# IEEE Future Networks Initiative

## *Enabling 5G and Beyond*


***Co-Chairs: Ashutosh Dutta (JHU/APL), Gerhard Fettweis (TUD), Timothy Lee (Boeing)***

***Harold Tepper, IEEE Senior Program Director***

***Presented by: Ashutosh Dutta, Ph.D.***


***October 23, 2018***

IEEE Future NETWORKS™ Enabling 5G and Beyond

IEEE Advancing Technology for Humanity

# Emerging Services Trends
# Our Connected World is Evolving!


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# Key Characteristics of 5G

- Massive MIMO
- RAN Transmission – Centimeter and Millimeter Waves
- New Waveforms
- Shared Spectrum Access
- Advanced Inter-Node Coordination
- Simultaneous Transmission Reception
- Multi-RAT Integration & Management
- D2D Communications
- Efficient Small Data Transmission
- Densification of Small Cells
- Wireless Backhaul / Access Integration
- Flexible Networks
- Flexible Mobility
- Context Aware Networking
- Information Centric Networking
- Moving Networks

# 5G Dimensions and Types of 5G Applications

## Enhanced Mobile Broadband

- Mobile Broadband, UHD / Hologram, High-mobility, Virtual Presence

## Critical Communications

- Interactive Game / Sports, Industrial Control, Drone / Robot / Vehicle, Emergency

## Massive Machine Type Communications

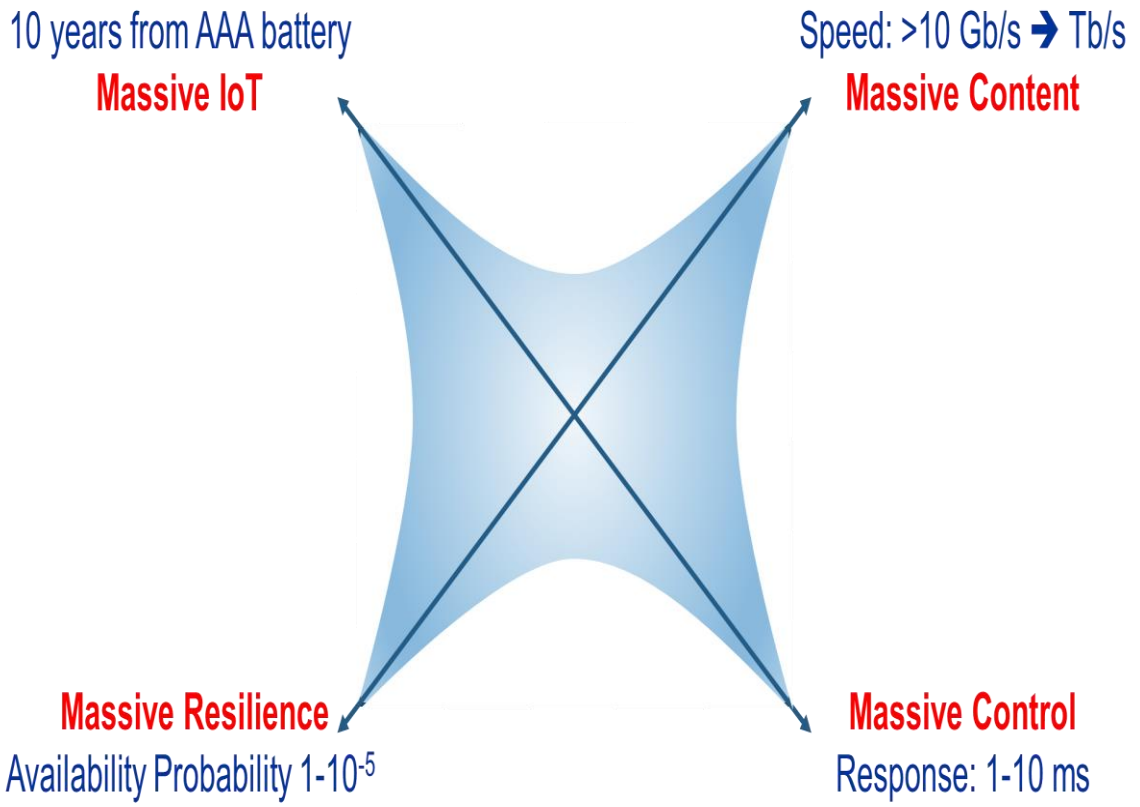
- Subway / Stadium Service, eHealth, Wearables, Inventory Control

## Network Operation

- Network Slicing, Routing, Migration and Interworking, Energy Saving

## Enhancement of Vehicle-to-Everything

- Autonomous Driving, safety and non-safety features




Courtesy: Gerhard Fettweis

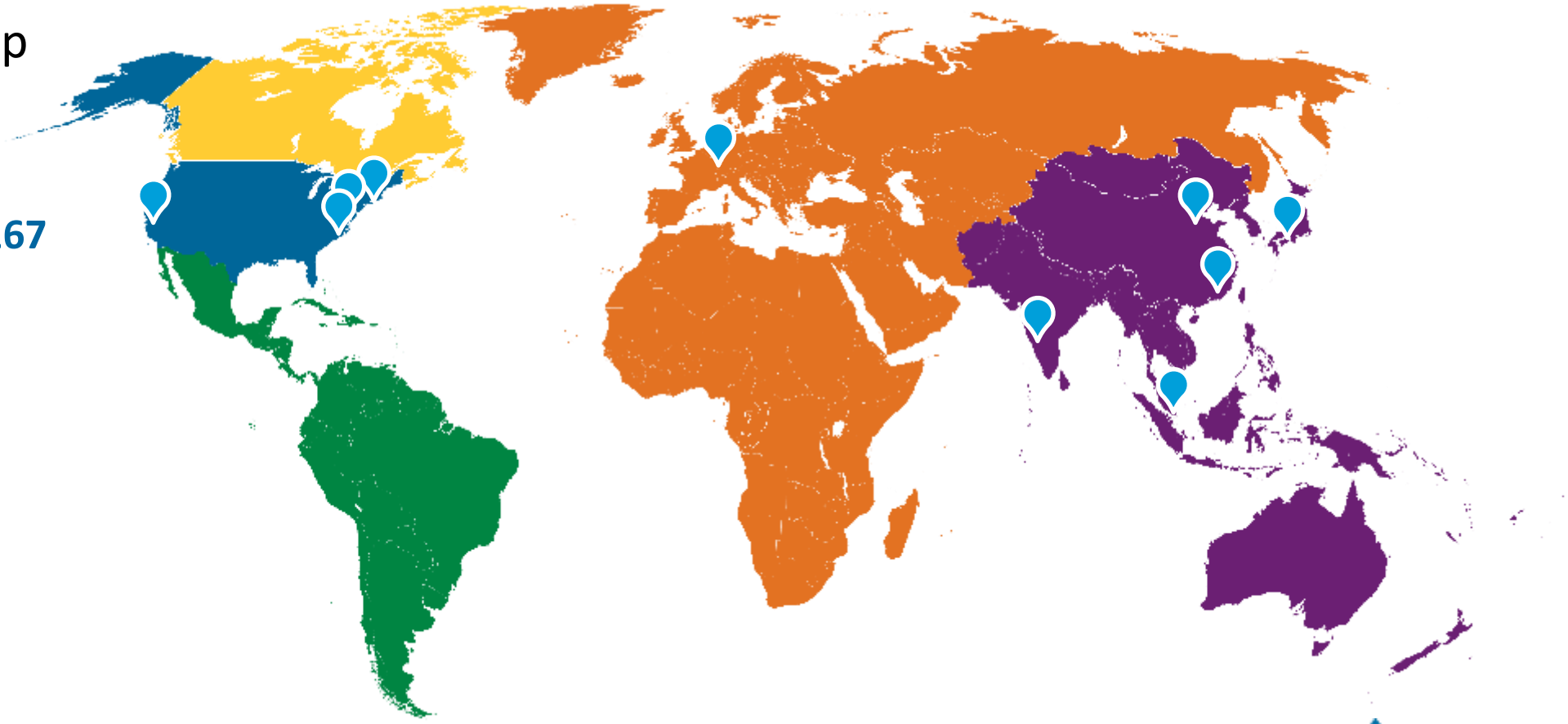
# What "5G and Advanced Communication Systems" is About

# IEEE Membership By Region

Total Membership

**421,355**

- R1 to 6 — **194,167**
- R7 — **17,163**
- R8 — **77,883**
- R9 — **18,569**
- R10 — **113,573**
- IEEE Offices



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# 2018 FDC Initiatives & Activities

## Small Projects

- Environmental Engineering
- Roadmaps Strategy and Governance (IRSG)
- Quantum Computing

IEEE BLOCKCHAIN™

IEEE Future NETWORKS™

IEEE brain

IEEE rebooting COMPUTING

IEEE Digital Reality

IEEE SYMBIOTIC AUTONOMOUS SYSTEMS™

IEEE TECHNOLOGY TIME MACHINE

# Graduated Initiatives

IEEE BigData

IEEE Smart Cities

IEEE CLOUD COMPUTING

IEEE SMARTGRID

IEEE CYBER SECURITY

IEEE SOFTWARE DEFINED NETWORKS

IEEE Internet of Things

IEEE lifesciences

IEEE TRANSPORTATION ELECTRIFICATION COMMUNITY

IEEE SUSTAINABLEICT™

[ieee.org/futuredirections](ieee.org/futuredirections)

# Introduction

## Initiative Overview

- The IEEE 5G Initiative (Now known as Future Networks Initiative) engages professionals worldwide from industry, government and academia to work together to solve the challenges associated with 5G and beyond and lay the foundation to realize its many opportunities.
- The IEEE 5G Initiative, which includes contributions from over 22 IEEE societies, has several working groups focused around specific activities
- These include its 5G and Beyond Technology Roadmap, testbeds project, standards, events and conferences such as the IEEE 5G World Forum, educational materials including IEEE 5G Transmissions Podcasts, the IEEE 5G Tech Focus publication, IEEE 5G Webinar series, and IEEE 5G Learning Series of tutorials.

## Goals/Objectives

- Foster collaboration and connect technical & business communities to IEEE 5G experts and resources
- Be the catalyst for IEEE cross-society activities on 5G
- Establish IEEE as a thought leader and essential to the 5G community
- To be recognized as the go-to resource for engineering and technology professionals in industry, academia and government working on 5G
- Develop and promote valued programs, products and services for the 5G community
- Present a single IEEE face/voice to the 5G marketplace
- Be a true global 5G initiative capturing the needs of all global regions
- Create a neutral platform/forum where those interested in 5G can engage and collaborate

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# Key Stakeholders

## IEEE Societies (22 so far)

## Industry

## Academia, Students

## IEEE OUs

IEEE STANDARDS ASSOCIATION

IEEE EDUCATIONAL ACTIVITIES

## Initiative Profile

- Launched August 2016
- Technical Activities Board Funded
- 20+ Participating Societies/OUs

# 5G.IEEE.ORG




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IEEE 5G

IEEE



# The global team of experts involved in IEEE 5G are producing programs and activities including…

## The 5G Technology Roadmap

short-term (~3 years), mid-term (~5 years), and long-term (~10 years)

research, innovation, and technology trends

## Publications

IEEE 5G Transmissions podcast series

IEEE Tech Focus

IEEE Talks 5G Q&A article series

## Conferences & Events

1st Annual IEEE 5G World Forum in 2018

5G-related IEEE conferences

5G Summits

## Education

IEEE 5G Learning Series

IEEE Live Online Courses

Webinar series

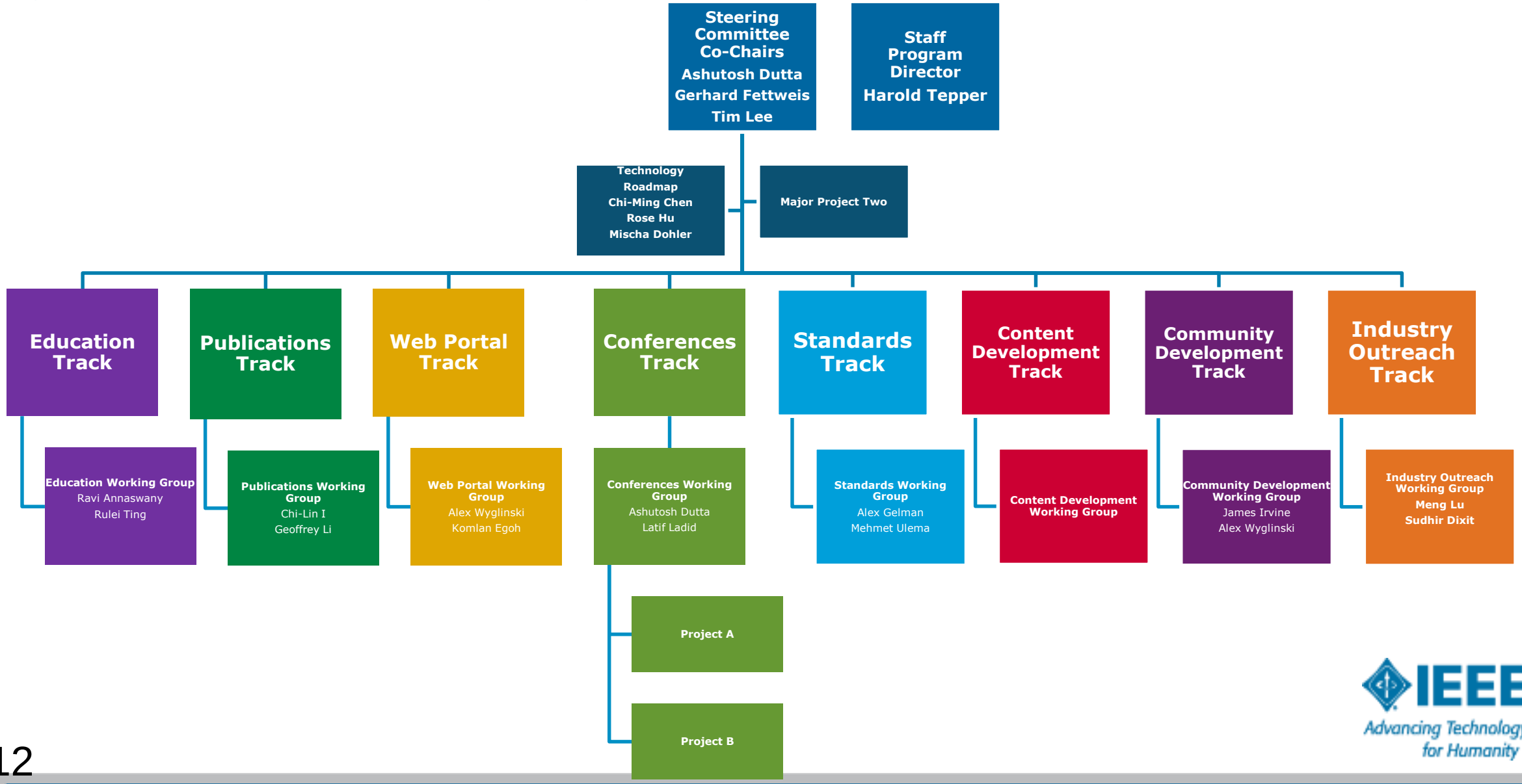
## Expert Articles

Published on IEEE 5G web portal and in industry media

## Standards

Global, open, and collaborative

# 5G Initiative Structure



# Getting involved

Working Group Scope

## Education Track
(R. Ting, R. Annaswamy)

**Define, develop and manage portfolio of offerings/activities including:**

- eLearning Modules
- Tutorials
- Webinars
- Podcasts
- Google Hangouts

## Publications Track
(C-L. I, G. Li)

**Define, develop and manage portfolio of offerings/activities including:**

- eNewsletter
- Journal, Transactions
- Magazine
- Supplements to other publications
- Special issues in other publications

## Web Portal Track
(J. Irvine)

**Determine, source and manage content placed on portal**

**Ensure that portal is refreshed on a continuous basis**

## Conferences Track
(A. Dutta, L. Ladid)

**Manage Initiative events**

- Conferences
- Workshops

**Determine and manage participation in other events**

- Patron
- Exhibitor
- Panelist
- Keynote

# Getting Involved

## Working Group Scope

### Standards Track
(A. Gelman, P. Nikolich)

**Manage portfolio of activities including:**

- New projects
- Workshops for needs definition and connection with technology developers
- Roundtable program for industry leaders
- Engagement with SDOs and other external organizations

### Content Development Track
(B.Das)

**Develop and source content for posting / publication including:**

- By-lined articles
- Q&As
- Expert Interviews
- Whitepapers
- Scenarios/Use Cases
- Media Interviews
- Analyst Briefings

### Community Development Track
(J. Irvine, A. Wyglinski)

**Establish and grow a broad IEEE 5G Community including:**

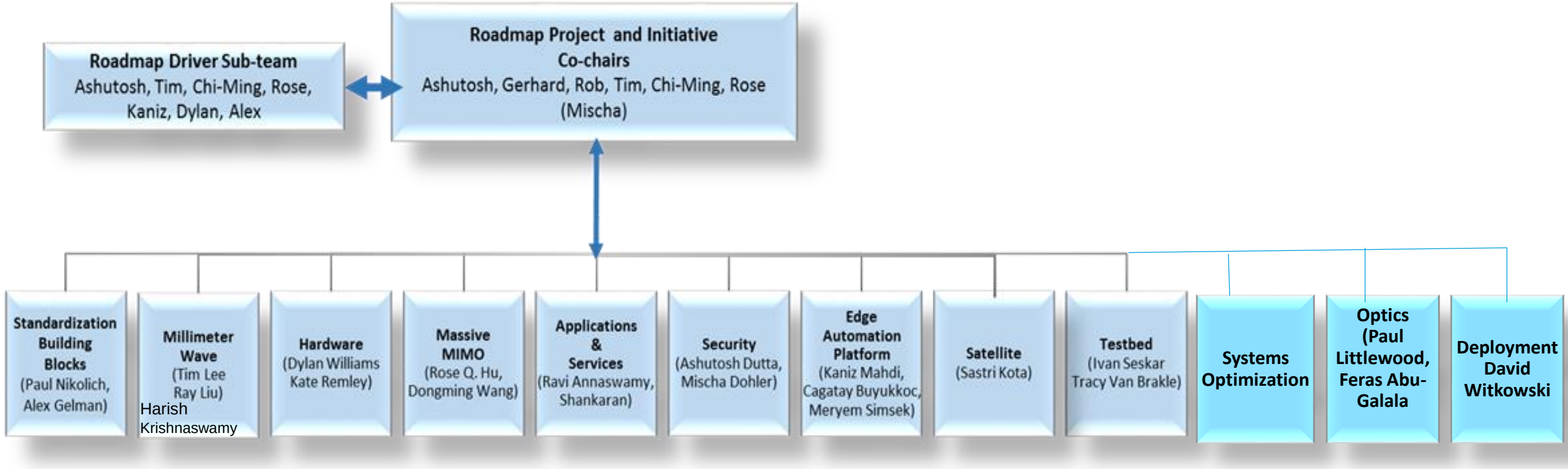
- IEEE Technical Community
- Collabratec
- Twitter
- LinkedIn
- Facebook
- FlipBoard

### Industry Outreach Track
(M. Lu, M. Condry)

**Drive engagement with industry including:**

- Partnerships
- Training
- Career Development

# 5G and Beyond Roadmap Working Group

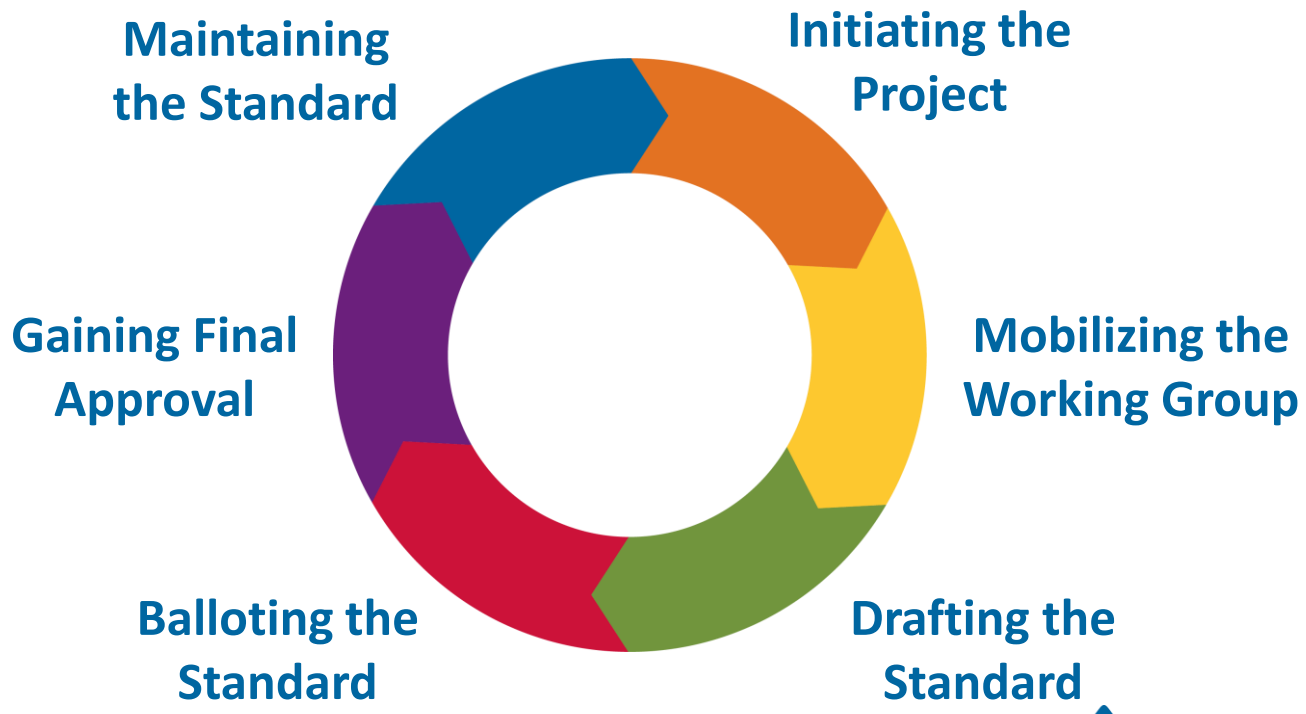


# IEEE Standards Association

Drives the functionality, capability, and interoperability of a range of products and services that affect the way people live, work, and communicate.

**6,879**
**Individual Members**
in 90 countries

**187**
**Corporate Members**
in 23 countries



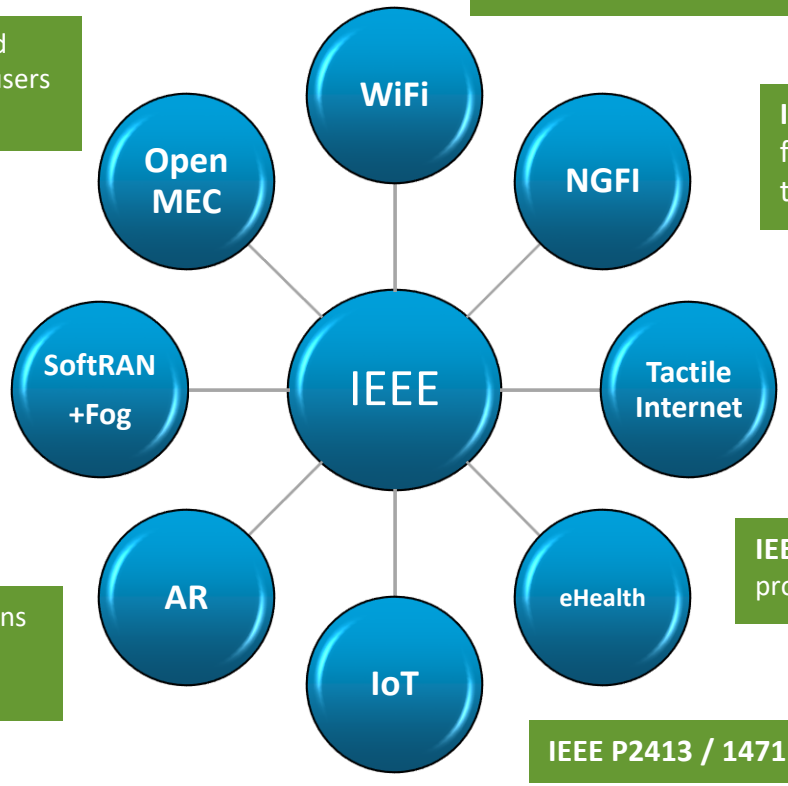

IEEE

# IEEE: Standards and Global Collaboration for 5G

IEEE provides a complete, end-to-end, collaborative framework today for accelerating the realization of 5G and its revolutionary use cases tomorrow.

**IEEE 802.11**
standard supported by almost any mobile device in the market today

**Mobile Edge Cloud** brings SDN/NFV frameworks and data path programmability to the proximity of end users as key enablers for service differentiation




**IEEE 1914/1904**
flexible, efficient and scalable packet-based fronthaul transport networks

SoftRAN is to create a SD RAN flexible enough to control applications with the wireline centric concepts of "fog" in a SD-controller

**IEEE 1918**
non/mission-critical applications (e.g. manufacturing, transportation, healthcare, mobility, edutainment, events)

**IEEE 11073**
provides a global platform for eHealth stakeholders

IEEE P1589/P1587.6/P1857.9/P3333.2.4 Industry Connections the integration of computer-generated sensory content with the physical world

**IEEE P2413 / 1471 / 42010**

# Standards Applicable to 5G

## Computer Society:

### IEEE 802.1 - Higher Layer LAN Protocols Working Group

- IEEE P802.1CM — Profile of Ethernet networks utilizing Time Sensitive Networking
- IEEE P802.1CF — Netw. Ref. Model, and Func. Description of IEEE 802 Access Network

### IEEE 802.3 - Ethernet Working Group

- IEEE P802.3bs — 200 Gb/s and 400 Gb/s Ethernet
- IEEE P802.3ca — 25 Gb/s, 50 Gb/s, and 100 Gb/s Ethernet Passive Optical Networks (EPON)
- IEEE P802.3cc — 25 Gb/s Ethernet over Single-Mode Fiber
- IEEE P802.3cd — 50Gb/s, 100 Gb/s, and 200 Gb/s Ethernet

### IEEE 802.11 - Wireless LAN (aka Wi-Fi) Working Group

- IEEE 802.11ac-2013 — Up to 7 Gbps in 5 GHz
- IEEE 802.11ad-2012 — Up to 7 Gbps in 60 GHz
- IEEE P802.11ax — Up to 10 Gbps in the 5 GHz
- IEEE P802.11ay — Up to 20 Gbps in the 60 GHz band
- IEEE 802.11ah-2016 — “HaLow”: Massive Machine Type Communications

# Standards Applicable to 5G (Cont'd)

## Computer Society:

- IEEE 1903–2011 Standard for the Function Architecture of Next Generation Overlay Network

### IEEE 802.15 - Wireless Personal Area Network (WPAN) Working Group

- IEEE 802.15.6 Wireless Body Area Networks (BAN)
- IEEE 802.15.7 Visible Light Communications
- IEEE 802.15.12 Upper Layer Interface (ULI)

### IEEE 802.16 - Broadband Wireless Access Working Group

### IEEE 802.18 - Radio Regulatory Technical Advisory Group

### IEEE 802.19 - Wireless Coexistence Working Group

- IEEE 802.19.1 TV White Space Coexistence Methods

### IEEE 802.21 - Media Independent Handover Services Working Group

- IEEE 802.22 Point-to-Multipoint Wireless Broadband
- IEEE 802.11P Vehicular Communication System (amendment to 802.11)

# Standards Applicable to 5G (Cont'd)

## IEEE Vehicular Technology Society/ Intelligent Transportation Systems:

- 1609 Series - IEEE Wireless Access in Vehicular Environments (WAVE)

## IEEE Antennas and Propagation Society/Antennas and Propagation:

- P211 - Standard Definitions of Terms for Radio Wave Propagation
- P149 - Recommended Practice for Antenna Measurements
- 1720-2012 - IEEE Recommended Practice for Near-Field Antenna Measurements

## SASB/SCC39-SCC39 - International Committee on Electromagnetic Safety:

- 1528-2013 - IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques

## Instruments & Measurements:

- 1451 Series - Smart Transducer Interface for Sensors and Actuator Wireless Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats

## Audio Video Coding Working Group:

- IEEE P1857.6™ - Standard for Digital Media Content
- IEEE P1857.9™ - Standard for Immersive Visual Content Coding

## 3D Based Medical Application Working Group:

- IEEE P3333.2.4™ - Standard for Three-Dimensional (3D) Medical Simulation

# Standards in Development Applicable to 5G (Cont'd)

## IEEE SA Design Automation Standards Committee (DASC)

- IEEE 1666 (SystemC) Modeling of 5G designs at a pre-implementation level
- IEEE 1666.1 SystemC AMS)
- IEEE 1800 (SystemVerilog) Design/Verification of 5G devices
- IEEE 1076 (VHDL)
- IEEE 1076.1.1 (VHDL AMS)
- IEEE 1647 (the e language)
- IEEE P1800.2 (UVM)
- IEEE 1801 (UPF) Low power hardware analysis 5G hardware designs
- IEEE 1685 (IPXACT) 5G Semiconductor IP design
- IEEE 1734 (IP quality)
- IEEE 1735 (IP encryption)

# Standards in Development Applicable to 5G (Cont'd)

## Communications Society

- IEEE P1903.1 Content Delivery Protocols of Next Generation Service Overlay Network (NGSON)
- IEEE P1903.2 Service Composition Protocols of NGSON
- IEEE P1903.3 Self-Organizing Management Protocols of NGSON
- IEEE P2413 Architectural Framework for the Internet of Things
- IEEE P1914.1 Standard for Packet-based Fronthaul Transport Networks
- IEEE P1915.1 SDN and NFV Security
- IEEE P1916.1 SDN and NFV Performance
- IEEE P1917.1 SDN and NFV Reliability
- IEEE P1918.1 Tactile Internet
- IEEE P1918.1.1 Haptic Codecs for the Tactile Internet
- IEEE P1921.1 SDN Bootstrapping Procedures
- IEEE P1930.1 Recommended Practice for (SDN) Middleware
- IEEE 1931.1 Architectural "ROOF "Framework for the IoT

# Standards in Development Applicable to 5G (Cont'd)

## IEEE Microwave Theory and Techniques:

- IEEE P1765 Recommended Practice for Estimating the Uncertainty In Measurements of Modulated Signals for Wireless Communications with Application to Error Vector Magnitude and Other System-Level Distortion Metrics
- IEEE P1770 Recommended Practice for The Usage of Terms Commonly Employed In the Field of Large-Signal Vector Network Analysis
- IEEE P1785 IEEE Frequency Bands and Waveguide Dimensions

## IEEE Instrumentation and Measurement Society:

- IEEE P287 Standard for Precision Coaxial Connectors at RF, Microwave and Millimeter-wave Frequencies
- IEEE P1415-99 Harmonization of Internet of Things (IoT) Devices and Systems

## Augmented Reality Learning Experience Model:

- IEEE P1589 Standard for an Augmented Reality Learning Experience Model

# GLOBAL

# IS

# WHAT IS NEEDED

# LOCALLY EVERYWHERE

# 40 Summits
# IEEE 5G Summit Series – 2015 - 2018 (www.5gsummit.org)

50 5G Summits, More than 5000 attendees (onsite and online), 400 Speakers, Streaming and Recording Archieved

# IEEE 5G Summit Series – 2015 – 2018 (www.ieee-5gsummit.org)


3 IEEE 5G Summits in 2015


8 IEEE 5G Summits in 2016


19 IEEE 5G Summits completed in 2017


9 IEEE 5G Summits planned in 2018

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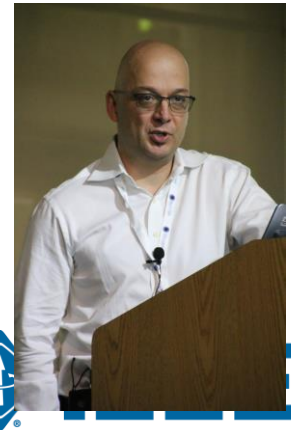
# First 5G Summit
# Princeton University May 2015

- A successful event

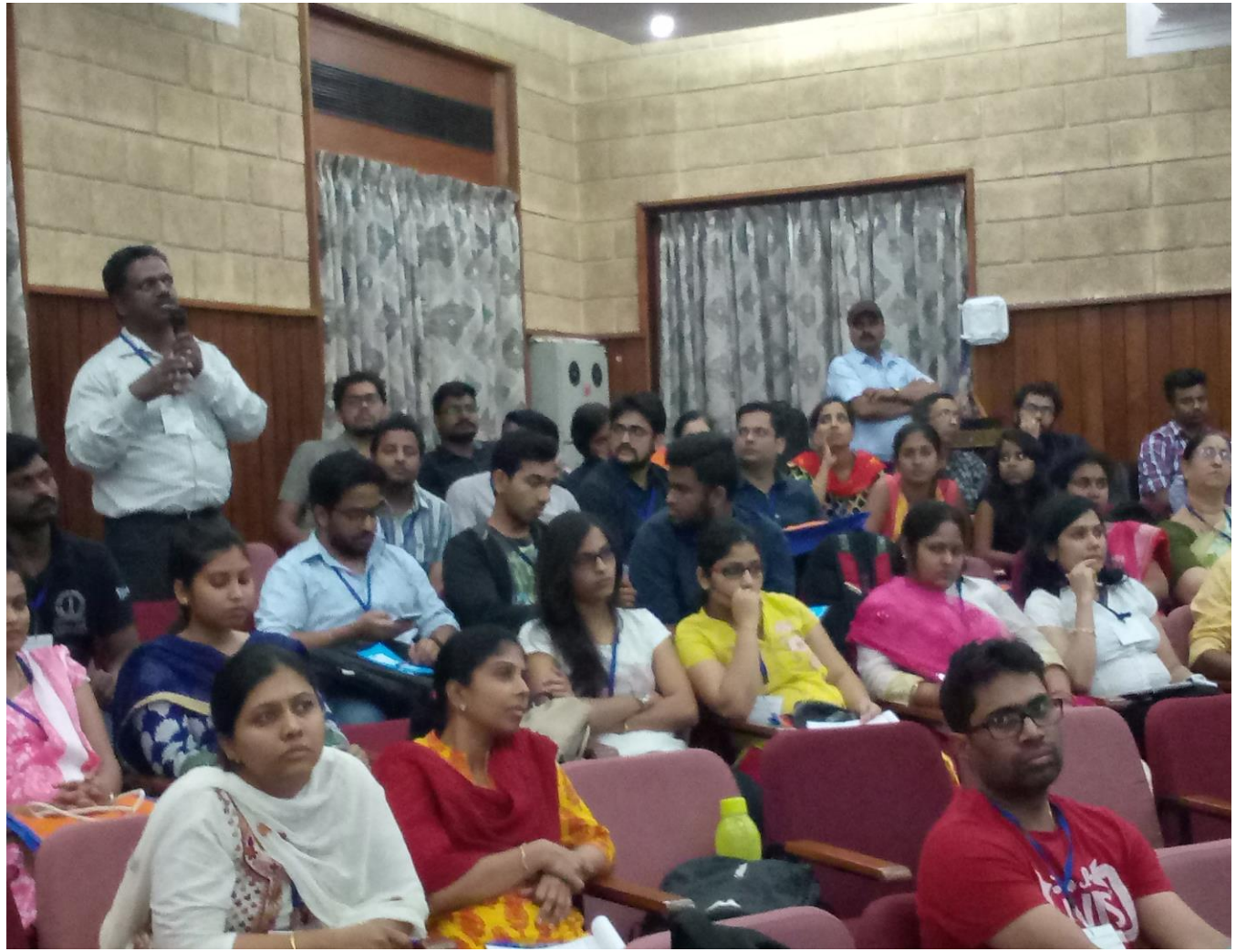


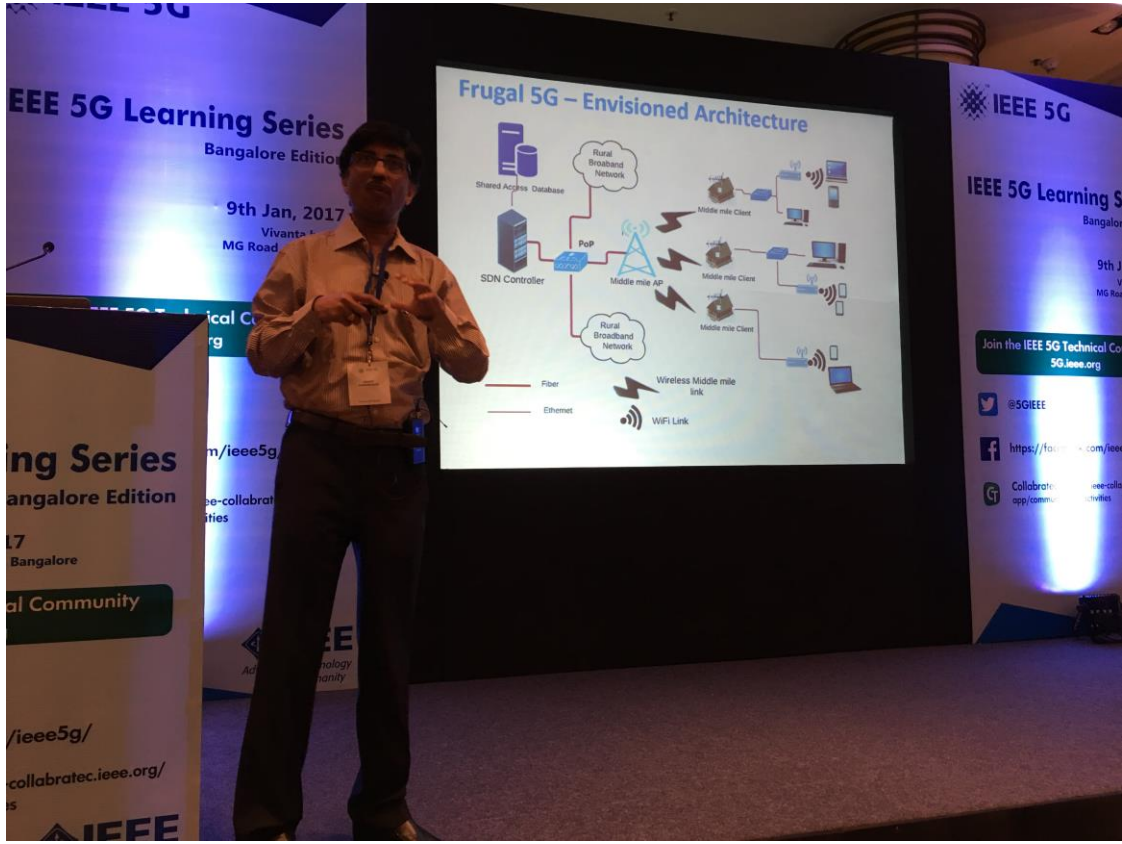
IEEE

# SANTA CLARA SUMMIT, 2015

# BANGALORE SUMMIT 2017





# Engaging Industry

# Industry Input

*AN INDUSTRY-WIDE DIALOGUE*


- *You're invited to participate* in the IEEE Beyond 5G Technology Roadmap effort *to help stimulate an industry-wide dialogue to outline a technology and innovation vision of the development and deployment of 5G and beyond*.

- *Your expertise as an industry subject matter expert is needed* in the roadmap dialog regarding the evolution, the challenges faced, and identification of solutions and areas of innovation.

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# Ecosystem Stakeholders

- End users
- Application developers
- Service providers
- Equipment manufacturers
- Component suppliers
- Technology innovators
- Governments
- Standards and guidelines producing bodies
  - IEEE-SA
  - 3GPP
  - ITU

**Industry Interaction at Large**

- The Roadmap effort will also include a series of meetings to gather additional inputs and feedback on trends related to:
- Business
- Technology
- Societal
- New fields
- Other industries

Join the Tech Community!

# From IEEE 5G to IEEE Future Networks

IEEE Future NETWORKS

- 5G has promised us ultralow latency and record-breaking data speeds, which will enable advances in everything from small cell research to virtual reality applications. This technology will create **tremendous growth opportunities**, but it won't stop there. That is why, in August 2018, the IEEE 5G Initiative has rebranded to become the IEEE Future Networks Initiative. The Initiative will pave a clear path through development and deployment of 5G and beyond. We will accomplish this through the creation of:

| | | |
|---|---|---|
| ✓ Standards | ✓ Webinars | ✓ Testbeds |
| ✓ Publications | ✓ Tutorials | ✓ Podcasts |
| ✓ Newsletters | ✓ Roadmaps | AND MORE |

Sign up for free at futurenetworks.ieee.org

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**Whether you are a platform provider, operator, manufacturer, or service/ content provider, there is a path for you and your business to be seen, heard, and make an impact in 5G**

**…contribute to the inaugural IEEE 5G Initiative Roadmap Working Groups …**

**…contribute to our publication, IEEE 5G Tech Focus…**

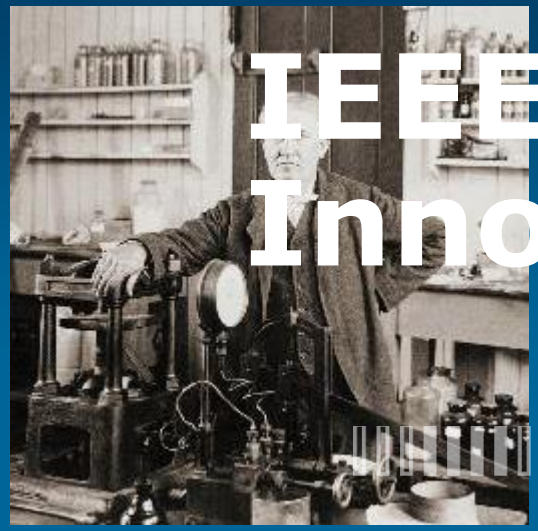
**…lead an IEEE 5G use case or infrastructure project.**

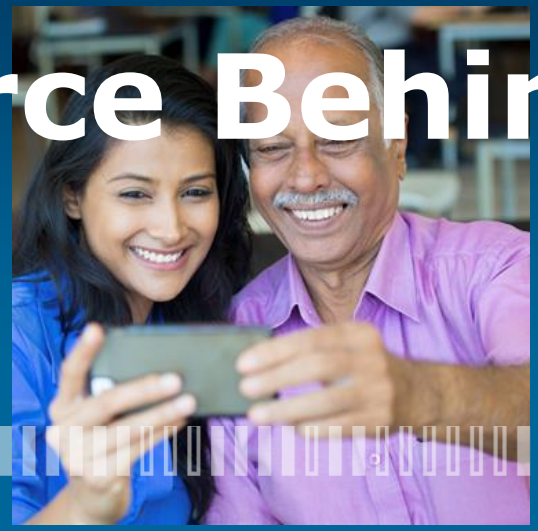
# THANK YOU

and

# JOIN US FOR THE INNOVATION REVOLUTION

LEARN MORE AT
5G.IEEE.ORG





# IEEE: The Force Behind Innovation

IEEE ComSoc
IEEE Communications Society

IEEE STANDARDS ASSOCIATION

**Ashutosh Dutta, Ph.D., Johns Hopkins University/Applied Physics Lab, Maryland, USA**
**IEEE 5G Initiative Co-Chair**
**IEEE Communications Society Director of Industry Outreach**
**IEEEE Communications Society Distinguished Lecturer**
**September 17, 2018**

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# OUR MISSION

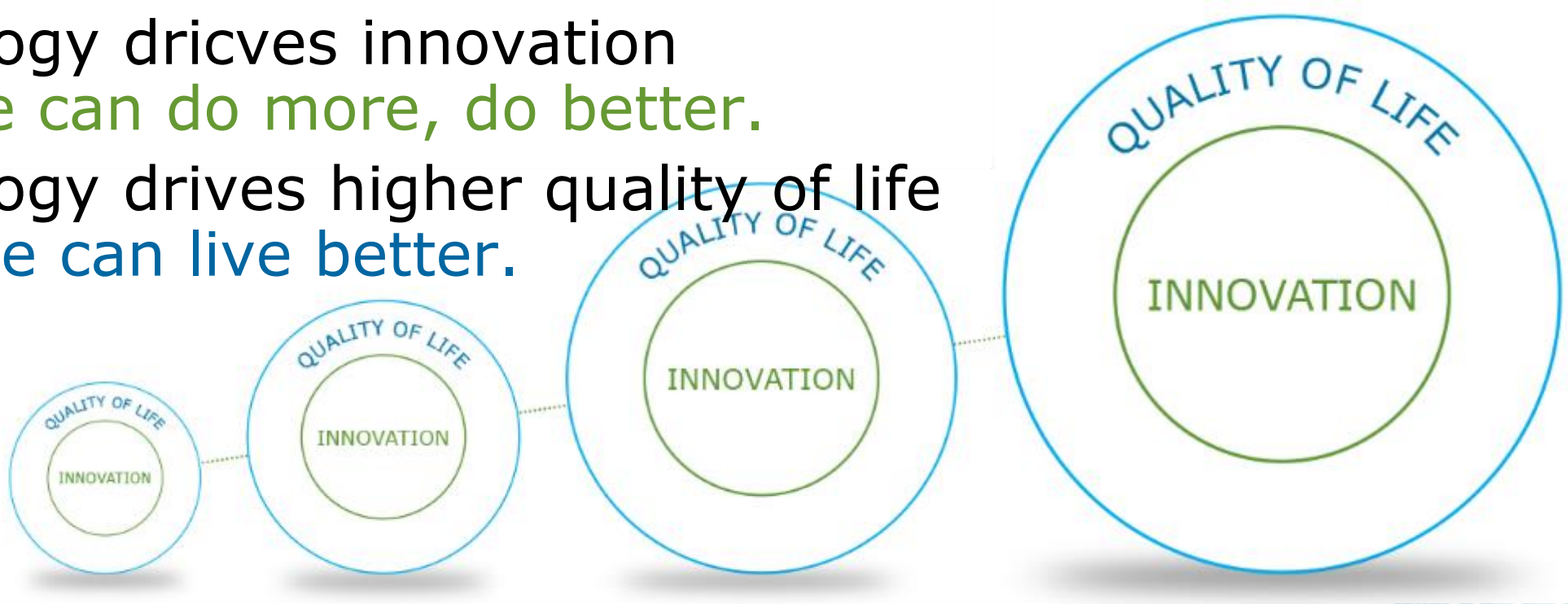
The core purpose of IEEE is to foster technological innovation and excellence for the benefit of humanity.

## Our Vision

IEEE will be essential to the global technical community and to technical professionals everywhere, and be universally recognized for the contributions of technology and of technical professionals in improving global conditions.

# Advancing Technology

- IEEE is behind the technology that drives innovation and better living.
- Technology dricves innovation
  – people can do more, do better.
- Technology drives higher quality of life
  – people can live better.

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# Advancing Technology

IEEE facilitates the cross-pollination of ideas, giving people access to ideas developed in other disciplines.

IEEE information is more than just electrical engineering and computer science

**IEEE TECHNICAL AREAS:**

- Aerospace
- Biomedical Engineering
- Circuits
- Cloud Computing
- Communications
- Electronics
- Imaging
- Information Technology
- LTE Wireless
- Broadband
- Nanotechnology
- Optics
- Renewable Energy
- Semiconductors
- Smart Grid
- And more…

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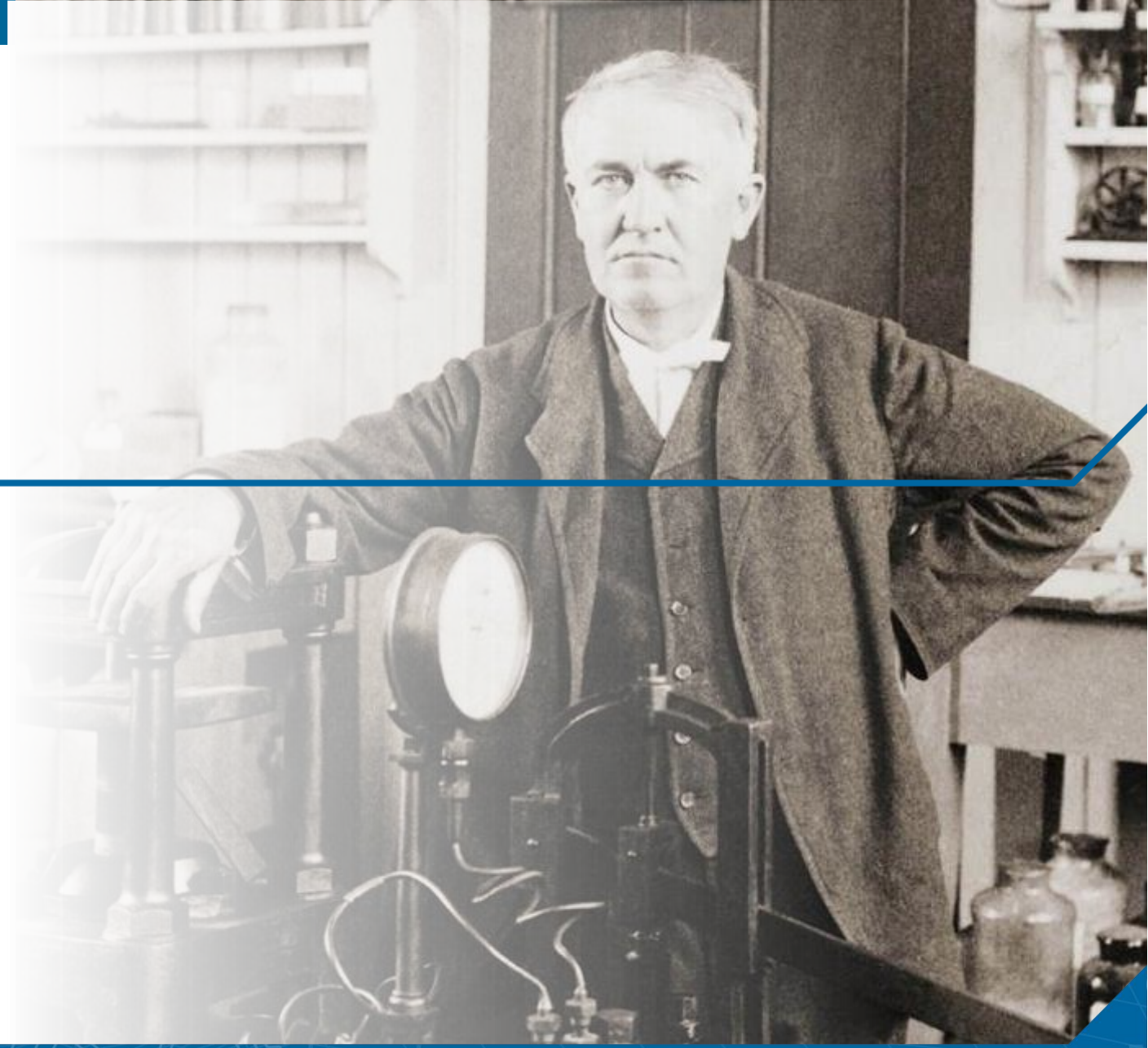

Our story of innovation begins with our spirit of collaboration.

# OUR HISTORY

# The Founding of IEEE

**1884** ..... **1912** ..... **1963** ..... **Present**

Thomas [illegible]xande[illegible] and oth[illegible]unde[illegible] **Ameri[illegible]f E[illegible] Engi[illegible]**

Pioneers of wireless technologies and electronics founded the **Institute of Radio Engineers**.

**AIEE**
American Institute of Electrical Engineers

**IRE**
Institute of Radio Engineers

AIEE and IRE merged to become the Institute of Electrical and Electronics Engineers, or **IEEE**.

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# IEEE Today at a Glance

## Our Global Reach

**423,000+**
Members

**42**
Technical Societies

**160**
Countries

## Our Technical Breadth

**1,800**
Annual Conferences

**4,000,000+**
Technical Documents

**170+**
Top-cited Periodicals

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# Technical Expertise that is Broad and Deep

## Electrical and electronic engineering, computer science, and beyond:

Aerospace
Biomedical Engineering
Broadcasting
Circuits
Communications
Computing
Control and Automation
Electronics
Energy and Smart Grid
Environment
Industrial Systems
Information Technology
Internet of Things
Life Sciences
Nanotechnology
Optics
Robotics and AI
Semiconductors
Smart Cities
Transportation and Vehicles
And more…

# IEEE Membership By Region

Total Membership

**421,355**

- R1 to 6 — **194,167**
- R7 — **17,163**
- R8 — **77,883**
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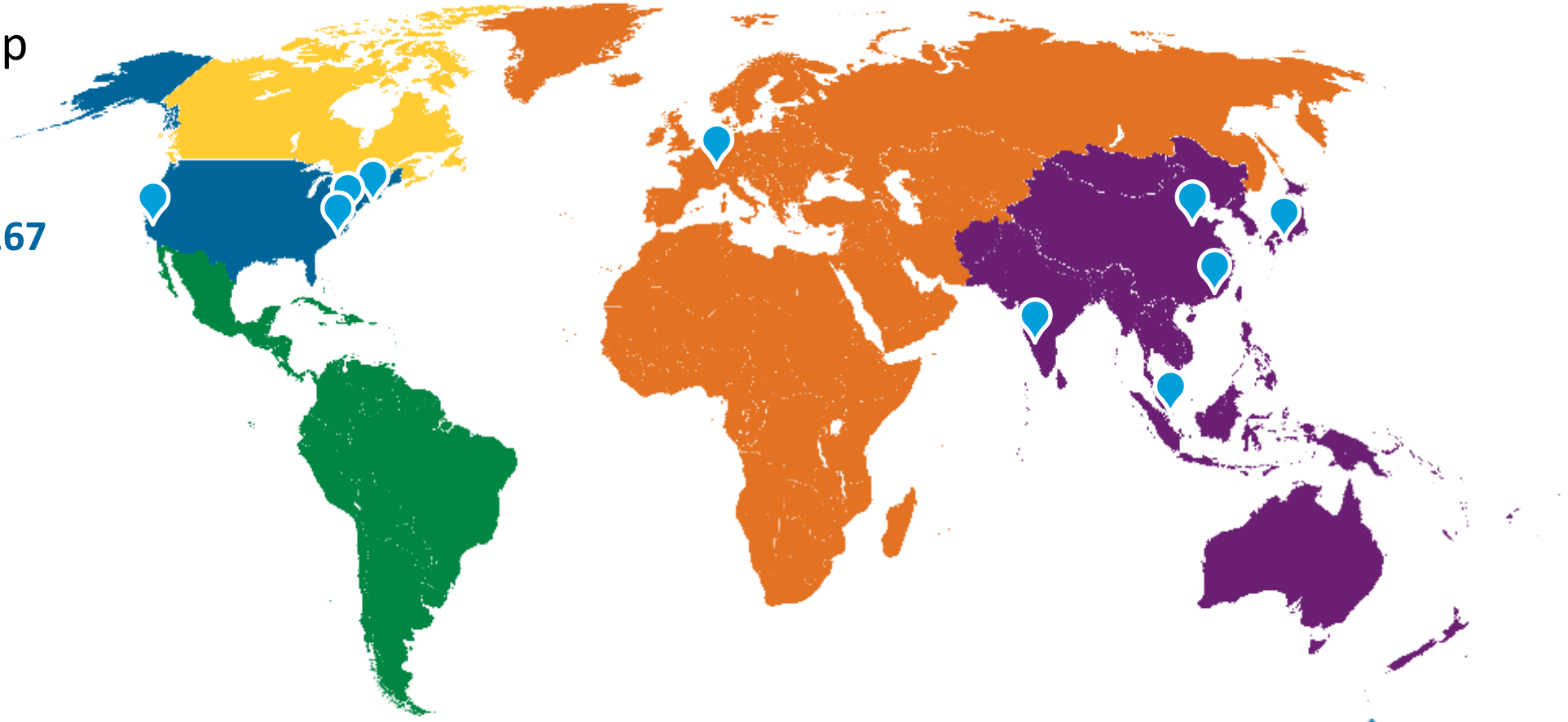

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# Sections, Societies, and Councils

## Geographic Sections

- Local colleague community
- Cross-and inter-disciplinary networking through local Section, Chapter, Student Branch activities
- Volunteer leaders gain management, teamwork, and leadership experience
- Local professional and technical activities
- Recognize and honor achievements of members and others in their community

## Global Societies & Councils

- Bring together international member coalitions of shared technical interests
- Sponsor and organize conferences, workshops, tutorials, seminars, etc.
- Develop publications: journals, magazines, newsletters
- Recognize and honor member accomplishments

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# Worldwide Impact of IEEE Geographic Units

## Global Geographic Units

**335** Sections

**2,274** Chapters

**2,845** Student Branches

# Worldwide Impact of IEEE Geographic Units

## India

**11** Sections

**116** Chapters

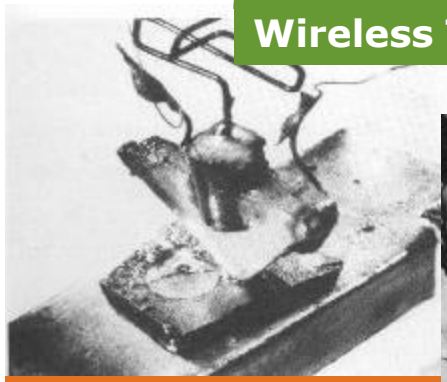
**1,020** Student Branches

# *"If I have Seen Further than Others..."*

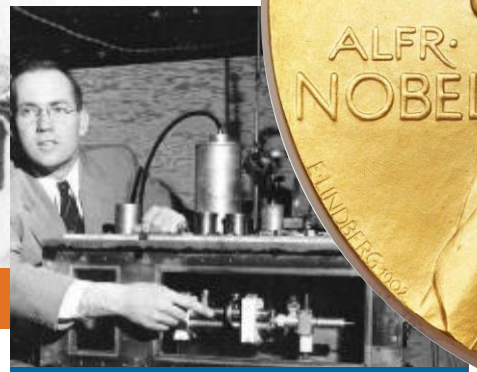
## Notable IEEE Nobel Prize winners:

- **Guglielmo Marconi 1909**
- Robert Andrews Millikan 1923
- Irving Langmuir 1932
- Willem Einthoven 1924
- Edward Appleton 1947
- **William Shockley 1956**
- Walter Brattain 1956
- **Charles Townes 1964**
- John Bardeen 1972
- Leo Esaki 1973

Wireless Telegraphy



Transistor



MASER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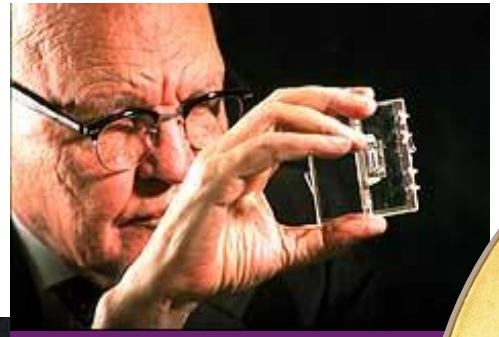
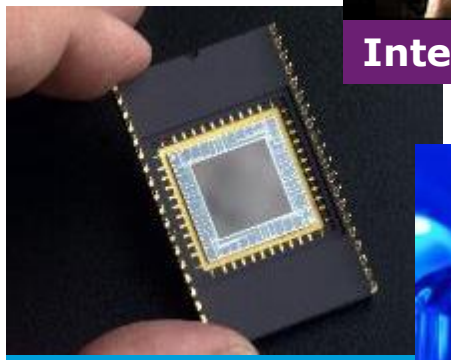
# *"...It is by Standing upon the Shoulders of Giants"*

## Notable IEEE Nobel Prize winners:

- Brian Josephson 1973
- Arthur Schawlow 1981
- Nicolaas Bloembergen 1981
- **Jack S. Kilby 2000**
- **Willard S. Boyle 2009**
- Charles K. Kao 2009
- George E. Smith 2009
- **Isamu Akasak 2014**
- **Hiroshi Amano 2014**
- **Shuji Nakamura 2014**



Integrated Circuit



Charge Coupled Device

Blue LED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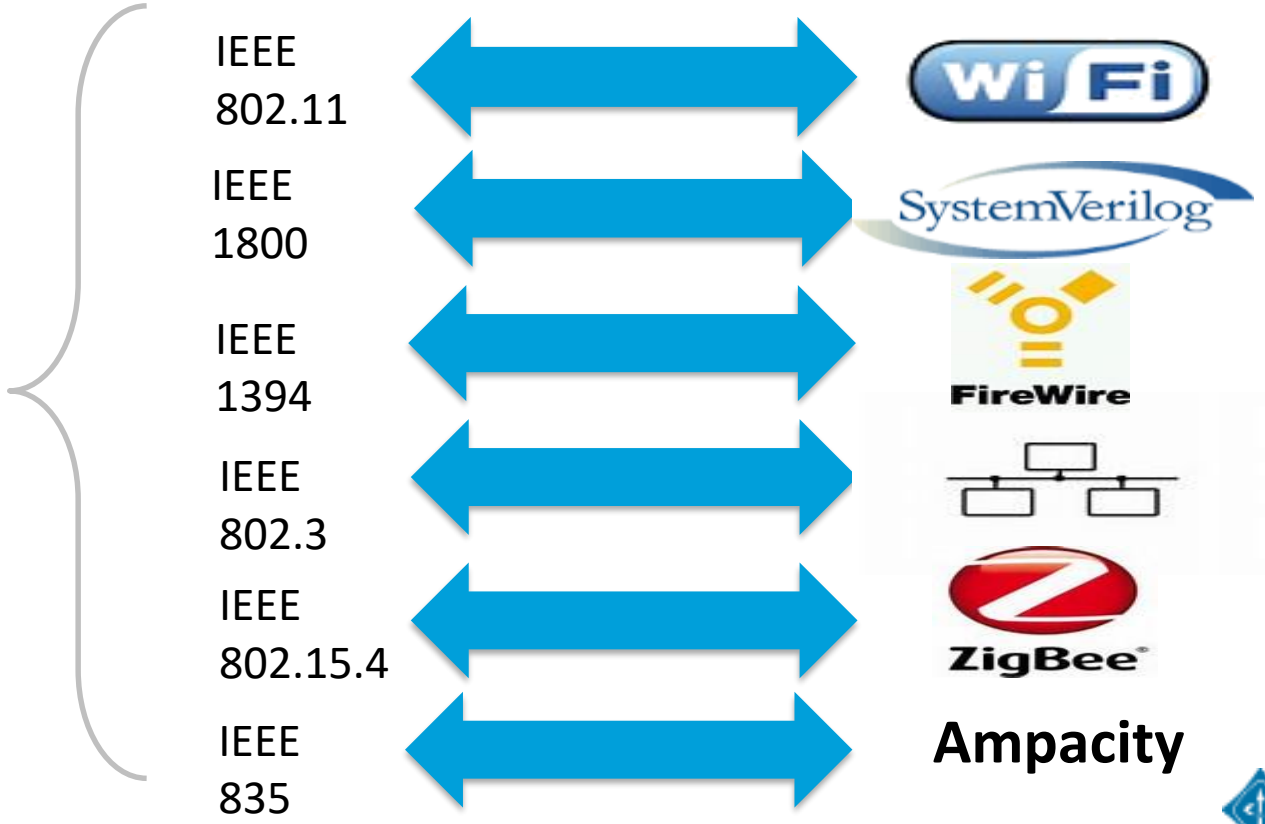


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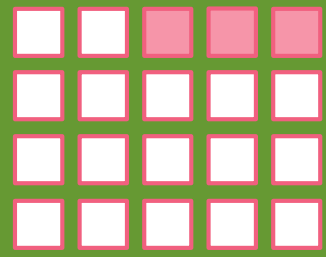

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Source: 2013 Thomson Reuters Journal Citation Reports® (JCR)

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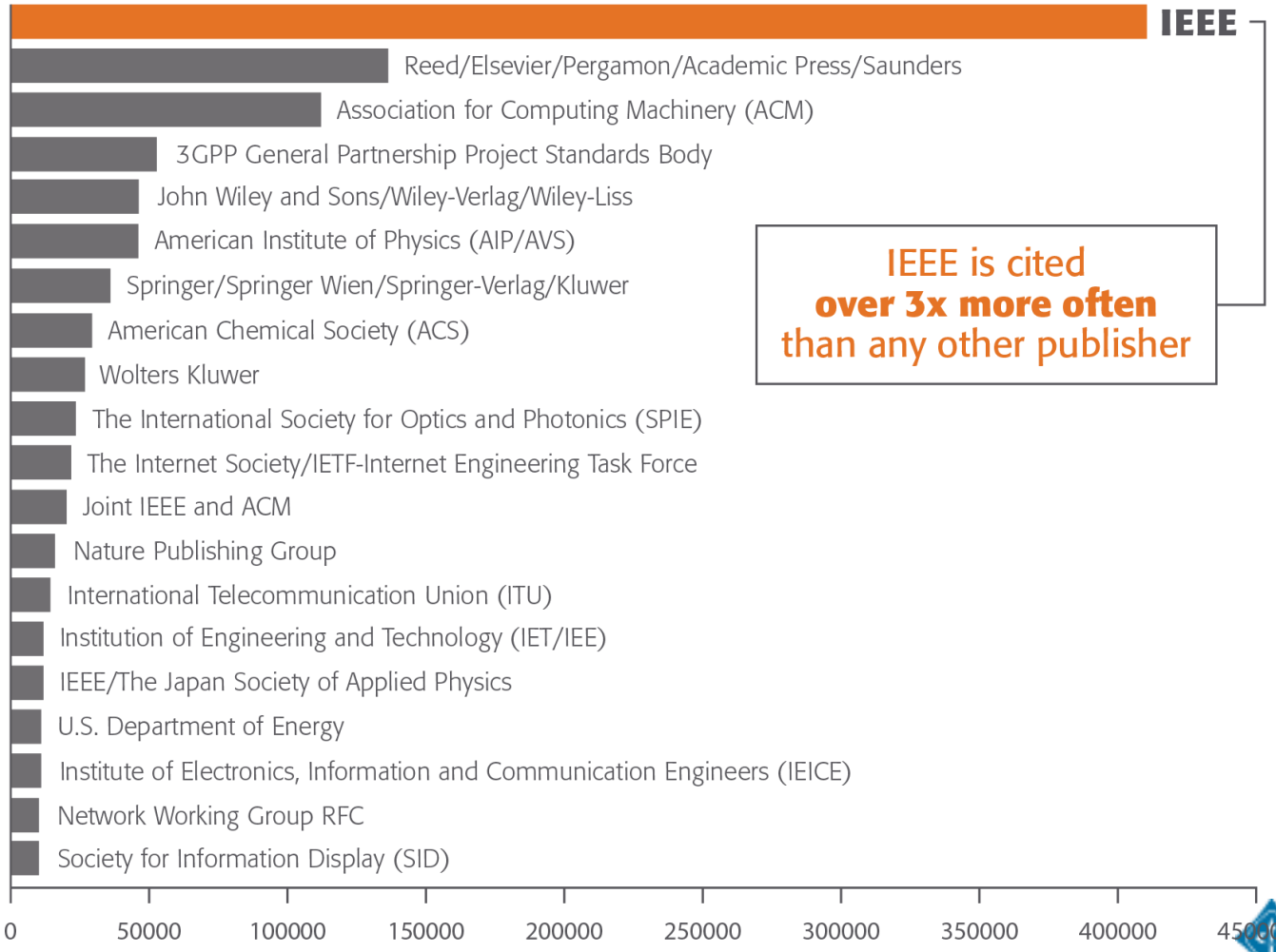


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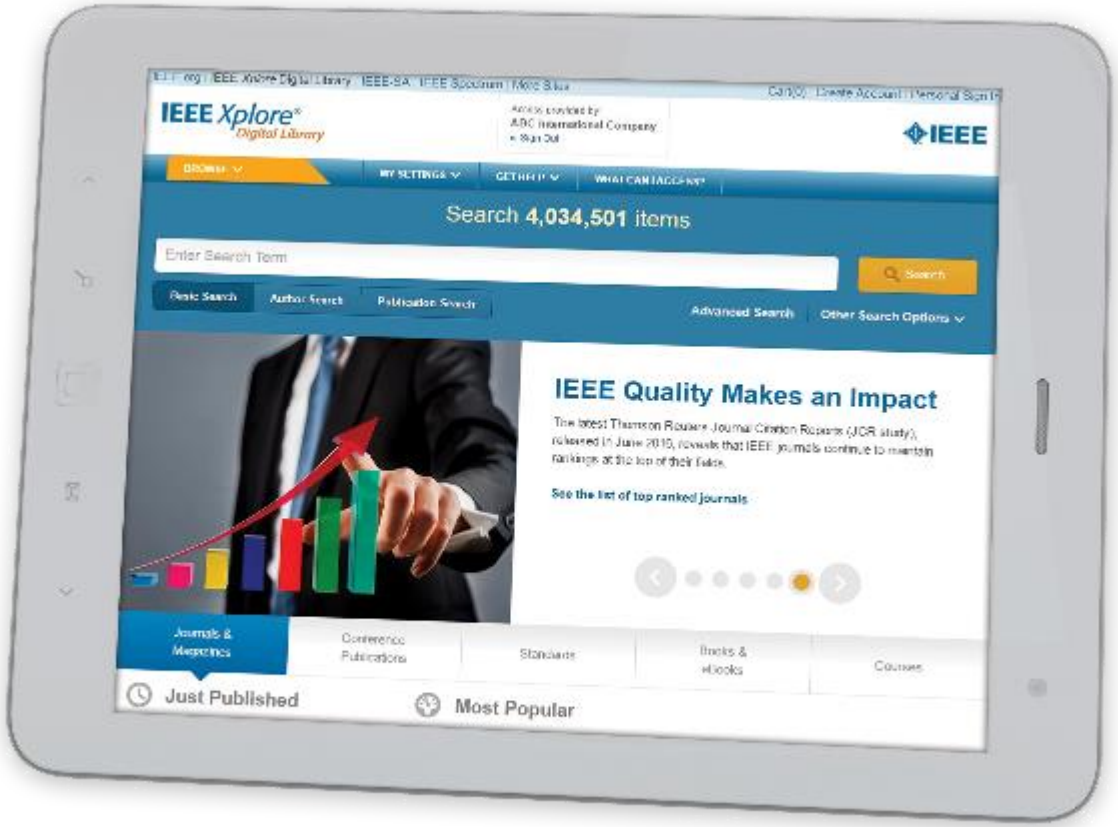


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Through humanitarian efforts supported by the IEEE Foundation—like IEEE Smart Village—technology is applied to improve conditions for people around the globe.

IEEE smart village™

***Pranav Mehrota (left), IEEE Smart Village volunteer, assisting with solar panels and a local energy entrepreneur.***

Ladakh, India 2013.
Photo credit: Paras Loomba.

***Paul Lacourciere with Sirona Cares introducing proper use of the portable battery kit to energy entrepreneurs.***

Haiti, 2015
Photo credit: Ray Larsen.

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IEEE Entrepreneurship


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