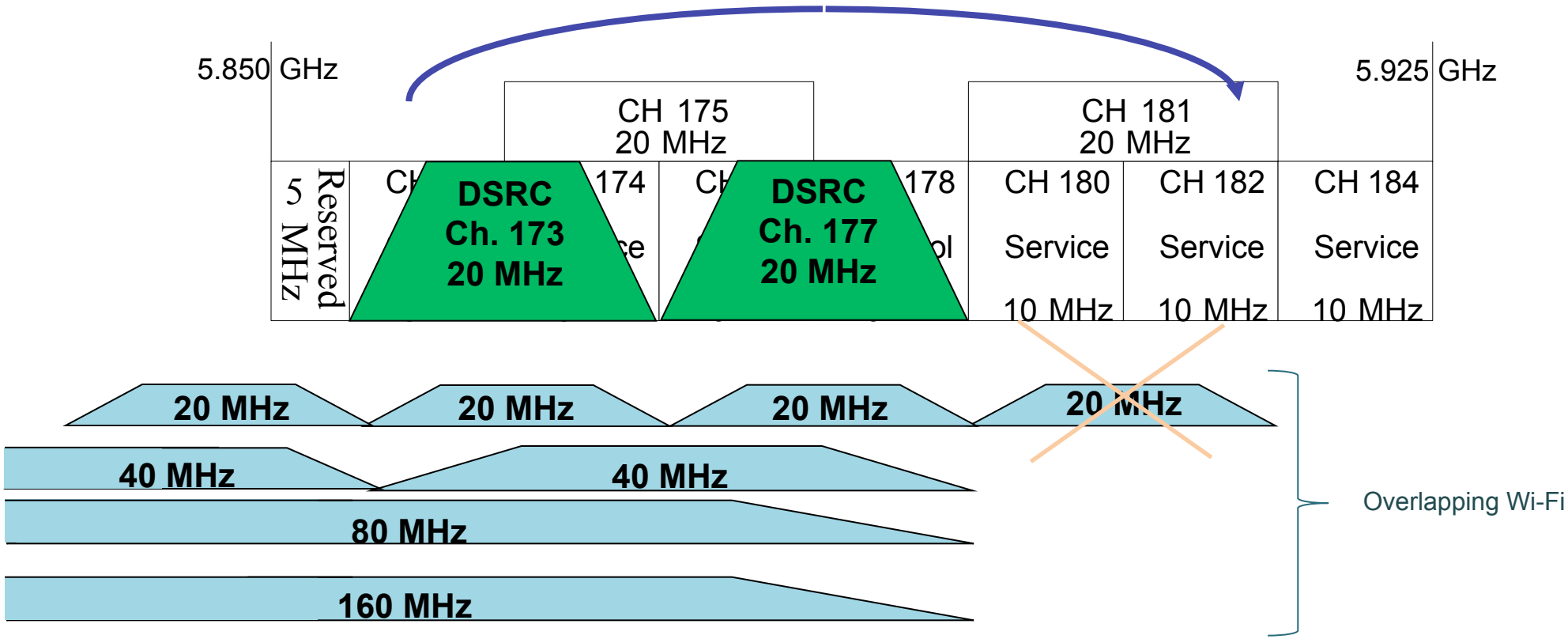
- Initial FCC allocation 1999
- definition of channels and rules in 2003 & 2006



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?

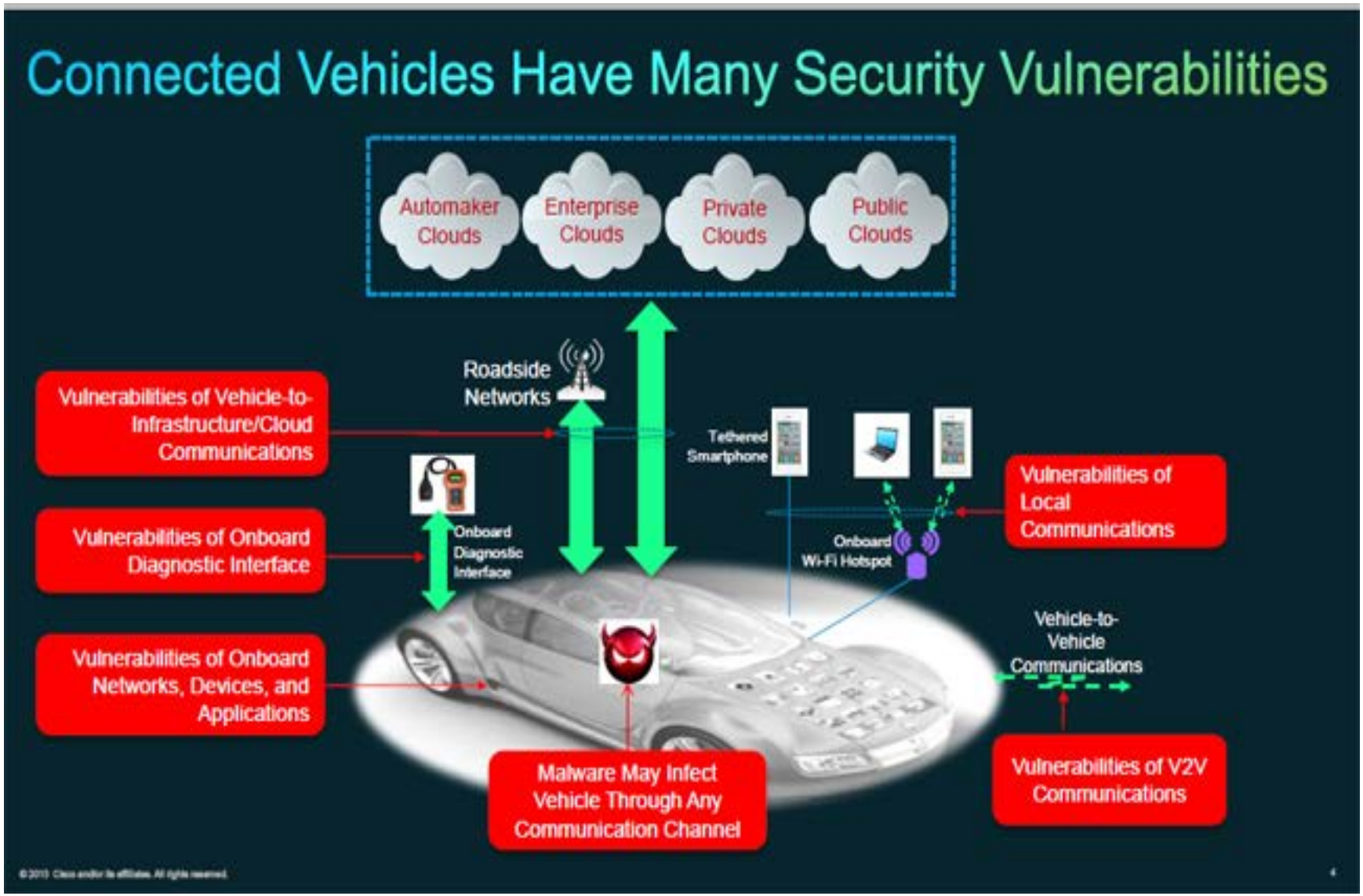
- First iterations of 5G will focus on mobile broadband & will occur in 2020/2022

- 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



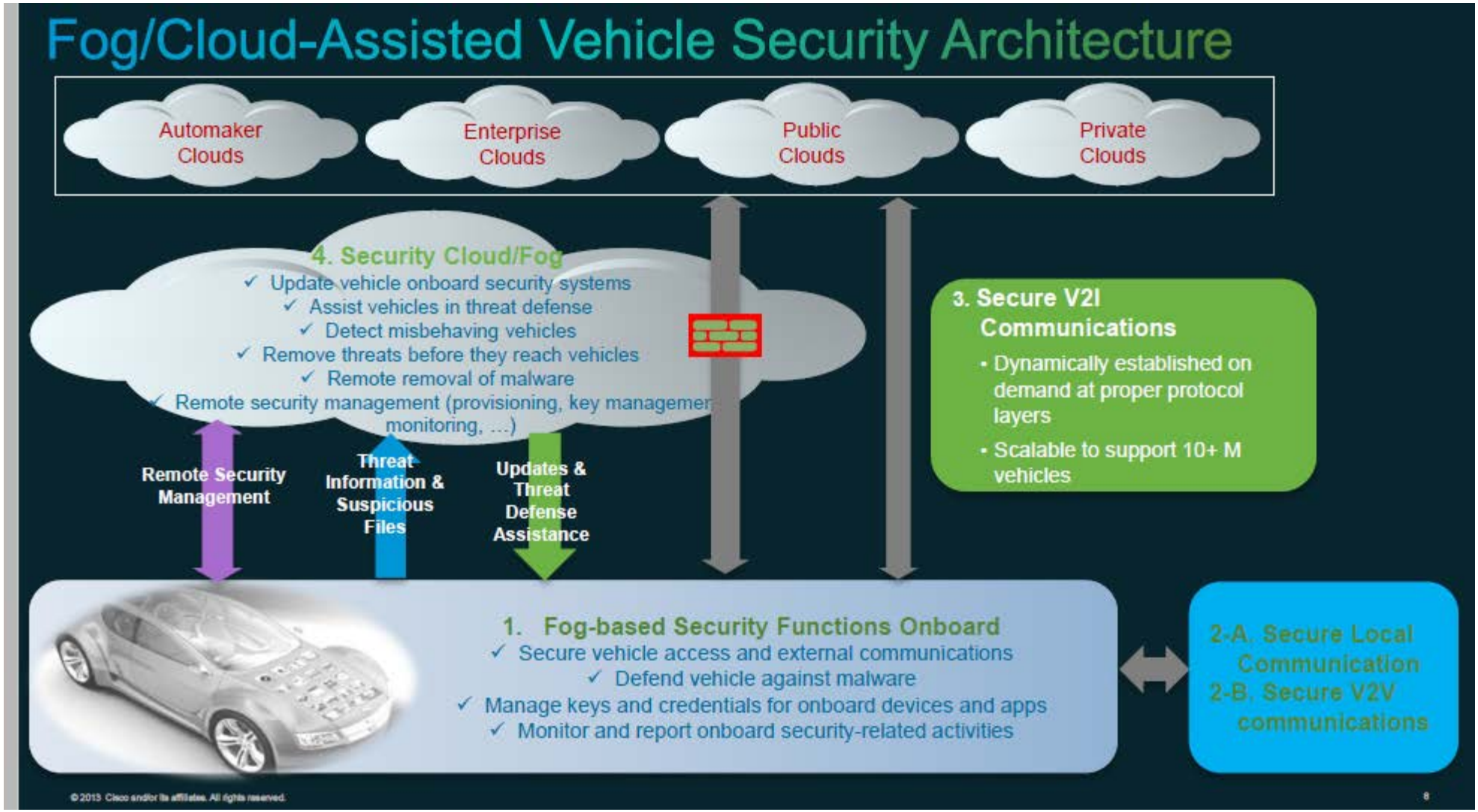
Securing Connected Vehicles

What's Unique about Securing Connected Vehicles?

Vehicles	Vehicles have long lifespans and yet highly constrained resources that cannot be upgraded or replaced easily	• Vehicles will need external help/services for adequate security
Environment	Vehicles operate in highly vulnerable or completely unprotected environments	• Existing "Firewalled Garden" security paradigm no longer sufficient
Vehicle Operations	Vehicles have little tolerance for down times	• Existing "Shutdown-Cleanup-Restart" incident response paradigm no longer adequate
Security Operations	Vehicles are not managed by IT experts, and sending them to repair shops can cause intolerable disruption/inconvenience to users	• Security operations must be significantly more automated and manageable • Remote online threat mitigation will be essential

5

Securing Connected Vehicles



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

MICHIGAN MOBILITY TRANSFORMATION CENTER

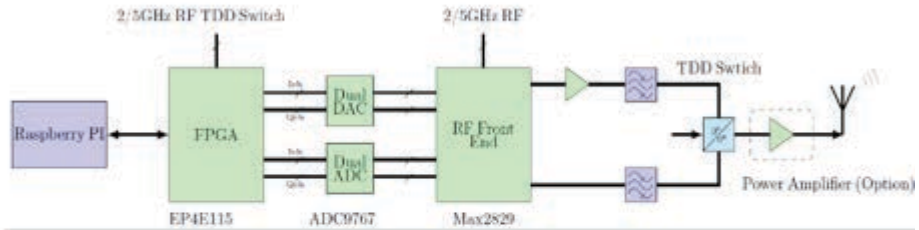
The UM Mobility Transformation Center Annual Project Review

Development of DSRC Radios upon the IEEE 802.11p Standard and Physical Layer Security for Automated and Connected Vehicles Applications

Weidong Xiang and Kai Zeng, University of Michigan, Dearborn

June 9, 2015

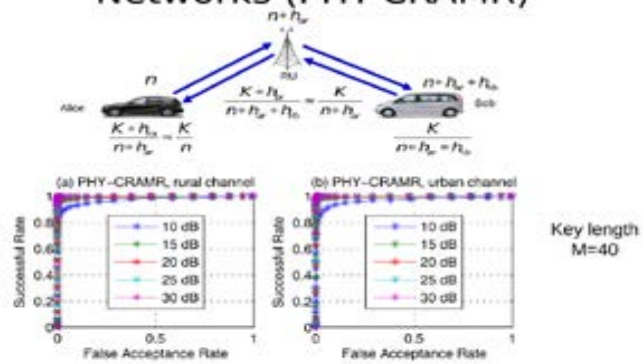
Highlights I: DSRC Development Kits



Highlights II: Connected and Automated Vehicle Emulator

Highlights V: Secure DSRC Module

Authentication in Multihop Wireless Networks (PHY-CRAMR)



X. Du, D. Shan, K. Zeng, and L. Huie, "Physical Layer Challenge-Response Authentication in Wireless Networks with Relay", *IEEE Infocom 2014*, Toronto,

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Lightening Talks at GLOBECOM 2015

IEEE GLOBECOM 2015
GLOBAL COMMUNICATIONS CONFERENCE, EXHIBITION & INDUSTRY FORUM
6-10 DECEMBER 2015 // SAN DIEGO, CA, USA
CONNECTING ALL THROUGH COMMUNICATIONS

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LIGHTNING TALKS

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

Moderator: **Leonard Reder, JPL, USA**

Lightning 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 lightning 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 Modula/on in Foggy Mountain Breakdown

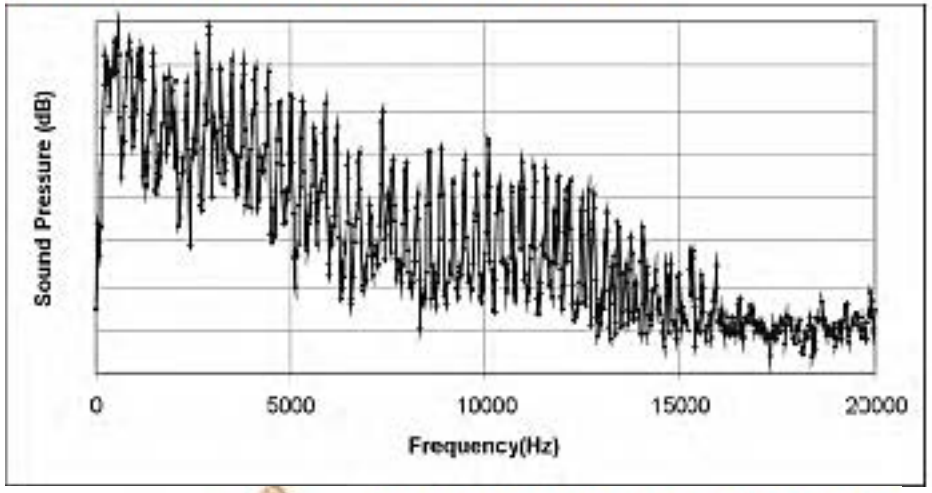
▪Foggy Mountain Breakdown is a bluegrass tune written by Earl Scruggs and first recorded in 1949

- 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 cord, followed by slow backward roll*
- ***The slide effectively frequency modulates a note from D# to E creating pronounced breaks within the tune***

•A Mathematicalcal Analysis of this FM characterisic 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

BANJO SOUND

A 5-STRING BANJO IS USUALLY TUNED TO D,B,G,D,G (294, 248, 196, 147, AND 393 Hz, RESPECTIVELY). THE BRIGHT SOUND HAS MANY HARMONICS.



BANJO WITH RESONATOR OFF AND ATTACHED

DEERING GOODTIME SPECIAL BANJO

REFERENCES:
"How a Banjo Works" J. Rae and T. Rossing, Proc. ISMA 2004.
"Banjos" J. Rae (in *Science of String Instruments* ed. T. Rossing, Springer 2010)
"The structural dynamics of the American five-string banjo" J. Dickey, *JASA* 114, 2958 (2003)
"Experimental investigation of an American five-string banjo" L.Stephey and T. Moore, *American Journal of Physics* 124, 3276 (2008)

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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

IEEE

Call for Technical & Industry Submissions

IEEE GLOBECOM 2016 will include a Technical Program omprised of 13 specific symposia, tutorials and workshops as well as an Industry Program featuring panels, posters, demonstrations, tutorials and workshops.

Technical Workshop Proposals: Due 15 February 2016
Proposals are sought that emphasize current topics of particular interest to the community on the latest technical and business issues in communications and networking, and should include a mix regular papers, invited presentations and panels that encourage the participation of attendees in active discussion.

Technical Tutorial Proposals: Due 15 March 2016
Proposals are sought for new and emerging topics within the scope of communications.

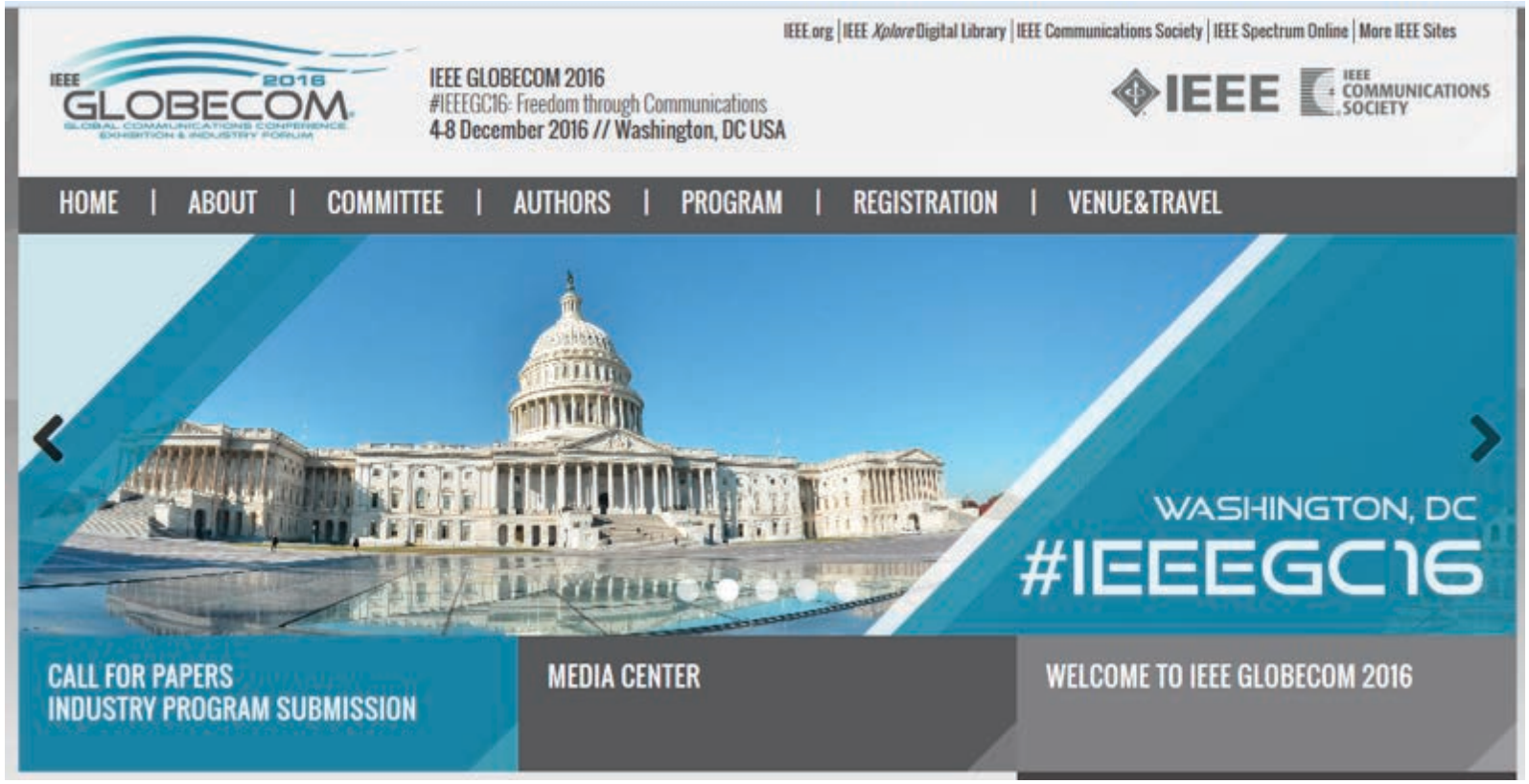
Technical Symposia Papers: Due 1 April 2016
Authors are invited to submit original technical papers in the following areas:

- Selected Areas in Communications
- Access Networks & Systems
- Big Data
- Cloud Networks
- Data Storage
- e-Health
- Internet of Things
- Molecular, Biological and Multi-scale Communications
- Power Line Communications
- Satellite & Space Communications
- Social Networks
- Ad Hoc and Sensor Networking
- Cognitive Radio and Networks
- Communication & Information System Security
- Communication QoS, Reliability and Modeling
- Communications Software, Services and Multimedia Applications
- Communication Theory
- Green Communications Systems and Networks
- Mobile and Wireless Networks
- Next-Generation Networking and Internet
- Optical Networks and Systems
- Signal Processing for Communications
- Wireless Communications

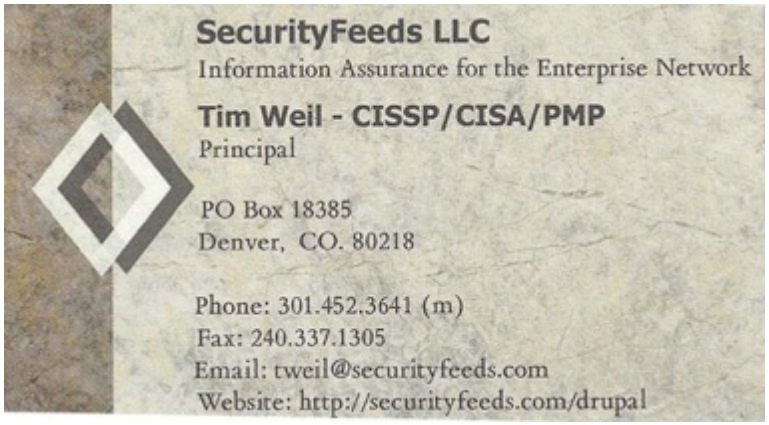
Industry Panels: Due 20 April 2016
Proposals are sought that focus on latest topics, products, and innovations of particular interest t industry in communications and networking.

Industry Demonstrations: Due 7 July 2016
Hardware and/or software demonstrations are sought that are meant to showcase new and innovative technology.

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