IEEE 5G and Beyond Initiative - A Perspective

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Sommario

Il 5G non rappresenta solo l'evoluzione del 4G ma un cambio di paradigma. Il 5G fornisce una maggiore capacità di banda e una più bassa latenza delle attuali generazioni ed ha una architettura in grado di abilitare nuove applicazioni soddisfacendo requisiti molto più stringenti consentendo l'esecuzione di funzionalità in tempo reale a larga banda.

La 5G Initiative lanciata dalla FDC (Future Direction Committee dell'IEEE) ha un approccio a 360° sul tema andando oltre gli aspetti tecnologici per affrontare e promuovere la standardizzazione, lo sviluppo di tutorial e corsi di formazione, la creazione di una forte comunità di specialisti attraverso workshop, conferenze e uno spazio per la collaborazione on line che sta coinvolgendo quasi 10.000 membri.

Abstract

5G is not just the next evolution of 4G technology; it's a paradigm shift. Not only is 5G providing higher bandwidth and lower latency than current-generation technology, more importantly, 5G is expected to enable fundamentally new applications with much more stringent requirements in latency (e.g., real time) and bandwidth (e.g., streaming).
It will be exploited in smart transportation, eHealth, smart cities, entertainment services transforming IoT into a sensing and actuating infrastructure by ensuring effective and pervasive connectivity.
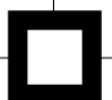
The IEEE FDC 5G Initiative takes a 360° view on 5G, capturing a truly global perspective when looking beyond the technical aspects by fostering standardization, developing an education framework with tutorials and courses, and creating a strong community through workshops, conferences, publications and an online collaboration workspace that is approaching 10,000 members.

Keywords: 5G, 5G Standardization, 5G centric applications, SDN, Paradigm Change, FDC IEEE 5G Initiative

Starting with the introduction of 1G back in the early 80s, the world has seen a rapid evolution of wireless and cellular technologies through each subsequent decade. Over this period, wireless networks have also evolved to support much higher bandwidth and lower end-to-end delay, supporting delay-sensitive applications such as interactive voice and video. For example, the 1G and 2G networks that were deployed in the late 1980s and early 1990s, respectively, could only support data rates of up to a few tens of kilobits per second, but by the start of the new century, they had evolved into 3G networks supporting up to 2 Mb/s data rate. The first generation mobile systems (1G) were analog in nature with large end-terminals and supported voice only. Some examples of 1G cellular systems are NMT (Nordic Mobile Telephone), TACS (Total Access Communications System), JTACS (Japan TACS), and AMPS (Advanced Mobile Phone System). During the early 1990s, different flavors of second generation cellular systems (e.g., GSM, IS-95) were developed in different parts of the world. This 2G cellular technology introduced digital communication with smaller phones and lower power consumption supporting low data rate services such as SMS and email. With the start of the new Millennium, third generation cellular systems (e.g., UMTS, CDMA) emerged and they ushered in the era of smart phones that were capable of supporting a wide range of services with higher data rates. More than a decade later, the world is seeing the wide spread deployment of 4G/LTE technologies supporting bandwidths of up to 100 Mb/s and less than 100 ms of end-to-end latency that can support interactive multimedia services. However, momentum is now building up to develop 5G technologies with a goal to deploy it by 2020. The fifth generation mobile technology is expected to provide a number of improvements compared to its predecessors in terms of higher data rates (up to 1 Gb/s), massive connectivity, flexible service creation and low latency, among others.

One of the goals of 5G technology is to provide ubiquitous connectivity while also addressing the demands of both individual consumers and businesses, in 2020 and beyond. Using advanced technologies, these 5G wireless technologies will purportedly further increase bandwidth, improve QoS, provide better usability and security, reduce delays as well as the total cost of service. These 5G technologies are expected to not only provide higher throughput, and lower latency but also a higher connectively density and mobility range without compromising reliability. Along with network optimization, 5G technology is

flexible by design allowing its networks to support a wide range of use cases. By virtue of its flexibility and an agile development methodology that uses modular network functions, it supports various use cases that are both scalable and cost effective. Software Defined Networks (SDN) and Network Function Virtualization (NFV) can play a big role in providing this functional modularity.

Today, several standards organizations and forums are working on defining the architecture and standardizing various aspects of 5G technologies. These include NGMN (Next Generation Mobile Network), ITU (International Telecommunication Union), GSMA (GSM Association), 3GPP (3rd Generation Partnership Project), WWRF (Wireless World Research Forum), 5G Americas, 5GPPP (5th Generation Public Private Partnership), 5GMF (5th Generation Mobile Communications Promotion Forum), 5GForum, and IEEE to name a few.

For example, an operator driven standardization organization, NGMN has defined five different use cases that could benefit from 5G technology and serve as the drivers. These five areas are categorized as Mobile Broadband, Mission Critical Communications, Massive Internet of Things (IoT), Broadcast-like Services, and Higher User Mobility. Mobile Broadband could include broadband access in dense areas and broadband access everywhere. Mission Critical Communications could include Extreme Real-Time Communications, Lifeline Communications, and Ultra-reliable Communications. In order to support use cases like Internet of Things (IOT), high frequency communication and low latency applications 5G technologies may need to introduce new radio interfaces. Hence, there will be a need for additional spectrum supported by flexible spectrum management techniques. However, 5G is not confined to development of new radio interfaces or physical layer only but will focus on an end-to-end system that includes all aspects of the network and will involve multiple layers. Future networks will consist of heterogeneous access technologies, will support multiple types of end user devices and will be subjected to context-based communications.By way of rapid service creation environment, 5G will be able to enhance service delivery in a highly cost efficient and energy efficient manner.

5G is not just the next evolution of 4G technology; it's a paradigm shift. Not only is 5G evolutionary (providing higher bandwidth and lower latency than current-generation technology), more importantly, 5G is revolutionary—in that it is expected to enable fundamentally new applications with much more stringent requirements in latency (e.g., real time) and bandwidth (e.g., streaming). 5G should help solve the last-mile/-kilometer problem and provide broadband access to the next billion users on earth at much lower cost because of its use of new spectrum and its improvements in spectral efficiency.
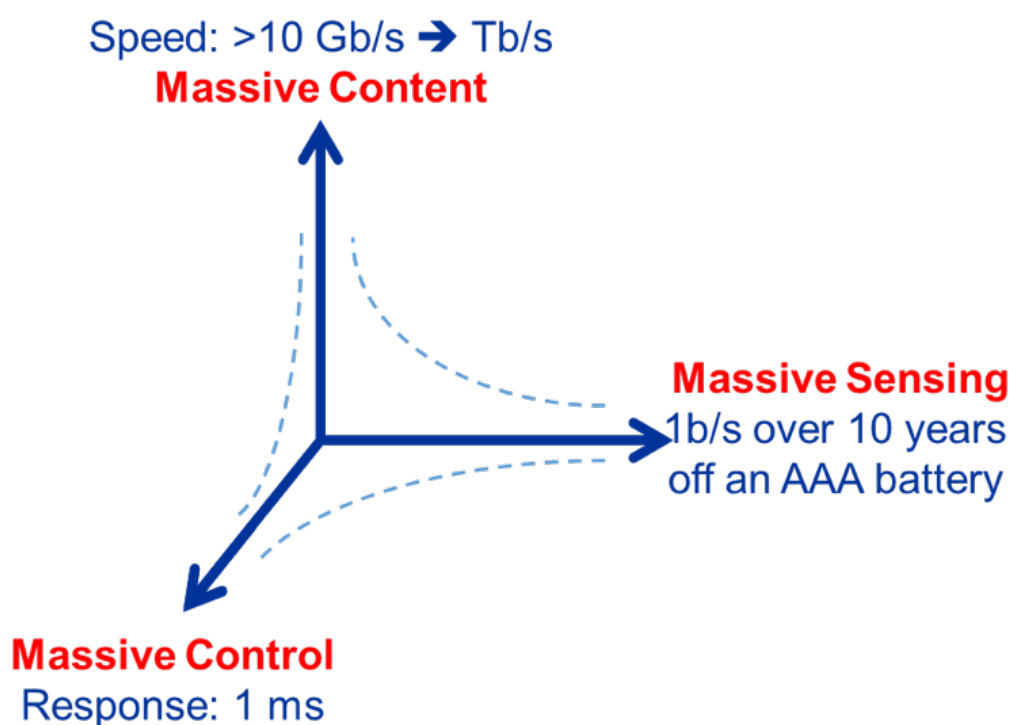
Flexibility, ease of use, dynamic nature of the network, Quality-of-Service (QoS), and anytime/anywhere to end users are some of the benefits for end users in the move to 5G. 5G is an enabler of exciting use cases that will transform the way humanity lives, works, and engages with its environment. In the short term, 5G can support exciting use cases such as the IoT, smart transportation, eHealth, smart cities, entertainment services, etc. For example:

- IoT—as 5G will enable more than 1,000 times more mobile data vs. today's cellular system by 2020, it is expected that it will serve as the backbone enabling the industrial IoT. In other words, 5G will help support IoT's communications needs on both IoT sensor and control networks.

- Smart transportation—short latency and short-wave communication is essential for emerging autonomous driving. Vehicles could be alerted to dangerous situations in real time and prevent crashes with intelligent emergency braking or steering systems. 5G plays an integral role in helping connect the LAN/MAN architectures, coupled with other communication structures, to enable avoidance of such incidents, as well as quickly addressing such issues when they occur.

- eHealth—with 5G's nearly real-time response times, doctors could perform operations around the world with video controls and machines to respond with limited delay. The medium, enabling coupling of robotics and sensors (among other technologies), will benefit from low latency and ability to handle scale with higher bandwidths in a secure connection. Further, 5G may offer the possibility to realize "zero physical distance" from patient to accessible and more affordable healthcare without quality reduction. Wireless sensor networks would provide the ability to remotely monitor parameters, such as heart rate and blood pressure through the use of sensors.

- Smart cities—5G stands to undergird smart cities in which intelligent stoplights monitor and control traffic and proactive capabilities' emergency management systems are enabled. Multi-level parking facilities could communicate with in-car navigation systems to guide drivers to the best parking spaces and prevent traffic jams; service workers could quickly assess power outages while simply wearing smart contact lenses or glasses, etc.

- Entertainment services—because the current 4G cannot economically support such bandwidth-hungry applications, 5G could support interactive mobile games. Sporting events could utilize effective and efficient usage of spectrum and leverage new broadcast capabilities, such as 4D.
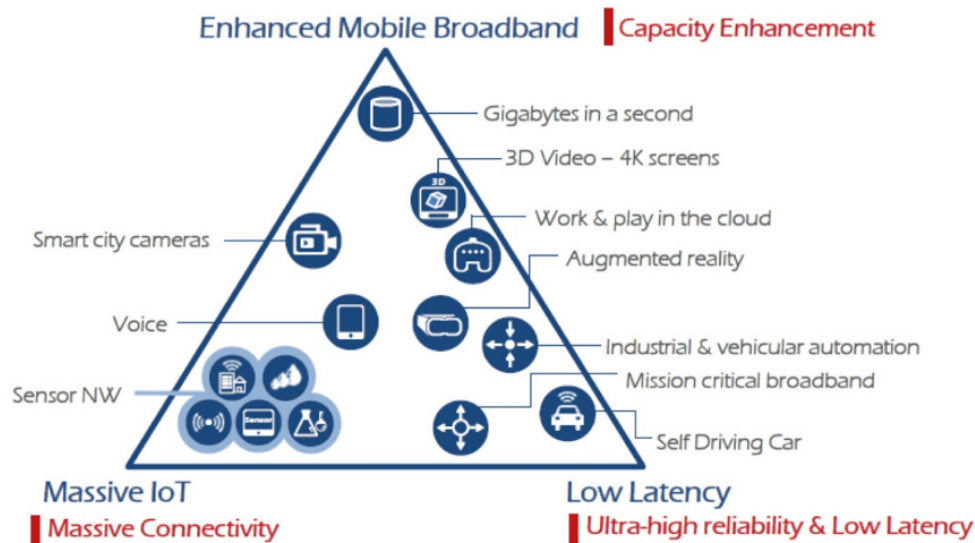
In the longer term, 5G use cases can include:

- Tactile computing and kinesthetic communication—The introduction of this technology, coupled with 5G, the ability to hold mobile devices to accident victims coupled with pressure sensitivity from doctors and health specialists would provide valuable opportunities. For example, emergency rooms could be quickly prepared for immediate surgery, and life-saving opportunities could be enhanced by ensuring the right specialists are on hand

- Holographic interactions—for a variety of use cases, the ability to interact with a hologram and receive tactile responses presents an incredible future. For example, the ability to interact socially changes considerably as the zero-latency concept shifts from simply a Tweet as and interaction to actually being able to shake hands and see the person saying the comments directly. This also provides opportunities to reduce the global spread of diseases such as MERS, Ebola and other contagions.

The advanced capabilities of 5G mean that we're driving innovation along three different axes. Axis number one is based on the fact that cellular network data rates increase about 10x every five years – we've known that for 2 ½ decades – and that's going to leap ahead with 5G. This has big implications for mobile data networks. Think of sending massive files with the touch of your finger, or real-time virtual reality at 200Gb/s. The second, completely new aspect of 5G is that it will enable us to connect sensors, devices, objects, and so forth in a massive Internet of Things network. The interconnectedness of billions of objects, devices, and networks will generate a wave of innovation that will take decades to fully realize. The third major category of capability is that 5G will enable us to build infrastructure for remote controls, often known as , "tactile Internet." This means we can have an interaction with virtual environments just as we are used to from tactile interaction with objects around us, which means real and virtual object will be able to interact with a reaction time of one to 10 milliseconds to enable a human to control things in a steady state that mimics reality. Conceivably, a person or a machine could be in one place, yet apply their physical skills in another place through the tactile Internet. This possibility will enable a burst of innovation in so many aspects of our lives that we simply cannot imagine all the applications at this point.

Speed: >10 Gb/s ➔ Tb/s
Massive Content

Massive Sensing
1b/s over 10 years
off an AAA battery

Massive Control
Response: 1 ms

Figure 1
Three axes of 5G Evolution

Enhanced Mobile Broadband — Capacity Enhancement

- Gigabytes in a second
- 3D Video – 4K screens
- Work & play in the cloud
- Augmented reality
- Smart city cameras
- Voice
- Sensor NW
- Industrial & vehicular automation
- Mission critical broadband
- Self Driving Car

Massive IoT — Massive Connectivity

Low Latency — Ultra-high reliability & Low Latency

(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Figure 2
5G Centric Applications

If one looks at 5G from an IEEE perspective, it's essentially a connectivity infrastructure that touches the innovation of sensors, integrated circuits, communications, computing, Big Data, and many further areas. It touches computing control theory, drives, as well as automatic controls. So, it will impact how we build the computer systems of the future to control interconnected objects. It will drive how we design integrated circuits, how we build antennas. We'll need to understand how power can be generated to run aspects of these systems. Standards for interoperability will be critical to all this. So 5G really touches many if not every IEEE society. The development of 5G will affect the future of research and development and the structure of our industrial base. That's why it makes sense to launch the IEEE Future Directions 5G Initiative, where all these focal areas can coalesce. As well, IEEE is a global organization with hundreds of thousands of volunteers focused on these technologies and with knowledge of their unique region's circumstances and requirements. As an organization, IEEE has deep expertise in fostering collaboration and achieving consensus, which is critical to a sea change like 5G.

Because 5G touches so many technical areas, the Initiative is currently driven by IEEE Future Direction Committee (FDC) and consists of 20 specific IEEE technical societies – though the initiative eventually will involve additional societies. We have a 5G Steering Committee composed of leaders from IEEE Future Directions as well as the technical societies and organizational units involved. IEEE 5G Initiative was launched on August 29, 2016 in Princeton, NJ.

More details of IEEE 5G initiative can be found at 5g.ieee.org. Figure 3 shows the picture of attendees for IEEE 5G Initiative kick-off meeting and Figure 4 shows the list of currently participating technical societies.

Figure 3
*IEEE 5G Initiative Kickoff Meeting at Princeton, New Jersey, August 29, 2016*

Figure 4
Participating IEEE Societies for IEEE 5G Initiative

Primary objectives of IEEE 5G and Beyond Initiative are as follows:

- Foster collaboration and connect technical & business communities to IEEE 5G experts and resources
- Act as 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.

IEEE 5G and Beyond Initiative is governed by a steering committee that includes steering committee co-chairs, the representatives from the contributing societies and co-chairs from various working groups, namely Standards, Education, Publication, Conferences, Content Development, Community Development, Industry Outreach, and Technology Roadmap. Each of these working groups consists of a committee of 10 – 20 members chaired by two working group co-chairs. Similarly, Technology Roadmap WG consists of several focused technical working groups, namely Standardization, MIMO, mmWave, Hardware, Security, Edge Automation Platform, Applications, Satellite, and Testbed. Figure 5 shows the organization structure of IEEE 5G and Beyond Initiative.
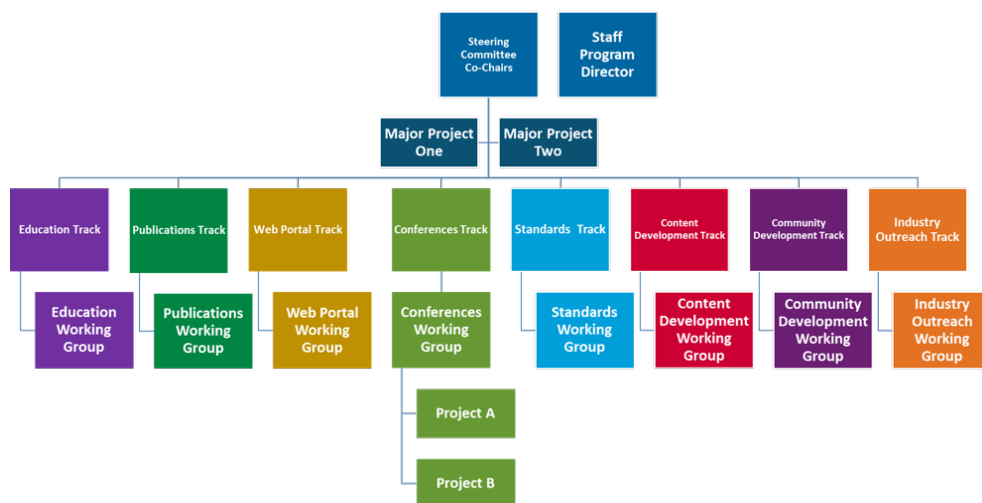
Figure 5
IEEE 5G Initiative Organization Structure

Since its inception each of the working groups of the Initiative has conducted several activities. Some of these activities are mentioned below.

Education WG

Education working group consists of about 15-20 active members who meet on Friday every two weeks. This working group has produced several deliverables, including, webinars, tutorials,

Webinars

5 webinars have taken place during 2017 and more webinars are planned for 2018. The list of webinars conducted during 2017 is given in bibliography.

Tutorials

IEEE 5G Initiative Education WG continues to organize IEEE 5G tutorials in various parts of the world with the help of the local organizers. This provides an opportunity to offer 5G related technologies to the local audience around the world who cannot attend big size conferences happening others parts of the world due to cost or need to travel. During 2017, IEEE 5G Initiative has conducted different tutorials in three different locations, namely Bangalore, India, Edison, NJ, and Shanghai China. These tutorials were attended by both onsite participants and online attendees from various parts of the world through Webex. Plans are underway to conduct similar tutorials at other parts of the world including Toronto, California, Malaysia, Europe and Australia. More details about some of these tutorials, webinars and how to get involved in some of these activities can be found at the following link. https://5g.ieee.org/education. This also lists webinars hosted by other societies such as IEEE Communications Society.

Publications WG

Publications WG has been focusing on various aspects of publications in the areas of 5G including online publications through Tech-Focus and special issues through magazine and journals of various societies. During 2017, Publications WG has published four issues of Tech-Focus issues with each Issue covering four articles. These issues cover various topics ranging from basics of 5G, how 5G can be applied to various verticals such as automotive, mmwave, Massive MIMO, Network Slicing, Standards for 5G and Beyond. Complete details of the Tech-Focus publications can be found at the following link, https://5g.ieee.org/tech-focus. This process provides a very quick way of publishing new and upcoming development in the areas of 5G covering various verticals and technology areas to a wider community. This site provides the details of all the published Tech-Focus articles and list of upcoming articles including Call-For-Papers for future series. In addition to online Tech-Focus articles, IEEE 5G initiative is also sponsoring special issues through various societies. IEEE Vehicular Technology Society just published the first special issue on 5G Technologies and Applications sponsored by IEEE 5G Initiative. List of 5G related articles and call for publications can be found at the following link https://5g.ieee.org/publications. Authors interested in exploring potential publication opportunity will find this site very useful.

Community Development

One of the objectives of IEEE 5G and Beyond initiative is to provide a platform to the world community and reach out to all regions of the world to contribute to 5G evolution efforts in a neutral manner. Hence, community development is an important aspect of IEEE 5G Initiative to be able to reach out to every corner of the world. Community Development WG within IEEE 5G Initiative makes every attempt to build the 5G community. As of November 2017, there are about 2000 members who have enrolled in Technical community. IEEE Collabratec has about 10000 members. In addition, there is an increasing trend of followers in Twitter, LinkedIn and Facebook. Web Portal traffic growing steadily at 15%/month – 5K+ visitors/10K+ page views monthly, Collabratec Community increased to 8K+ members, Technical Community, Twitter. Facebook growing at 10%/month. The following IEEE 5G and Beyond Dynamic Web

Metrics link provides a dynamic statistics https://datastudio.google.com/u/0/org//reporting/0B_h6zJpdQdsXYm1aalpGdTRhTGc/page/EzT.
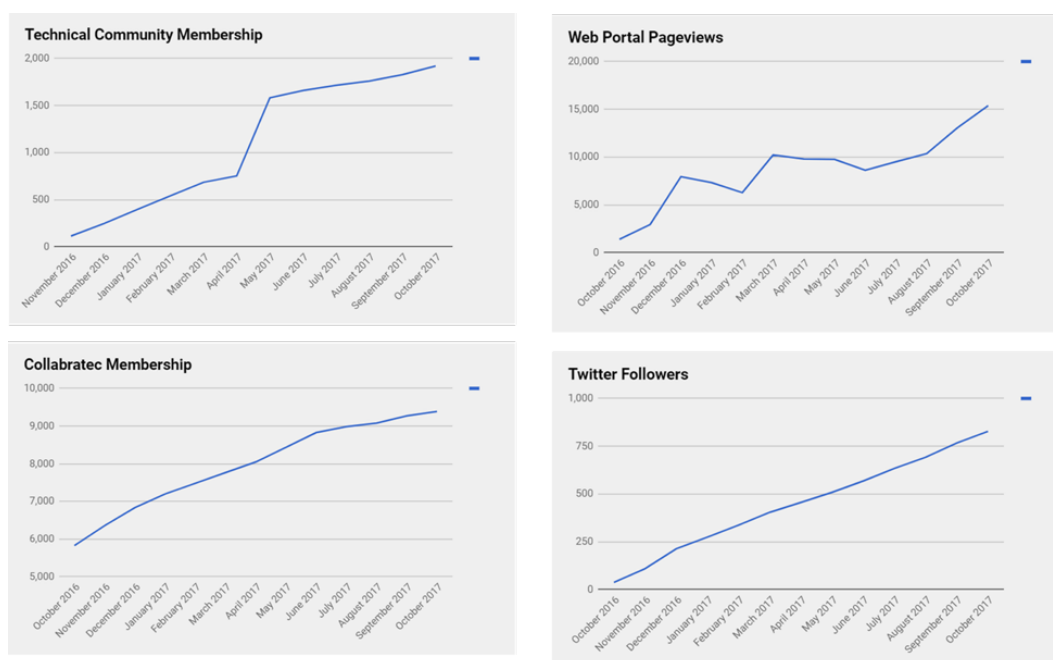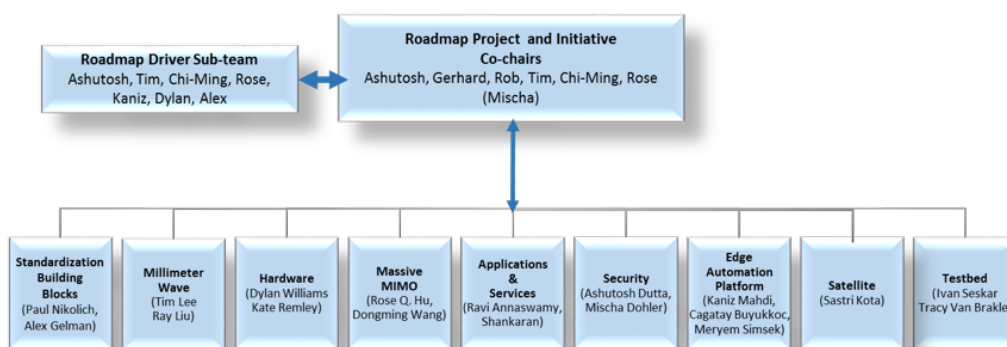

Figure 6
Snapshots of Community Development for IEEE 5G Initiative

Technology Roadmap

The IEEE 5G and Beyond Initiative Roadmap working group began work in 2017 to produce an industry technology roadmap that covers the entire ecosystem. A team of experts co-wrote a white paper that outlines the IEEE 5G and Beyond Technology Roadmap objectives and scope of topics, which are the following:

Applications and Services, Hardware, Massive multiple input, multiple out (MIMO), Millimeter Wave (mmWave), Edge Automation Platform (EAP), Security, Standardization Building Blocks, and Testbed. The roadmap will also address Satellite. This whitepaper was published in October 2107. Figure 6 shows Roadmap WG structure.

Figure 7
Roadmap WG Structure

The mission of the IEEE 5G and Beyond Technology Roadmap working groups is to identify short (~3 years), mid-term (~5 years) and long-term (~10 years) research, innovation, business, and technology trends in the communications ecosystem. In 2018, the 5G and Beyond roadmap effort will build on the Working Groups efforts and project the evolution from current to future state by engaging all sectors of the 5G community and collaborating with industry subject matter experts (SMEs), technologists, and researchers. From this activity, a set of common challenges, technology needs, and areas for solution sets and innovation will be developed. Each of these WGs will continue to meet regularly to discuss the work items and how the specific areas of work will contribute to 5G evolution. For example, 5G Applications and Services WG has been working on creating position papers across the various applications that will drive the 5G technologies. Team has worked on the following areas : Automotive Industry, Factory automation , Smart Cities , Power management, LTE Broadcast/Multicast , Emergency Communications/ Public safety , Healthcare, Smart Home , OSS/ BSS Impact and 5G Data Analytics.

The work done mainly focussed on Industry Trends, Key Drivers and Business Model Perspectives, Technology Requirements and Link to 5G, Needs from Verticals and the Major Technology Challenges. There are 11 position papers reviewed and ready to publish. We are working to get these published on IEEE 5G blog and also have a special newsletter edition based on these.

5G Applications working group meets every fortnight on Tuesdays and there is a strong participation of over 15 members from industry and academia and across the globe. Similar format will be followed up by other working groups.

Additionally, the roadmap teams will encourage public input at the end of the year with a public conference of roadmap presentations to strengthen the technology roadmap content before final release. Roadmap Whitepaper was published on October 3, 2017. As of 28 November 2017, there were 1107 views/downloads of the PDF of the Roadmap whitepaper. Roadmap WG has continued to organize Technology Roadmap workshops at IEEE ICC and Globecom conferences. In addition, Roadmap WG will continue to hold focused technology workshop for various technology verticals.
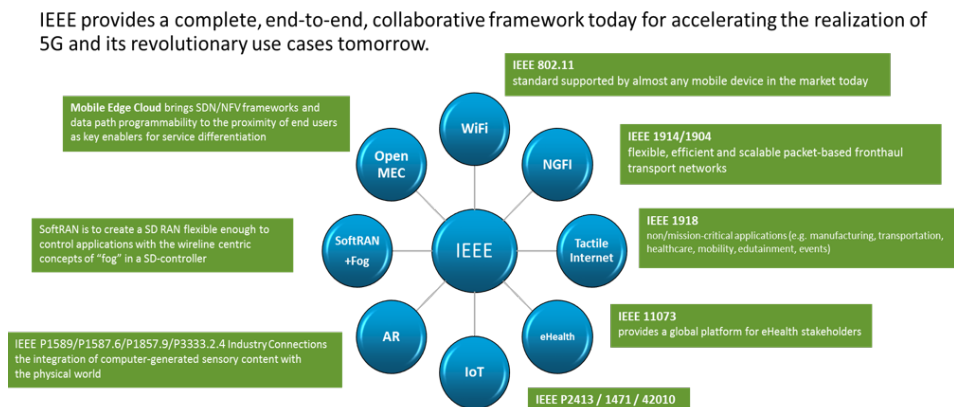
Standards WG

A variety of Societies within the IEEE are Sponsoring standards development activities that are directly related to the applications that will support the ultra-high bandwidth, ultra-low latency and ultra-low power requirements of next generation networking (aka 5G) applications such as networking vehicles, massive IoT and industrial automation.

Society Sponsors are the parent bodies for a variety of Working Groups that host the development of standard projects. An example is the Computer Society which hosts the Sponsor IEEE 802 LAN/MAN Standards Committee, which in turn hosts a number of Working Groups actively engaged in writing technical interoperability specifications in a wide range of standards projects. A specific example is Computer Society/IEEE 802 LAN/MAN Committee/IEEE 802.11 Wireless LAN Working Group/IEEE 802.11 ax High Efficiency WLAN Project.

The Standards Working Group Scope Included the following areas, 5G and Beyond Standardization Road Map, IEEE standards database, 5G and beyond technology components Standardization. The Road Map White Paper has been made available to wide audience, the database is in final stages of getting released. A number of Standards projects has been launched as a result of RRSA (Rapid Research Standardization Activities) sponsored by 5G Initiative and IEEE-SA. The projects are in relevant to 5G and beyond areas, such as SDN/NFV, Green ICT, IoT, FrontHaul Interfaces, Fog networking, etc. Newly created Standards Forum plans to work with all the 18 contributing societies and their standards representatives in order to help develop standards in the relevant technology areas. This forum will provide a platform where anybody in the world can bakeoff an idea related to 5G standards and then move it forward towards 5G standards development.

New Standards Development Sponsors have been created to govern these projects: COM/NetSoft-SC, COM/AcessCore-SC, COM/MobiNet-SC, COM/GreenICT-SC and COM/EdgeCloud-SC. Figure 7 shows a snapshot various 5G related standards that are under development within IEEE. One can refer to the following link to find out more details about 5G related standards, https://5g.ieee.org/standards.

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

Figure 8
IEEE standards and global collaboration for 5G

Testbed WG

Following the successful IEEE 5G Roadmap Workshop at ICC, the IEEE 5G and Beyond Initiative organized a Testbed Workshop focusing on experimental testbeds on 5G and Beyond. This workshop took place in collaboration with 2017 VTC, on Sunday September, 24th 2017 in Toronto. The objective of this workshop was to bring together developers, practitioners, technical experts and researchers to share experiences and advance the state of the art in all aspects of 5G systems prototyping, evaluation and testing. The workshop also included contributions and promoted discussion on the novel methodological studies and experimental paradigms for future 5G testbeds and co-development and co-deployment of experimental platforms. Of particular interest are ideas on extending publicly available testbeds with 5G related technologies as they become available and how they can be used to address common technological and scientific problems that are related to advanced wireless systems.

The workshop covered a spectrum of distinguished speakers from all over the world who shared their experiences about building testbed and experimental results. They also highlighted how these testbeds can be used by IEEE 5G Community. Talks for this Testbed were streamed online and have been recorded for later viewing. These can be found at the following link, https://5g.ieee.org/conferences/testbed-workshop-vtc.

In order to provide open access to IEEE members so that they can conduct 5G related experiments, IEEE 5G Initiative started a new project called 5G open testbed consortium. As part of this program many of the 5G Testbed owners around the world will make their testbeds available for use by IEEE members. Rutgers WINLAB's ORBIT testbed is the first such testbed that is available for use by IEEE members. One can find the instructions of how to access the testbed to conduct these experiments at the following link. http://www.orbit-lab.org/userManagement/register.

IEEE 5G Initiative has also collaborated with IEEE SDN initiative to come up with SDN Catalogue of Toolkits and Testbeds.

This wiki provides an overview of existing toolkits, and (federated) testbeds in the area of Software Defined Network (SDN), Network Function Virtualization (NFV), and Mobile Edge Computing which can be used for building prototypes boosting the development of the 5th Generation of Mobile Networks. In particular, each section provides a brief overview about the standardization and standard de-facto activities currently ongoing, what is the main reference architecture, and which tools can be used for implementing a comprehensive solution. All of this is supported by the IEEE SDN Initiative Outreach group, led by Fraunhofer FOKUS, Technical University of Berlin, and University of Campinas.

Conference WG

In order to provide a platform for the industry leaders, innovators, and researchers from the industry and academic community to collaborate and exchange ideas in this emerging technology that may help in driving the standards and rapid deployment, IEEE 5G initiative's conference WG has focused on organizing workshops, summits, and conferences in various parts of the world.

In order to engage industry members with high value and innovative 5G technologies at a local level throughout the globe, IEEE 5G initiative has been collaborating with IEEE Communications Society and IEEE MTT to hold a series of high impact one day Summits in 5G area. So far, thirty 5G Summits have been organized in various parts of the world with an attendance of 5000 onsite and online attendees and 400 speakers. By having these series of 5G summits, IEEE 5G initiative has been able to bring 5G technologies to various parts of the world who cannot otherwise interact with the 5G experts. More details about the 5G summits can be found at https://5g.ieee.org/5g-summit. Figure 8 shows the lists of 5G Summits organized at various parts of the world. Figure 9 shows the snapshot of first IEEE 5G summit that took place in Princeton University on May 26, 2015.

Figure 9
30 5G Summits around the world

Figure 10
Glimpses of First IEEE 5G Summit at Princeton University, May 2015

The 2018 IEEE 5G World Forum (5GWF'18) in Santa Clara, California is a unique event for industry leaders, academics, and decision-making government officials. This event is designed to examine 5G technologies and applications for the benefit of society. This conference aims to bring researcher from industry, academia and research to exchange their vision as well as their achieved advances towards 5G, and encourage innovative cross-domain studies, research, early deployment and large scale pilot showcases that address the challenges of 5G. More details about this conference can be found at http://ieee-wf-5g.org/. In addition to this flagship event, Conference working group also plans to organize Regional 5G world congress at various parts of the world. One such event is being planned for December 2018 in Bangalore, India.

In future, IEEE 5G Initiative plans to organize Technology focused workshops in conjunction with various workshops. Focused workshops in the areas of mmwave, Massive MIMO, Edge Automation Platform, Applications, Security, Hardware, Testbed, Satellite and Standardizations will help progress the roadmap project further with new contributions in this area. Testbed workshop in conjunction with Fall IEEE VTC 2017 is one such example.

Industry Engagement

In an effort to engage Industry leaders from various verticals with the 5G and Beyond Initiative, Industry Engagement WG organized several 5G focused panels that are co-located with various conferences. This provided an opportunity to discuss 5G specific topics pertaining to standardization and deployment. In addition to involving Industry leaders, this also helped to debate some of the burning points. As a result of these series of engagement, we have also formed Industry community that serve as a pool of resources for various 5G related activities. This endeavor has established a framework that will allow liaison between Industry professionals and IEEE 5G community.

Future Activities

As 5G technologies continue to evolve it becomes imperative for IEEE 5G and Beyond Initiative to involve the relevant IEEE societies more thoroughly and find opportunities for greater collaboration. The Roadmap work will continue to progress technically with relevant 5G use cases, by mapping of 5G technologies to different verticals where these could be applied. In this regard Roadmap WG plans to organize many technical workshop at working group levels and solicit feedback from various SDOs such as 3GPP, NGMN, 802.11, and ITU etc. IEEE FDC is currently looking into rebranding the current initiative to include the work around massive connectivity and as it applies to 5G and beyond technologies. This will help align the Initiative's work with the evolving 5G and beyond technologies. In addition to proposed plans for roadmap working group, the Initiative will continue to make progress on Education by conducting additional tutorials, webinars, Summer schools. Publications WG will continue the trend with Tech Focus in additional areas such as Testbed, Security, Applications and will work with other societies to bring forth specials issues either through magazines or journals. As part of Community Development work we hope to see an increasing trend in participation from different parts of the world. Content development WG will focus more on 5G use cases and deployment strategies for various verticals including automotive, ehealth, operators, remote surgery, connected cars, and tactile Internet. Standards WG will focus on making the 5G Standards Database available to the community and will continue with the Standards Forum meeting to involve additional societies for standards development in 5G areas. This will provide an umbrella under which 5G standards will continue to evolve covering many societies within IEEE. The initiative will find every opportunity to involve Industry leaders by organizing 5G panels in specific topic areas at appropriate conferences, workshops. Conference WG will continue to collaborate on 5G summits around the world and organize focused technical workshops for various Roadmap technology areas. In addition to the 1st IEEE 5G World Forum, the Conference WG plans to organize regional IEEE 5G World Congress in each continent in order to make the 5G technologies and deployment more customized to the local environment. Finally, as the relevant societies continue to evolve 5G related technologies as part of this eco system, it is important to create an open Testbed platform that will allow IEEE members and contributors to continue 5G related experiments for different 5G use cases. This experimental testbed consortium will complement the technology development efforts carried out by roadmap WG and will allow the members to continue with proof-of-concepts for many 5G . This will give an opportunity to blend theory and practice and will help accelerate the standardization and deployment of 5G and beyond technologies.

Getting Involved

The IEEE 5G Technical Community includes researchers, scientists, and engineers from industry, academia, and governments around the world working together to solve the challenges associated with the development and deployment of 5G. The community is a collaborative effort, bringing

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interdisciplinary exchange from a wide range of professional expertise and practical application knowledge.

Membership in the IEEE 5G Technical Community is complimentary, and you are invited to join and participate.

As an active member of the IEEE 5G community, you will have access to key information resources – including the IEEE 5G web portal, eNewsletters, conferences, educational opportunities, publications, standards development, and more. All of these components will help you stay abreast of new developments in this multi-disciplinary technology and keep you at the forefront of the research, development, planning, and deployment of 5G.

Visit the IEEE 5G Initiative web portal at 5g.ieee.org and get involved today with various aspects of 5G and beyond.

Acknowledgement

Bibliography

Webinars
Wednesday, June 21, 2017 at 11am EST - <u>5G: What Is It and What New Applications are Driving its Formation?</u> Presented by Robert W. Heath Jr., PhD., P.E., IEEE Fellow and Cullen Trust Endowed Professor, Dept. of Electrical and Computer Engineering, the University of Texas at Austin

Thursday, July 20, 2017 at 11am EST - <u>A Look at the Companies and Organizations Working to Make 5G a Commercial Success</u> presented by Daryl Schoolar, a senior industry analyst and Practice Leader for Next Generation Infrastructure at Ovum.

Wednesday, September 20, 2017 at 11am EST - <u>5G mmWave Revolution and New Radio</u> presented by Amitava Ghosh, Nokia Fellow and Head of Small research, Nokia Bell Labs

Thursday, October 19, 2017 at 11am EST - <u>5G and Satellite Spectrum and Standards</u> presented by Geoff Varrall, Director RTT Programmes

Wednesday, November 8, 2017 at 11am EST- 5G Technology is Fantastic, But Can We Afford It? presented by William Webb, CEO Webb Search

Tech Focus Articles for 2017

- **December 2017**
  - Adding Value to 5G Ecosystem by Joint Innovation
  - Driving UK's 5G Agenda - Strategy & Case Studies
  - Multi-Access Edge Computing: An Overview of ETSI MEC ISG
  - From Standards to Service - the European Way to 5G

- **September 2017**
  - 5G "On the Fly"
  - The Emergence of Experience Packages in the 5G Era
  - LTE Goes Unlicensed: How the 5G Era Changes the Way We Use Spectrum
  - Web 5G

- **June 2017**
  - Cellular V2X as the Essential Enabler of Superior Global Connected Transportation Services
  - V2X Communication for ITS - from IEEE 802.11p towards 5G
  - NOMA in 5G Systems: Exciting Possibilities for Enhancing Spectral Efficiency
  - Standards for 5G and Beyond: Their Use Cases and Applications

- **March 2017**
  - 5G Channel Model with Improved Accuracy and Efficiency in mmWave Bands
  - Massive MIMO for 5G
  - Ultra-Dense Networks (UDNs) for 5G
  - Towards 5G Network Slicing - Motivations and Challenges

Content Development

- **IEEE Talks 5G**
  - IEEE Talks 5G: Three Questions for Gerhard Fettweis Published: Jan 26, 2017, 244 pageviews
  - IEEE Talks 5G: Alex Wyglinski Published: Feb 28, 2017, 242 pageviews
  - IEEE Talks 5G: James Irvine Published: March 22, 2017, 164 pageviews
- **IEEE 5G Transmissions: Podcasts with the Experts**

Through our podcast series, the IEEE 5G Initiative interviews some of the top subject matter experts in the 5G field. Covering many topics including implementation challenges and connecting the disconnected, IEEE 5G Transmissions: Podcasts with the Experts provides you with access to the industry's top subject matter experts.

- Podcasts are available on the portal, iTunes, Google Play Music, and plans are underway to include it on IEEE.tv.
- 5G Transmissions: What Challenges do you Foresee in the Deployment of 5G? Published: mid-January 2017, 167 downloads
- Included accompanying poll posted on Collabratec and Twitter
- 5G Transmissions: What is Your Boldest Vision of What 5G Can Bring Us? Published: March 31, 2017, 74 downloads
- 5G Transmissions: The Future of Mobile Beyond 5G Part 1 (Mischa Dohler) Published: August 23, 2017, 122 downloads
- 5G Transmissions: The Future of Mobile Beyond 5G Part 2 (Mischa Dohler) Published September 26, 2017, 65 downloads
- 5G Transmission: The Main Transformative Aspects of 5G (David Soldani) - Published On November 6, 2017, 166 downloads

External Articles
- Futurism - Will Wireless Connections Between Autonomous Vehicles Make Them Safer? By Alex Wyglinski, Published: August 22, 2017
- ECN Brainstorm: How to Best Handle the Connected Car's Network Strain, Alex Wyglinski, Published: August 7, 2017

Press releases:
- 10/04/2017: New IEEE 5G and Beyond Technology Roadmap White Paper Published
- 3/16/17: IEEE 5G Summit in Kolkata to Look at "Digital India" and Possibilities for Connecting the Unconnected in 5G Rollout
- 2/24/17: New IEEE 5G Activities Designed to Help Connect Unconnected and Fuel Decades Long Innovation Wave

IEEE 5G Initiative Overview Video
- Located here: https://5g.ieee.org/about/overview
- Will be updated in early 2018 to reflect new logo and messaging

Biography

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